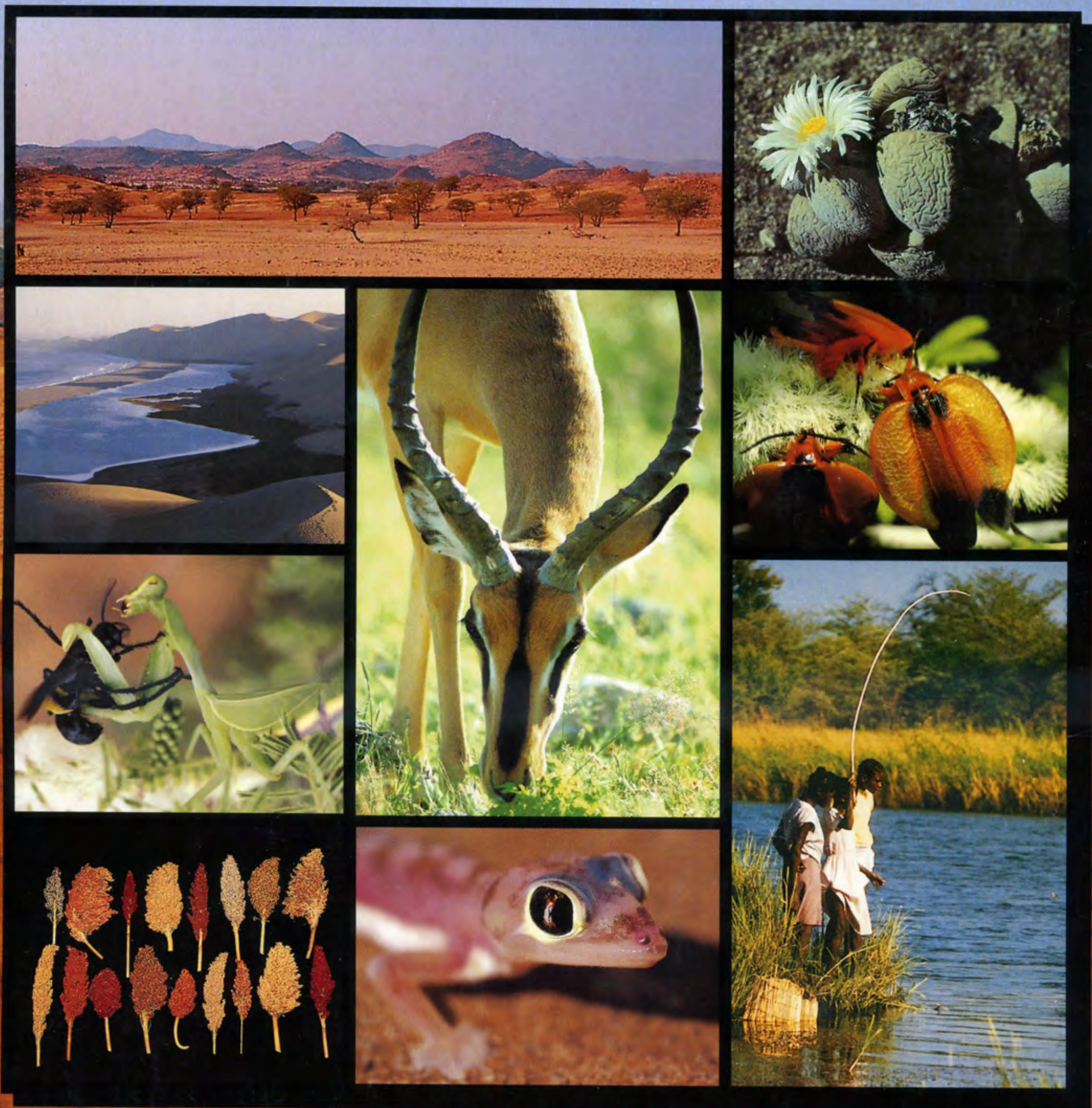

BIOLOGICAL DIVERSITY IN NAMIBIA

- a country study

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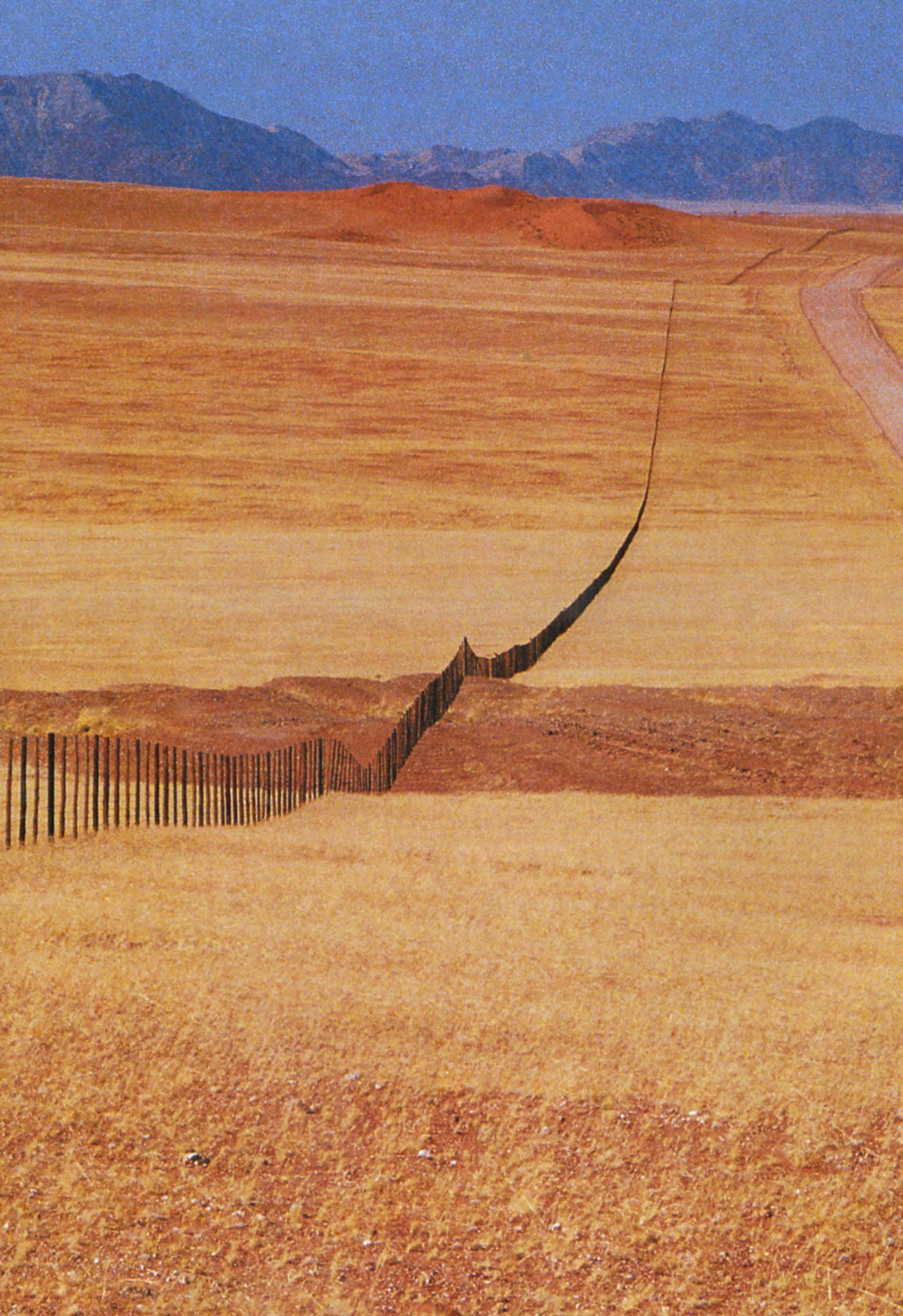
and the Namibian National Biodiversity Task Force



BIOLOGICAL DIVERSITY IN NAMIBIA

– a country study

PHOEBE BARNARD (*editor*)
and the Namibian National Biodiversity Task Force

NAMIBIAN NATIONAL BIODIVERSITY TASK FORCE

in cooperation with

- *Ministry of Environment and Tourism, Namibia*
- *United Nations Environment Programme*
- *Global Environment Facility*
- *Namibia Nature Foundation*

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Foreword

The importance of biological diversity, or biodiversity, to Namibians of today and tomorrow cannot be overemphasised. For millennia, people have relied on ecosystems to meet their basic needs for food, water and other natural resources. Preserving these natural systems is thus so vital for our national development, our livelihoods, and indeed our very survival, that severe environmental degradation would be calamitous. So too would it be if we do not strike the right balance between our demands on the natural environment and the productive potential of this environment. Essentially, this means safeguarding our biological diversity, that is, the entire, complex, fascinating variety of the living world and its ecological 'life support systems.'

Namibia has, by ratifying the Convention on Biological Diversity and related environmental treaties such as the Ramsar Convention on Wetlands and the Convention on International Trade in Endangered Species (CITES), joined the international community of nations in acknowledging the need for urgent action to conserve species and ecosystems and prevent, as far as possible, the loss of biodiversity during human development. In Namibia we have a fairly long history of information to support this process. Since the eighteenth century, early explorers and subsequent colonial administrators in Namibia have fostered scientific enquiry, including biological research. The problem lay in that such enquiry was often unfocused, uncoordinated, and lacked clear priorities.

This book — and the publications for lay readers which will follow — represents something of a milestone in Namibia's history of biodiversity knowledge and management. For one, it is an important snapshot of what we know and where we are in terms of biological diversity as we turn the corner of the next millennium. Second, it is a significant achievement in terms of bringing together previously fragmented, uncomputerised, inaccessible and poorly-understood information held by numerous biologists, ecologists, and biosystematists. Thirdly, it sets these data in a socioeconomic perspective by incorporating important analyses of the economic values of biological diversity, biological resources, and ecosystem functions which are so crucial to Namibia, as well as the legal framework under which these values can be protected and realised. And finally, it sets out some important priorities for the next century. With these priorities, we can fill gaps in our knowledge and understanding, synthesise material to support human development and the environmental planning process, and select and train the cream of Namibia's upcoming scientists, economists and development workers to carry this process forward into the foreseeable future.

Philemon Malima
Minister of Environment and Tourism

Namibia is one of the world's driest countries, skirted by the Namib and Kalahari Deserts and desiccated by the interplay of winds off the cold Atlantic and the hot southern African basin. It is therefore a nation with unusual and impressive habitats and species, many of them unique to the country or to the southwestern African arid zone.

This book summarises what is currently known of the country's biological diversity at the habitat, species and genetic levels, and how this diversity can be effectively safe-guarded through economic valuation, legislative protection, and policy reform. It is a national assessment, funded by the United Nations Environment Programme and Global Environmental Facility in order to aid Namibia's process of implementing the Convention on Biological Diversity (CBD). Namibia signed the CBD at the U.N. Conference on Environment and Development in 1992, and ratified it in March 1997. By this latter date, progress towards a National Biodiversity Programme and a national strategy and action plan was already well advanced. Below are some of the key points made in the book.

The country's context and constraints

As one of the world's driest countries, Namibia faces significant fundamental environmental constraints which it cannot ignore. Its annual rainfall is modest and highly variable, the more so the further west one travels. This has not only shaped a range of extraordinary arid-adapted ecological communities, but has also powerfully shaped the human development options of the modern Namibia. **Chapter 1** is a brief portrayal of the country, its biophysical and socioeconomic environments, and its history of resource conflict and rise to political self-determination. All of these major themes influence in some way the challenges which we in Namibia face today in our efforts to safeguard the nation's biological diversity and environmental health for our children and grandchildren, while using our living resources sensibly to sustain human development.

Modest diversity, impressive endemism on land and in freshwater systems

Chapter 2 follows with a detailed account of the country's terrestrial and freshwater diversity at the habitat, species and genetic levels. While the country and its habitats are diverse, the species richness of many groups in these habitats is only modest compared to other countries. What is most distinctive about Namibian biodiversity is its high degree of *endemism*, or the extent to which its organisms are found here and only here. As a dry country, Namibia depends heavily on its few wetlands, and these — and the species which depend on them — are under threat virtually everywhere. These wetlands range from subtropical floodplains to saline desert springs and limestone cave and sinkhole features, many of which support their own unique fauna. Other habitats under threat include the savannas which have been heavily appropriated for agriculture, most of which remain outside the state protected area network. Poor land management on farmlands is almost certainly one of Namibia's greatest threats to its biodiversity.

Low diversity, abundant productivity in the marine environment

Namibia's ocean and coastal environments and their extraordinary productivity are legendary, and compare favourably to the most productive marine upwelling systems in the world. Like these other systems, Namibia's Benguela Current system is a highly dynamic, complex and powerful upwelling which supports lucrative fisheries. Again like these other systems, the productivity of the Benguela has been badly abused in the past and has in many ways not yet recovered. Circumspection and wisdom in fisheries management are essential to Namibia's future economic development, and this means significant investment in understanding the natural complexity and dynamism of the ecosystem, in order to predict natural perturbations which reduce the available resource stocks. **Chapter 3** shows that this marine system features low species richness, but high abundance, in many taxa. It is still in a relatively pristine state, but faces potential and current threats through mining and fossil fuel exploration and development activities, as well as harvesting strategies which are mismatched to its natural variability.

Appropriate development strategies are illuminated by economic analysis

Working with, rather than against Namibia's fundamental environmental constraints is the only way to achieve sustained human development and economic growth. **Chapter 3** outlines imaginative strategies which can turn these constraints into significant assets for the country, particularly in the spheres of ecotourism and other forms of wildlife use. The vast majority of people in Namibia remain rural dwellers who depend directly on biological resources and a healthy environment for their survival. Enhancing opportunities for people to benefit from these resources in rural areas maximises their quality of life and minimises the risks of suffering from drought. It also keeps people productive and self-reliant on the land, rather than dependent and poverty-stricken in the demoralising and unhealthy urban squalour they may encounter as migrants to Namibia's rapidly growing towns. Policy and market failures which influence decisions about natural resource use, and the resulting success of biodiversity conservation, include excessive subsidies to the agricultural sector and overcentralised management structures.

Effective biodiversity conservation requires a progressive legal framework

Legal measures to protect biodiversity in Namibia are outdated, fragmented under the auspices of numerous controlling agencies, and often discriminatory to the majority of Namibians. **Chapter 5** outlines the development of a revised legislative framework to safeguard Namibia's environment, including its biological diversity. Aside from measures to secure the protection of species and habitats, which was the traditional core of nature conservation legislation, Namibia urgently needs mechanisms to realise profits from its genetic resources, traditional knowledge systems and biotechnologies. The rationalisation of Roman Dutch law, inherited from South Africa, and traditional common laws is also a priority for Namibia.

The way forward

Namibia's central gaps and priorities relating to biodiversity conservation have become clear in the preparation of this book. As **Chapter 6** concludes, these include the need for better (and more accessible) basic information on biological diversity; more focused analysis and prioritisation of conservation needs; more explicit data relating to the current harvesting levels of biological resources, and measures to put this harvesting on a sustainable footing; monitoring and evaluation of the biodiversity conservation implications of land use systems in Namibia, including those intended to further conservation aims; and focused research on key issues of conservation concern in terrestrial, freshwater and marine environments, such as the population fragmentation and viability of red data, endemic and indicator species and the safeguarding of genetic resources important in agriculture and other fields. To do all of these things, one of Namibia's overriding concerns is the development of a contingent of technically competent, dedicated and passionate young Namibian biodiversity specialists who will meet or exceed the standards of those active today.

Editor's preface

This book is the culmination of a two-year study of the biological diversity of Namibia, for Namibia, by Namibians. It was initiated after our President, Dr Sam Nujoma, signed the Convention on Biological Diversity (CBD) at Rio de Janeiro in 1992. With his signature, he led the way for our country to enter a new, more modern, and more comprehensive approach to the protection of its biodiversity, and the circumspect, sustainable use of its biological resources.

This is a 'semi-technical' study, something of a bet-hedging approach which we hope proves successful. On the one hand, it combines the analyses of professional ecologists, taxonomists, marine biologists, economists and lawyers to survey what we know of our biodiversity and the threats which it faces. We cast it as 'semi-technical' rather than 'semi-popular' to present much of the raw material from which upcoming summaries for decisionmakers, teachers and learners will be distilled. On the other hand, we have tried to make it a book to which the interested lay reader will refer and return. We have attempted to weed out as much of the irritating technical jargon as possible to make the book an absorbing, if perhaps not a lightweight, read. It may be unrealistic to process the work of 46 technical contributors — many of them iconoclastic, and some cranky — into a stylistically smooth and uniformly exciting book, but while attempting to cajole their submissions into a mutually compatible format, I trust they will ultimately forgive me for what they might currently see as ruthless homogenisation.

The structure and process underlying the book are relatively simple, and have so far served their purpose reasonably well. The Namibian National Biodiversity Programme (NNBP) was launched in 1994 and forms the overall structure under which several working groups, some of them relatively autonomous, operate. Through its National Biodiversity Task Force, the NNBP's central functions are to plan, coordinate, guide, and support research, management and policy actions related to biological diversity conservation in Namibia. It is housed in the Directorate of Environmental Affairs (DEA) of the Ministry of Environment and Tourism, with a base of expertise spread much more broadly through numerous ministries, institutes, non-government organisations and university departments. The Task Force and its associates (Appendix 1), who produced this book, reflect the range of this expertise. However, there are a few gaps in its composition which must be filled in the near future and are explored in Chapter 6.

Phase I 1994-1998	***Phase II*** 1995-1999	***Phase III*** 1999-2002
Secure funds and establish programme Establish multisectoral steering body (National Biodiversity Task Force) Prepare and publish Country Study	Increase information accessibility and analysis Establish key working groups Popularise Country Study Initiate targeted research to fill obvious gaps Prepare National Strategy & Action Plan	Evaluate and monitor key issues and programme activities Implement National Strategy/Action Plan Adapt planning and implementation to lessons learned

Many countries commit themselves to international conventions such as the CBD without being well prepared to tackle the commitments therein. Developing countries, for example, have often brought in foreign professional consultants to prepare biodiversity country studies. Our approach has been to make almost exclusive use of Namibian expertise in the preparation of this book: of the 46 text contributors, 44 are (or were until recently) Namibian citizens / residents working for Namibian institutions. We are pleased that a small and often overlooked country like Namibia has so much to offer in this respect, and we value highly the work of all our contributors and referees. We are also working to ensure that more young Namibians will enter this field, so that our busy programme ahead can also be handled 'in-house.'
— Phoebe Barnard

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A multi-authored book such as this is always a complex and exhausting team effort. An editor's role is inevitably a prominent one, but this book represents the collective experience and insight of nearly 50 specialists, 70 reviewers and several dozen photographers, some of whom have been active on the Namibian biodiversity scene for many decades. I thank the members of the Biodiversity Task Force and other contributors for their much-valued input and skills, their patience, their tireless checking and proofreading. While each person's role has been invaluable, the stamina of Shirley Bethune, Barbara Curtis, Herta Kolberg, Carole Roberts, Sem Shikongo and Rob Simmons in the book's late stages deserves special mention. I particularly thank Rob, Catherine and Julia Simmons for immense patience and support during the long weeks of burning too much editorial midnight oil.

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AIDS	Acquired Immune Deficiency Syndrome
c.	circa
CBD	Convention on Biological Diversity
CBPP	Contagious bovine pleuropneumonia (lungsickness)
DEA	Directorate of Environmental Affairs, MET
DERU	Desert Ecological Research Unit of the DRFN
DF	Directorate of Forestry, MET
DRFN	Desert Research Foundation of Namibia
DRM	Directorate of Resource Management, MET
DSSS	Division of Specialist Support Services, MET
DWA	Department of Water Affairs, MAWRD
EA	Environmental assessment
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth disease
GEF	Global Environment Facility
HDS	Half-degree square
IBPGR	International Board for Plant Genetic Resources
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
MAWRD	Ministry of Agriculture, Water & Rural Development
MET	Ministry of Environment & Tourism
MFMR	Ministry of Fisheries & Marine Resources
MLRR	Ministry of Lands, Resettlement & Rehabilitation
NAMDEB	Namibia-De Beers Diamond Corporation Ltd (previously Consolidated Diamond Mines)
NAPCOD	Namibia's Programme to Combat Desertification
NatMIRC	National Marine Information & Research Centre, MFMR
NBDTF	National Biodiversity Task Force
NNBP	Namibian National Biodiversity Programme
NBRI	National Botanical Research Institute, MAWRD
NDTC	Namibian Drought Tolerant Composite
NGO	Non-government organisation
nm	nautical mile
NOLIDEP	Northern Livestock Development Programme, MAWRD
NORAD	Norwegian Agency for International Development
PTS	Performance Testing Scheme (livestock)
PPRI	Plant Protection Research Institute, Agricultural Research Council, South Africa
QDS	Quarter-degree square
SADC	Southern African Development Community
SARDEP	Sustainable Animal and Range Development Programme, MAWRD
sp.	species (singular)
SPGRC	SADC Plant Genetic Resources Centre
spp.	species (plural)
TACs	total allowable catches
TASA	Tourism and Safari Association of Namibia
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

Tables, graphs, maps and appendices

Graphs

Maps

Text boxes

Appendices

1 Overview of Namibia and its biological diversity

Phoebe Barnard with contributors

Courtesy LC Weaver

1.1 Geographical features

Namibia's landscape is a stark, vividly coloured and remarkably varied one. It stretches from cold and desolate coasts through gravel plains, "dune seas" and rugged inselbergs to the scrublands, thorn savannas, ephemeral pans and rocky hills of the interior. Contrasting softly with these forbidding lands, the moist woodlands and tropical floodplains of the northeast help make Namibia one of the most fascinatingly varied countries of its size on earth. Its rapidly expanding tourism industry attests to the geographic variety of the country, with its unusual habitats and invigorating wilderness that people pay considerable money to experience.

Namibia is undoubtedly scenically diverse. But to what extent does this geographic diversity contribute to biological diversity? Because the country is so arid overall, one would think perhaps rather little. Compared to South America's or Australasia's tropical moist forests, or South Africa's Cape floral kingdom, Namibia does not have huge numbers of species. This reflects not only its aridity, but also its past ecological and climatic history. However, we have a high proportion of biota which are unique to the Southwestern Arid Zone, with many unusual restricted-range species. This first chapter sets the scene for a portrayal of this unusual and impressive biodiversity.

Box 1.1 Namibia at a glance

Land area	*823,988 km^2*
Population	*1.61 million (1995 estimate)*
Population growth	*3.1% per year*
Population density	*1.7 persons / km^2*
Mean fertility	*6.1 children / woman*
Urban population	*28% of total*
Life expectancy	*Men 59.1 years Women 62.8 years*
Per capita income	*US$1610 / year*
Economic growth	*Real GDP growth: 2.9% (see Box 1.2)*
Climate	*Hyper-arid (west) to dry subhumid (east)*
Rainfall	*Mostly summer rain, increasingly variable towards west coast*
Biomes	*Desert, savanna, broadleaf woodland*
Main languages	*English (official), Oshiwambo, Otjiherero, Nama-Damara, Afrikaans, Rukavango*

Updated from: NPC;[1] EIU[2]

Climate and palaeoclimate

The overwhelming two features of Namibia's climate are the scarcity and unpredictability of rainfall. Within Africa, our climate is second in aridity only to the Sahara. Rainfall everywhere in the country is lower and more variable than in the eastern subcontinent, and lower and more variable the further west one travels. Steep gradients thus characterise the country's rainfall (map 1.1), from tropical semi-humid in the northeast (3% of land area) to hyper-arid in the west (12%). The country-wide average rainfall of under 250 mm per year is coupled with annual mean evaporation of up to 3700 mm (map 1.2).[3] Overall, 69% of the country is regarded as semi-arid, with the remaining 16% as arid.[4] What little rain reaches the hard-baked soil is mostly lost again to the clouds. It is estimated that about 83% of rainfall evaporates, and a further 14% is transpired by plants. This leaves 2% to enter drainage systems, where some is retained in dams, and only 1% to recharge the land's severely stressed groundwater tables.[5]

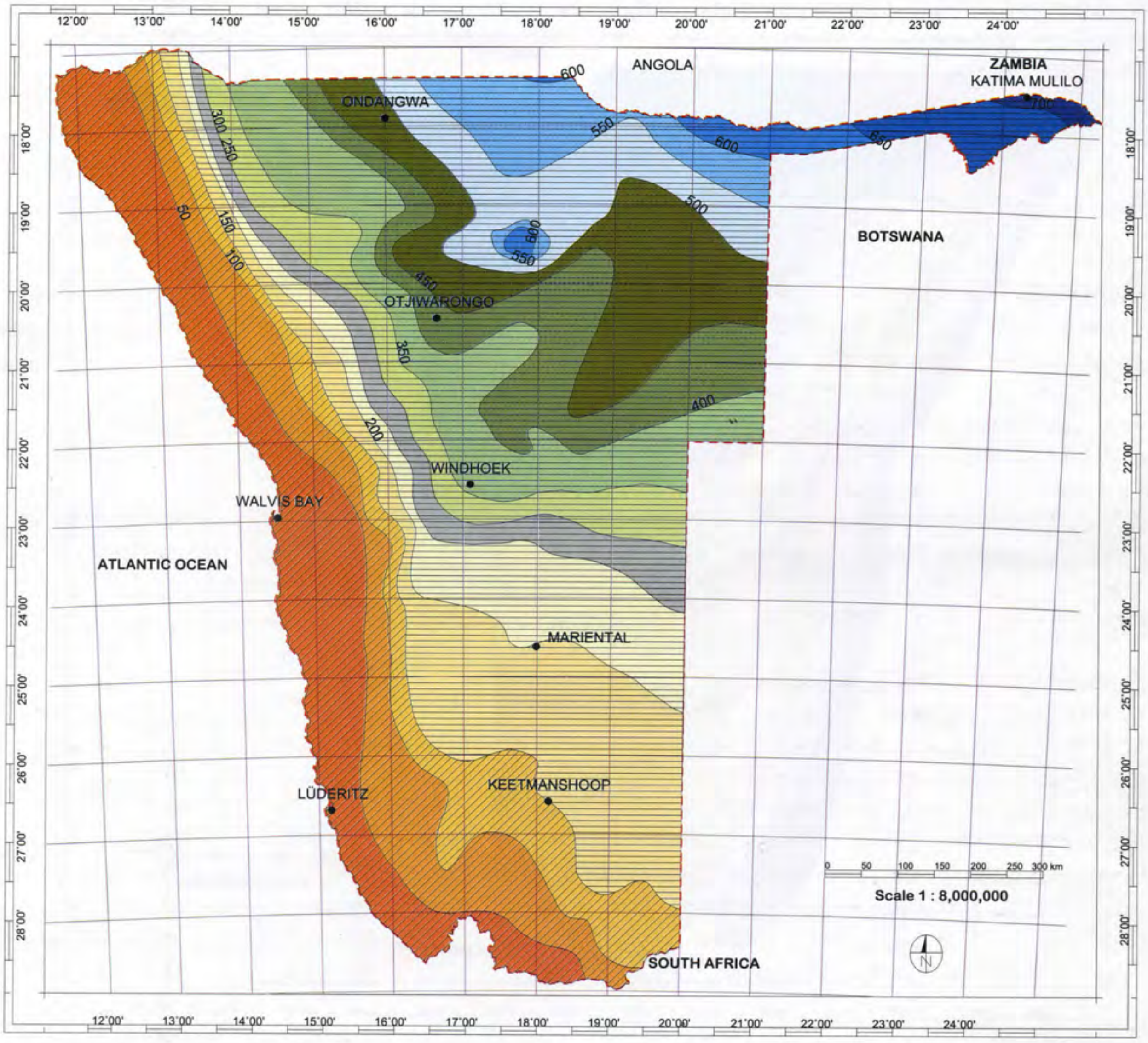
By themselves, the low rainfall and high evaporation over most of Namibia strongly limit the species composition of natural ecological communities, as well as the options for human development. The combination of a cold, subantarctic upwelling on the Atlantic coast and a hot subtropical interior have led to hyper-arid, bleak coastal conditions in the Namib Desert, similar to those of Chile's Atacama Desert and of Baja California, México. The effect of the Benguela Current on climate of the Namib is pervasive. Not only has the cold, nutrient-rich, north-flowing upwelling fostered one of the most productive marine ecosystems in the world, but it has also created a dramatic clash of sea and land, fog and dust, with implications for the southern African region as a whole. However, the obvious zone of transition between cold sea and hot desert is narrow. A thin strip of coastal fog, seldom reaching more than 30 km inland, frequently blows over the hyper-arid coast and sustains life there in the absence of rainfall[6] (map 1.2).

Most of Namibia's rain falls in summer, from November to April. There is extraordinary variation between years, with the driest areas having the least predictable rainfall. However, southwestern Namibia lies in the winter rainfall zone, which characterises Africa's entire southwest corner. In this zone, a diverse succulent flora has proliferated.

Temperatures in Namibia can also be extremely variable and challenging to plant and animal life, with temperatures well over 50°C and under 0°C recorded in the same parts of the country. Daily fluctuations are greatest in the hyper-arid zones, where there is little vegetation cover to moderate the temperature. In the tropical northeast and along the coast, by contrast, daily highs and lows can differ by as little as 2-5°C. Large diurnal temperature changes may act as a strong selective pressure on many plants and poikolothermic ('cold blooded') animals. Along with sporadic rainfall, high temperatures in the arid interior help create a high water deficit (map 1.2).

In geological time, the Namib Desert and its adjacent plateaus have been arid or semi-arid for many milennia. The convergence of the Benguela upwelling and the hot interior has certainly maintained, and perhaps increased, the aridity of the region in recent times.[7] Yet this convergence did not by itself generate the aridity. There is ample evidence that the Namib has been semi-arid to arid for at least 55 and possibly up to 80 million years, despite significant climate fluctuations, while the Benguela Current was forced northward along the southwest African coast only about 5-10 million years ago.[6,8,9] The slow continental breakup of west Gondwana, 130-145 million years ago,[9] set overlying conditions for the region's aridity, by shifting southern Africa to its present position astride the Tropic of Capricorn, and slowly readjusting adjacent marine currents and prevailing winds. In effect, the region has been an island of aridity in a 'sea' of more changeable climes.[10]

Map 1.1 Mean annual rainfall in Namibia



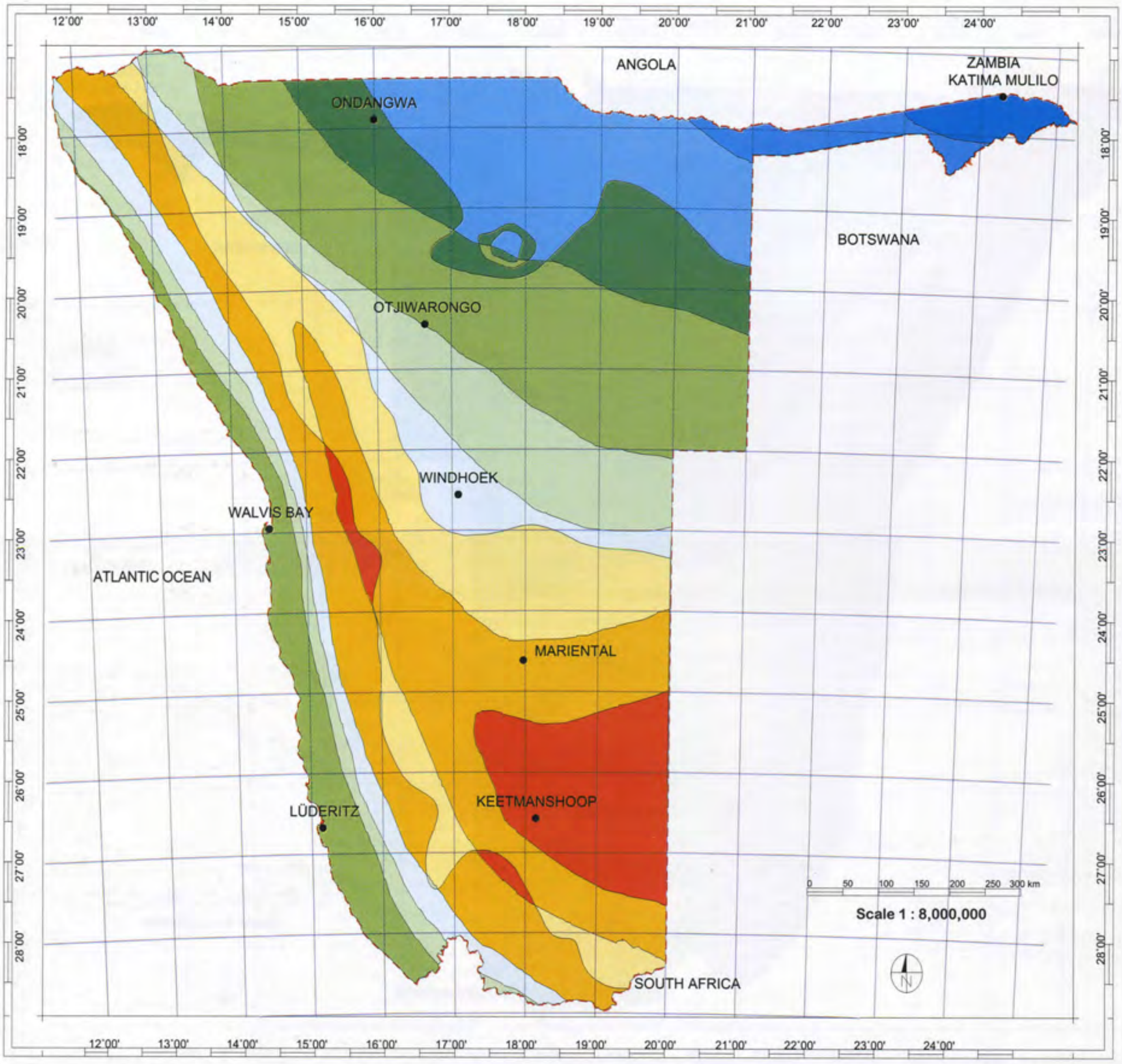
Mean Annual Rainfall

- 0-50 mm/yr
- 50-100 mm/yr
- 100-150 mm/yr
- 150-200 mm/yr
- 200-250 mm/yr
- 250-300 mm/yr
- 300-350 mm/yr
- 350-400 mm/yr
- 400-450 mm/yr
- 450-500 mm/yr
- 500-550 mm/yr
- 550-600 mm/yr
- 600-650 mm/yr
- 650-700 mm/yr
- 700-750 mm/yr
- Arid
- Semi-Arid

Source:

Ministry of Agriculture, Water and Rural Development Department of Water Affairs

Map 1.2 Mean water deficit in Namibia (mean annual rainfall minus mean annual evaporation, in mm)



Water Deficit

(Mean annual rainfall - mean annual evaporation in mm)

- -3800 to -3400
- -3400 to -3200
- -3200 to -3000
- -3000 to -2800
- -2800 to -2600
- -2600 to -2400
- -2400 to -2200
- -2200 to -2000
- -2000 to -1800
- -1800 to -1700

- Border
- Major Towns

Source:

Ministry of Agriculture, Water and Rural Development Department of Water Affairs

This very long, very dry period has had a profound influence on the region's biodiversity. The Namib is widely called the world's oldest desert, a description which reflects not only the age of its rocks and sands, but also, indirectly, its unique species and biological communities. Today, we find our major *centres of endemism* (areas rich in species unique to Namibia or the region) not in the tropical northeast, but in the arid northwestern escarpment and southern winter-rainfall zone[10] (Chapter 2). While most of Africa has undergone ceaseless climate fluctuations, generating the expansion and contraction of savannas and forests over milennia, the continent's arid coasts have remained relatively stable centres for the evolution of desert and dry-savanna species.[7,8] Dramatic bouts of volcanism have taken place in parts of Namibia over the past 40 million years,[9] but these have had only sporadic local effects within an overall context of stability. Namibia's centres of endemism are taken up further in Chapter 2.

Geology, soil and landforms

Namibia is a geologist's paradise. With so little 'annoying vegetation' to get in the way, so to speak, and with rich ore deposits over much of the country, it is hardly suprising that Namibia is very well known geologically and geographically. Even in the 1960s, a rather broadly defined bibliography of geography and related fields in the then South West Africa contained over 2000 titles.[11]

The geology of Namibia is complex and fascinating, and attempts to distill it into a few landform categories will always seem simplistic. However, although the country is divided into numerous minor landforms or geophysical zones (map 1.3), four major categories can be distinguished: **coastal plain and Namib Desert**; the broken and rugged **Namib escarpment**; the rocky **central plateau**; and the **Kalahari sandveld.**[12,13] Only the sandveld is fairly simple geologically; the other zones conceal a hodgepodge of intrusions, ridges, dykes, sills and outcrops.[14]

The Namib Desert and coastal plain give the country its name, as well as its most forbidding and distinctive scenery. Yet the Namib as a geo-ecological zone extends about 2000 km from the Carunjamba River in Angola to the Olifants River in South Africa.[6,8] Bounded sharply by the Atlantic on the west, its eastern reaches are ill-defined. The Namib reaches 80 to 200 km inland, roughly coinciding with the 100-mm annual rainfall line (map 1.1), the 1000 m altitude contour line (map 1.4), or the Namib escarpment.[6,15] It covers about 15% of Namibia's land area.[13] There are three broad desert landforms:

- the southern Namib, with spectacular "dune sea" and "islands" of black outcrops and inselbergs;[16]
- the central Namib, with gravel plains between the Ugab and Kuiseb Rivers;[15]
- the northern Namib, with rugged mountains and dunefields reaching northwards into Angola.[6,15]

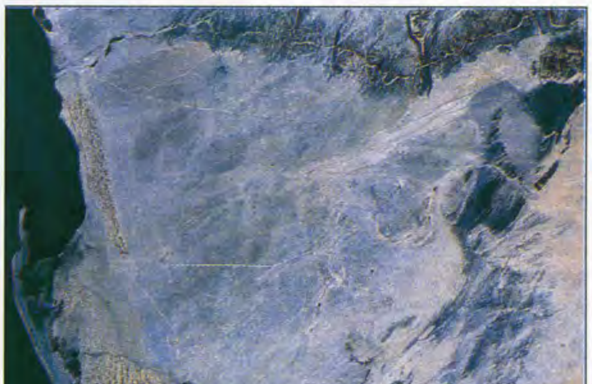
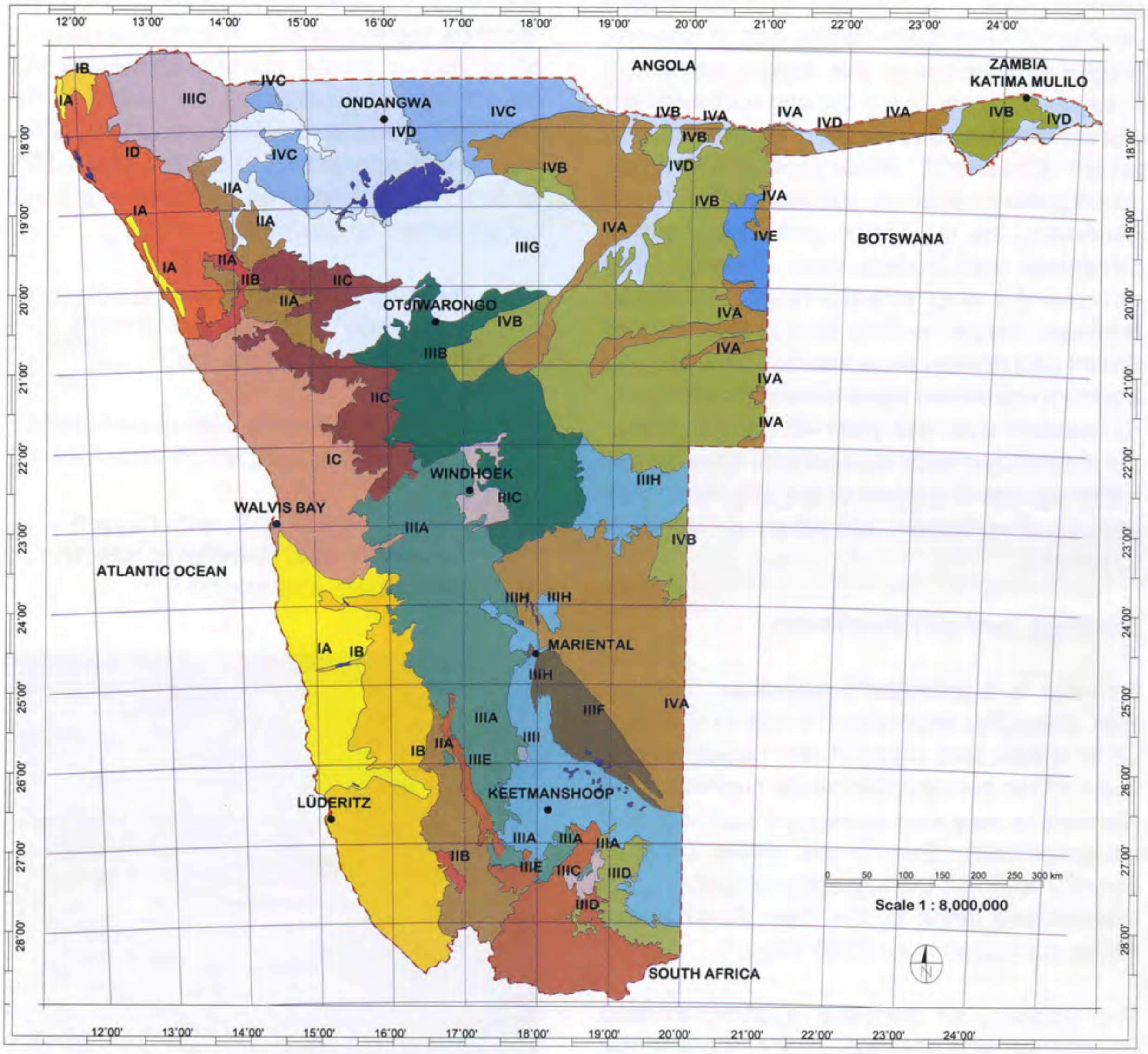


Fig. 1.1 The Kuiseb River slices through the central Namib, cutting off the northward movement of dunes. Courtesy NASA.

Map 1.3 Landforms of Namibia



Landforms

IA	Namib sand dunes
IB	Complex of Namib sand drift and association of hills and valleys
IC	Namib desert pavement
ID	Namib hills and valleys
IIA	High mountains of the escarpment
IIB	Plateau remnants of the escarpment
IIC	Erosion surface of the degraded escarpment
IIIA	Plateaus proper of the plateau
IIIB	Plateau with ridges in the plateau
IIIC	Highlands of the plateau country
IIID	Dissected plateau fringes of the plateau country
IIIE	Foothills and slopes in the plateau country
IIIF	Plateau of soft porous Kalahari limestone in the plateau country
IIIG	Karst and hard Damara limestones in the plateau country
IIIH	Erosion forms (hills and slopes) on Karoo rocks in the plateau country
IIII	Structural hills in the plateau
IVA	Fossil sand dunes of the Kalahari
IVB	Loose sand drift of the Kalahari
IVC	Compact sandy deposits of the Kalahari Region
IVD	Flooded and overflowing areas in the Kalahari Region
IVE	Hills in the Kalahari basin
	Pan

--- Border

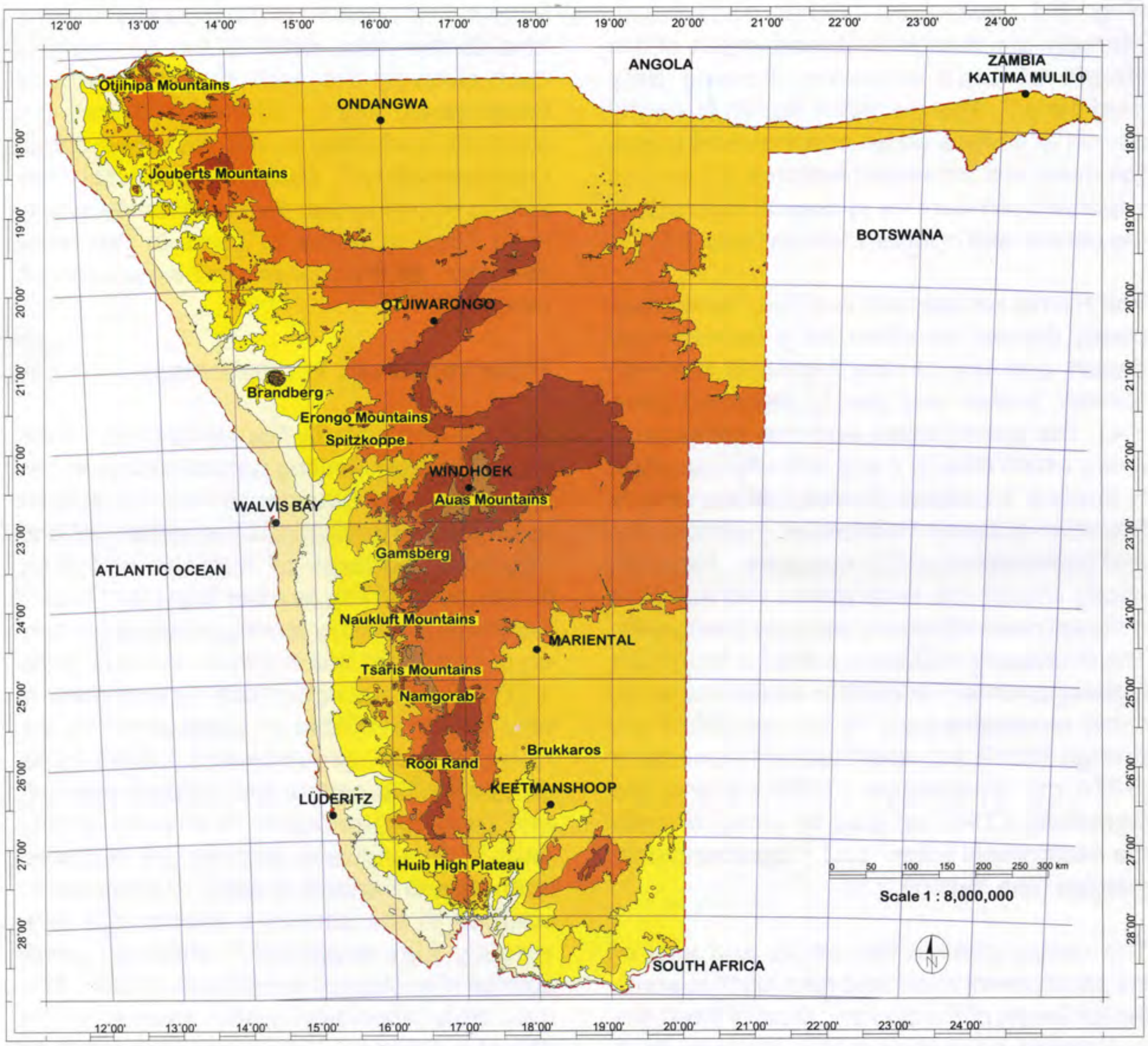
• Major Towns

Source:

FAO 1983

AG: DP/NAM/78/004

Map 1.4 Elevation contours of Namibia (300 m intervals)



Contours

Measured in meters

0-300	1500-1800
300-600	1800-2100
600-900	2100-2400
900-1200	> 2400
1200-1500	

--- Border

• Major Towns

Source:

Ministry of Lands, Resettlement and Rehabilitation
Division of Survey and Mapping

In reality, the Namib Desert has few sharp transitions. A dramatic exception is the Kuiseb River, which cuts off the northerly march of the southern Namib's dune sea[6] in a dividing line as sharp as a knife edge and spectacularly apparent from satellite images (Fig. 1.1, map 1.3). Other ephemeral, normally dry riverbeds dissect much of the Namib at wide intervals, flowing only irregularly.[17] The southern Namib is nearly devoid of surface water or ephemeral rivers, but rivers are prominent features, as well as important corridors for biological diversity, in the central and northern Namib (map 1.5).[6,17]

The Namib escarpment is a thin, sometimes poorly defined transition zone between the desert and the central highland plateau. Narrow, broken and deeply dissected (map 1.4), the escarpment and the ephemeral rivers which breach it are critically important in terms of biological diversity. Many unique Namibian endemic vertebrates, invertebrates and plants are found in this zone. Although poorly known, the escarpment and adjacent mountains are extremely valuable biologically. The Brandberg or Dâures massif is Namibia's highest mountain at 2579 m above sea level. Other mountains such as Baynes (2038 m), Erongo (2319 m), and Naukluft Mountains (1974 m), Spitzkoppe (1759 m) and the Gamsberg (2347 m) also lie along or near the escarpment edge[12] and support endemic species (see section 2.3).

The central plateau lies above and east of the escarpment zone, and runs north to south the full length of the country. Most of the rivers in Namibia have their major watersheds in this highland (map 1.4). It is stony and flat in places, and dramatically mountainous in others, at altitudes between about 1000 and 2000 m.[13] The capital city, Windhoek, lies between two mountain ranges running along the south and east, with the Khomas Hochland plateau undulating west to the Namib escarpment. The northwestern highlands are rugged, with broad valleys and inselbergs, while the south is a flat stony plateau dissected by deep valleys.[12] Mountains in both regions are ecologically valuable and interesting.

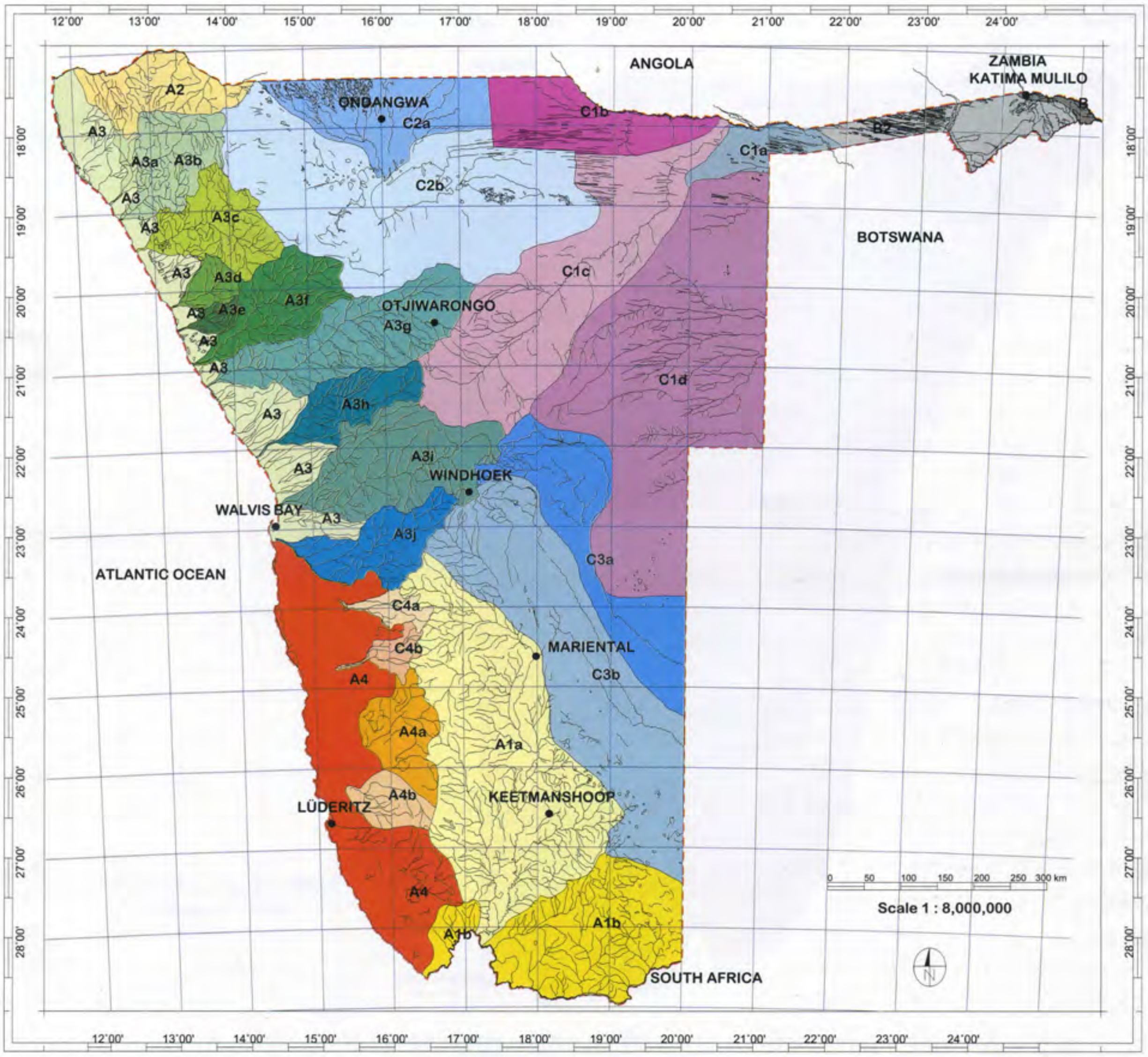
Finally, the Kalahari sandveld stretches east from the central plateau, with deep sands overlaying bedrock. A thick layer of red or pale sand is characteristic of the Kalahari, but the brittle alkaline soils of the north, including the Etosha Pan region, are also part of this system.[12] In contrast to the rugged and stony land to the west, most of the sandveld is excruciatingly flat, with sporadic thorn or broadleaved trees. To the northwest, the sandveld undulates in low, fossilised dunes interspersed with shallow ephemeral river valleys or *omiramba*. Most *omiramba* simply form lines of pools or pans in the rainy season,[12] as the coarse sand is very porous (map 1.6).

Water resources and hydrology

Water is undoubtedly Namibia's most limited and, ultimately, limiting natural resource. Its distribution and abundance have for at least two millennia determined the settlement and migration patterns of humans and their livestock, as strictly as other fauna and flora.[15] Perennial, if variably flowing, rivers occur only on our northern and southern borders (map 1.7). Patchy and ephemeral surface water is only briefly available in some areas in the rainy season, groundwater tables have dropped in the central and western regions, and fossil groundwater is already widely mined. Groundwater sources are of limited quantity and variable quality.[5] Larger water sources in the country's interior are now virtually fully exploited,[18] although small springs of ecological importance remain. The only truly abundant water source is the Atlantic Ocean. The high water deficit throughout the country (map 1.2) makes water management and storage difficult.

Such data make one wonder how economic or population growth can continue in Namibia, given the human and livestock pressure that already exists. Water management strategies to sustain economic growth are neither easy nor palatable, and include conservation, demand management, prioritisation of uses, and development of alternative sources.[18]

Map 1.5 Drainage basins or catchments of Namibia



Drainage Systems

A1a	Fish River	A3f	Huab	B2	Zambezi via Kwando	C4a	Tsondab
A1b	Orange River	A3g	Ugab	C1a	Okavango Delta	C4b	Tsauchab
A2	Kunene River	A3h	Omaruru	C1b	Okavango		
A3	North Coast	A3i	Swakop	C1c	Omatako		
A3a	Khumib	A3j	Kuiseb	C1d	Omurambas		
A3b	Hoarusib	A4	Namib	C2a	Cuvelai		
A3c	Hoanib	A4a	Tsaris	C2b	Etosha		
A3d	Uniab	A4b	Koichab	C3a	Nossob		
A3e	Koigab	B1	Zambezi, direct	C3b	Auob		

A: To Atlantic Ocean
B: To Indian Ocean
C: Endoreic Drainage

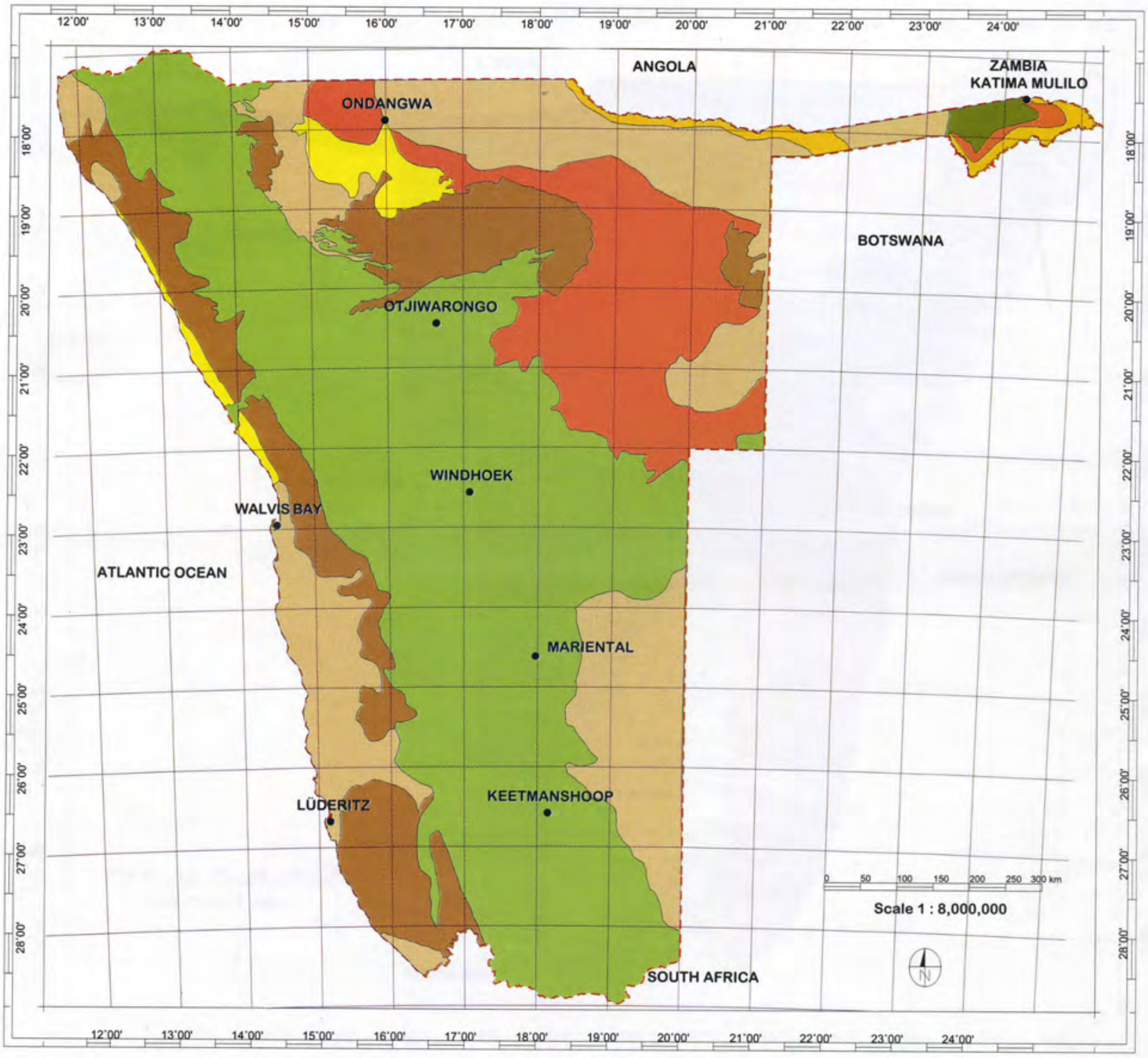
- - - Border
—— Drainage Line
• Major Towns

Source:

United Nations, Cartographic Unit
Department of Conference Services
New York

Jacobson et al. 1995
Ephemeral Rivers and their
Catchments. DRFN, Windhoek

Map 1.6 Simplified soil map of Namibia



Soils

- Lithosols
- Fersiallitic soils
- Solonetzic and planosolic soils
- Halomorphic soils
- Arenosols
- Alluvial and other soils of low-lying areas
- Weakly developed shallow soils of arid regions

--- Border

• Major Towns

Source:

Simplified from:
Engineering Geology of Southern Africa, Vol 4; 1985.
Map Compiled by Soil Survey Staff, Institute for Pedological Research Potchefstroom University.

Map 1.7 Wetlands and ephemeral rivercourses of Namibia

Wetlands

- Border
- Perennial river
- Non-perennial drainage line
- Ephemeral river or main drainage line

Black text indicates the names of drainage systems and pans

Blue text indicates the names of dams

- Pans
- Marshes
- Salt marshes
- Springs according to MAWR database
- Dams according to MAWR database

Source:
United Nations, Cartographic Unit
Department of Conference Services
New York

Ministry of Agriculture, Water and Rural Development
Department of Water Affairs

Vegetation zones

Namibia's steep northeast-to-west climatic gradient, plus its varied soil types and landforms, largely determine the distribution of its characteristic vegetation zones. Annual rainfall determines the three main vegetation zones of Namibia: **deserts**, **savannas**, and **woodlands**.[19] Temperature and seasonality of rainfall, plus topography and soil, influence the 14 major subdivisions of these vegetation zones (map 1.8).

The Namib can be subdivided into true Namib (Northern, Central and Southern Namib) and Succulent Steppe vegetation zones. The Succulent Steppe lies within and is determined by Namibia's winter rainfall area.[19] This is the northern limit of southwestern Africa's Mediterranean-type winter rainfall zone, which contains two of the world's major hotspots of botanical diversity and endemism, the Cape Floristic Kingdom and Succulent Karoo.[20,21] The winter rainfall area and foggy coast are typified by succulent shrubs, mainly in the family Mesembryanthemaceae. Perennial grasses such as *Stipagrostis sabulicola* characterise the Namib mobile dunes, while annual herbs and grasses including other *Stipagrostis* species occur on gravel plains.[22]

The desert fringe, including inselbergs and the Namib escarpment, forms a transition between desert and savanna, termed the Semi-desert/ Savanna Transition zone.[19] Many endemics and species of conservation importance occur here (section 2.3). Although the mountainous Kaokoveld, in the northwest escarpment zone, was classified as Mopane Savanna by Giess,[19] he recognised this as due to inadequate data. The Kaokoveld is part of the transition zone, and is extremely valuable botanically, with high endemicity (Fig. 1.2) and several monotypic general.[23]

Most of Namibia is covered by savanna, especially thorny shrub and tree savanna. Mountain, Thornbush and Highland Savannas dominate the central highlands, while Dwarf Shrub Savanna covers the southern inland plateau. Camelthorn *Acacia erioloba* and Mixed Tree and Shrub Savannas are largely confined to the Kalahari sandveld, and Mopane Savanna dominates the northwest of Namibia, east of the escarpment.

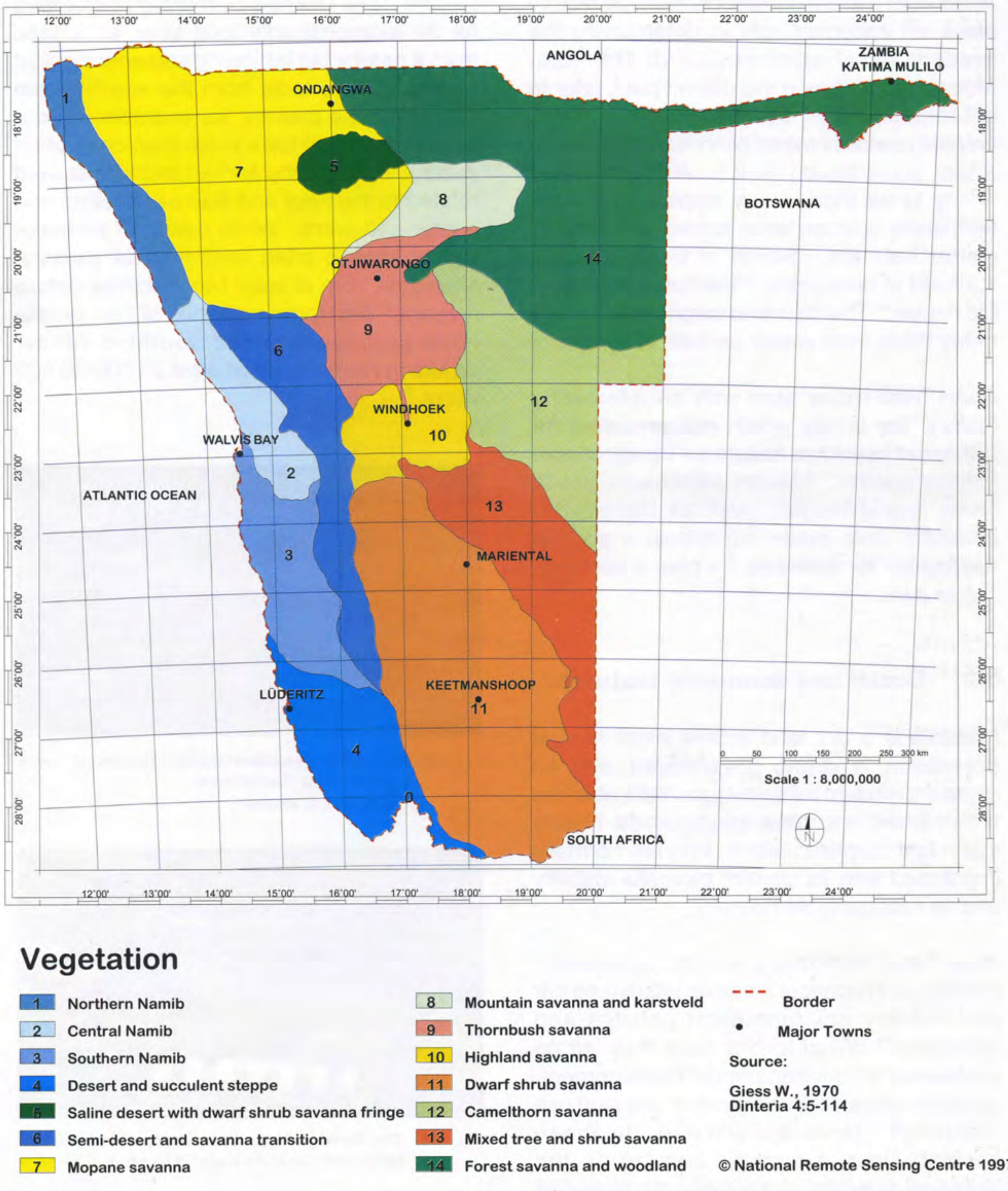
Two types of woodland are distinguished in Namibia. Forest Savanna and Woodlands cover the moist northeastern region, with tropical trees such as *Baikiaea plurijuga*, *Burkea africana*, *Lonchocarpus capassa* and *Terminalia sericea*. Riverine Woodlands are azonal and associated with the continuous moisture supply along rivers. Virtually all rivers are lined with woodlands. Permanent rivers harbour lush, diverse vegetation; the ephemeral riverbeds support trees and shrubs such as *Faidherbia albida*, *Salvadora persica* and *Ziziphus mucronata*.

Fig. 1.2 *Aloe dinteri*, endemic to north-central and northwest Namibia. Courtesy HH Kolberg

Fig. 1.3 Three winter rainfall zone endemics: *Tylecodon aurusbergensis*, *Crassula aurusbergensis*, *Conophytum taylorianum ernianum*. Courtesy G Williamson

Fig. 1.4 *Dracophilus delaetianus*, endemic to the winter rainfall zone. Courtesy G Williamson

Map 1.8 Vegetation types of Namibia (Giess 1970)



What makes the Namibian flora unique? Variable environmental conditions have created a diverse flora with mainly palaeotropical floral elements in the north, cold-temperate elements in the south, and transitional elements between the two.[24] Apart from current conditions, climatic history plays an important role in determining the present floral composition of Namibia. Moister conditions in the distant past, prior to establishment of the Benguela Current, created relatively mesic conditions supporting a less arid-adapted flora.[25] With increasing aridity since then, many tropical and cold-temperate species were forced to retreat to wetter habitats. Some of these species survived in favourable microhabitats even in the desert.[26] The Namib escarpment harbours many relics from wetter periods in the past.

Apart from many taxa with an interesting history, the aridity which has prevailed for millions of years has fostered a variety of arid-tolerant species. Species with bizarre growth forms and strategies, such as *Welwitschia mirabilis*, have made the Namib a popular destination for scientists for over a century.
—Antje Burke

1.2 Social and economic features

Namibia is a dry land with a small human population, a young government, and an excellent modern infrastructure. Yet it also has a tormented and bitter sociopolitical history that might surprise visitors, who are normally impressed with its current peaceful stability and its multiparty democracy.

How have Namibia's social, economic, political and historical contexts influenced our present-day environmental policies and institutions? What legacy have they left on processes of environmental management, scientific research, conservation and land use planning? More specifically, do these contexts have a specific bearing on the biological diversity conservation strategies we must develop? The following sections sketch out an overview of these factors, and attempt to draw broad conclusions about the social, economic and political contexts in which biodiversity conservation actions must proceed.

Human palaeoecology

People have roamed Namibia's landscapes for an extraordinarily long time, as judged from a patchy but intriguing palaeoecological record. Stone tools from the south-central plateau of the country, for example, span a sequence dating back more than one million years.[27] Perhaps the earliest inhabitants were related to the Khoi and San pastoralists and hunter-gatherers. While dating of archaeological sites is often controversial, pastoral sites date from at least two millennia before present,[15] and foraging bands of San people have probably roamed southern Africa, including Namibia, for at least 20 000-30 000 years.[28]

Fig. 1.5 Early 'written' records of Namibian biodiversity — rock engravings at Twyfelfontein.
Courtesy L C Weaver

Fig. 1.6 The Naukluft holds many clues to early human settlement. Courtesy National Museum of Namibia

These early Namibians inhabited a land not very different to that of today: an arid interior and coastal plain, with a productive intertidal zone influenced by the Benguela Current. Radiocarbon dates of shellfish middens in the

Kuiseb Delta, on the Atlantic coast, range from 1870 years ago to about 130 years ago.[15] Traces of extinct freshwater springs can sometimes be found there, along with white mussels *Donax serra* and reeds *Phragmites australis*, which still inhabit patches of the coast today. From these we can infer a highly dynamic dune-lined coast, very similar to that of today, at which small groups of nomads used resources from both land and sea.[15]

An orthodox pre-history of Namibia dates the major immigration waves of cattle-owning pastoralists from east-central Africa, the ancestors of today's Herero- and Aayamba (Owambo)-speaking Namibians, to the 16th and 17th centuries AD.[29] Such accounts were intended to establish the arrival of European explorers and Bantu-speaking people at about the same time, for political reasons, and have been thoroughly refuted by archaeological evidence.[15,30,31] Williams[32] draws on oral records to trace early Owambo settlements to the 10th century AD or before. Copper and other minerals were mined and smelted by people settled in the north of present-day Namibia for weapons, utensils and ornamentation.[32] Well-established kingdoms and chieftancies, with diverse and structured economies, existed long before the arrival of Europeans in Namibia.

Political history

The written record of Namibia's history has been mainly one of bitter resource conflict. The territory had certainly not been free of conflict before European exploration and settlement, but was characterised by periodic violent clashes of nomadic pastoral clans over grazing and other rights, and somewhat more peaceful relations between settled communities. Clashes between communities in the late 1800s allowed Europeans to negotiate advantageous land-for-weapons treaties with individual chiefs. One such agreement between trader Adolf Lüderitz and the Nama chief at the coastal port of Angra Pequena (now Lüderitz) concerned rights over land which later became one of the world's most productive diamond-mining areas, and was seen as a pivotal historical event.

Namibia's substantive written history begins around this time, with key events initiated, as if by remote control, by ambitious European leaders. In 1884, Chancellor Otto von Bismarck proclaimed a German protectorate in what is now Namibia, allowing for the expansion of German control into the interior with its lucrative rangelands.[2,33] He dispatched Heinrich Göring (father of Nazi general Hermann Göring) as first Imperial Commissioner to ensure the acquiescence of Namibian kings and chiefs to German 'protection.' In Hamutenya's[33] words, since Germany was a late arrival to the scene of colonial expansion and conquest, it was hastier and more brutal than most of its colonial competitors. Merchants and speculators from that country had, by 1883, already acquired large chunks of Namibian land as private property and concessions.[33] Defending the potential export markets and resource acquisitions of these early businessmen was a substantial additional reason for Germany to stake out an aggressive presence in Namibia.

Fig. 1.7 German Schutztruppe at a camel race, c. 1910. Courtesy National Archives of Namibia

Fig. 1.8 Typical German colonial homestead. Courtesy National Archives of Namibia

The notorious Berlin Conference of 1884-85 consolidated the European hold over the entire African continent, dividing it into colonies and protectorates for political influence and natural resource exploitation. The new borders were based more on perceived resource distribution than on intrinsic cultural, geographic or ecological divides. This extraordinary process rapidly transformed Africa, including Namibia, into a 'sphere of monopoly expansion and influence.'[33]

The century following the Berlin Convention was frequently marked by appalling and brutal administrative and miltary policies on the part of successive German and South African colonial administrations. Policies and actions by the colonists to expropriate land, livestock, and other vital natural resources held by Herero- and Nama-speaking clans led to the 'Great Uprising' or 'Great War of Resistance' in 1904-1908. Of roughly eighty thousand Hereros, only about fifteen thousand survived, and many of these were driven across the Kalahari into Botswana. More than half of the Nama people, and at least a third of the Damaras, were exterminated.[33] More than 17 000 survivors of these massacres were brutally thrown into concentration camps, where nearly half died. Africans living in the 'Police Zone' after 1908 were barred from owning cattle, forced into indentured labour on settlers' farms, and progressively driven onto ethnically-divided 'native reserves.' This policy was continued with greater fervour by South African colonial planners.[2, 33]

Fig. 1.9 Boer settlers in the South African-subsidised settlement scheme, c. 1925. Courtesy National Archives of Namibia

The outbreak of World War I led to military occupation of Namibia by British South Africa in 1915, supported by many Namibian kings and chiefs, and marked the end of German rule. In 1920 the League of Nations granted South Africa a mandate to administer the land, with obligations to promote the welfare of Namibians which were generally ignored.[2] A legislative assembly for whites, set up in 1925, constantly lobbied for the inclusion of Namibia into South African territory. Hopes for the restoration of land confiscated by the Germans were frustrated, as prime land was parcelled out to Afrikaans settlers under a costly subsidised settlement scheme in the 1920s and 1930s (Fig. 1.19).[2,34] Two uprisings against such policies in the 1920s were violently crushed by South African police. The German colonial programme of resource exploitation and land theft, backed up by brutal armed force, was thus continued more systematically by the South Africans.[33]

Resource conflicts also plagued Namibia's efforts to free itself from South African rule, which was subject to Cold War meddling in the interests of political influence and land control. Namibia was declared a trust territory with rights of self-determination by the United Nations in 1945, just after the UN's birth. It became a battleground for political posturing by South Africa, which rejected the UN's authority, by the UN and Namibian resistance bodies, which rejected South Africa's authority, and later by the USA, USSR and Cuba, which were engaged in wars for regional political and economic influence. The UN terminated South Africa's mandate in 1966, set up a council with authority for the territory and appointed a commissioner in 1974. The Security Council called for UN-supervised elections, endorsing an International Court of Justice ruling on the illegality of South Africa's occupation.[2] All of this failed to force South Africa from the territory. Only in 1989, when UN-sponsored elections were imminent, did the South African media report that Pretoria's war effort in Namibia and Angola was simply too costly to sustain, at a million rands per day.

Following Independence on 21 March, 1990, and the election of a multiparty democratic government led by the Southwest African People's Organisation (SWAPO), Namibia has finally made strides to redress the resource inequalities of the past century. The national constitution supports a unitary republic with a bill of rights, an executive president and strong prime minister, a two-chamber legislature, multiparty elections, and an independent judiciary.[2] Ownership of land, water and other natural resources is vested in the State unless otherwise 'lawfully owned,' and the State must pay market-related compensation for property it nationalises or expropriates.

Land reform, so central and burning an issue throughout the colonial period, has been broached, but not substantially implemented eight years after Independence. Major public land reform conferences were held in 1991 and 1994; legislation to support reform is in effect or underway; and technical groups are studying ways to implement recommendations of the conferences. Yet public perception is that few, if any, real changes have taken place in the ownership of major enterprises, or in the distribution of land and wealth. This has posed difficulties for the government in striking a balance between its policy of national reconciliation, which aims to unite formerly divided communities, and its land reform policies, which aim to redress social and political inequality within a mixed economy (see below, 'Land use and the economy').

Fig. 1.10 Independence Day 1990. Courtesy National Archives of Namibia

Demography

Descriptions of Namibia commonly note that we have one of the lowest human population densities in the world, and the third lowest in Africa after Western Sahara and Botswana.[2] Namibia has nearly 3% of Africa's total land area, but only about 0.2% of its population.[13] The 1991 national census estimated our population at 1.43 million, including the Walvis Bay enclave which was then under South African control, with a projected 1995 population of 1.61 million.[1] Overall, there are about 1.7 people/ km^2. Dry countries of a similar size, such as Pakistan or Turkey, by contrast, have about 30 times the population.[18]

However, these statistics are deceptive. Namibia's sparse population density has led to much complacency, as captured in a popular pre-Independence bumper sticker, 'Sleep with a Southwester: we need more of them.' The missing ingredient in this misguided sentiment is, of course, awareness of Namibia's acute limitations in the physical ability of its land to support more people. The country's dry climate, erratic and very localised rainfall, infertile soils, and large areas of saline groundwater make most of the land unable to support much higher population densities.

Combined with highly skewed distribution of wealth, low economic productivity and inequal access to resources and appropriate technology, these constraints in effect make some areas of Namibia already over-populated, with unsustainable population densities and growth rates in several areas. Most sparsely populated regions of the country, such as in the south, cannot support significantly higher human densities due to the patchy availability of surface and non-fossil groundwater.[35]

Namibia may have a low overall human density, but our estimated annual population growth rate of 3.1% is one of the world's highest. It is the highest in southern Africa,[1] which averages 2.4% population growth, even though our country is the region's most arid. This rapid growth is certainly not sustainable. Per capita economic growth often lags behind population growth (Box 1.2; see Chapter 4). Namibia's economy grew fast in the years after Independence, reflecting an optimistic investment climate and government commitment to stimulating the economy. However, our leaders face a herculean task to maintain our current political and economic stability in the face of this population pressure.

Box 1.2 Population and economic growth in Namibia

Annual real economic growth (averaged)

	1981-89	1990	1991	1992	1993	Mean 1990-93
Real GDP growth	1.0%	0.0%	6.8%	6.8%	-1.5%	2.9%
Per capita real GDP growth	-2.1%	-3.1%	3.5%	3.6%	-4.6%	-0.2%

Source: NPC[1]

Past and projected future population growth (averaged)

	1980-85	1990-95	2000-05
Annual population growth	2.9%	3.2%	2.9%

Source: WRI[36]

The government has made large strides in managing the daunting social and health needs of the Namibian population. For example, ambitious primary health care programmes, including family planning initiatives, were launched by the Ministry of Health and Social Services after Independence. These have involved massive investment in infrastructure, staff and training.[1] Namibian women currently have an average of 6.1 children in their reproductive lifetimes.[1] Yet a woman's fertility decreases rapidly with increasing education (Box 1.3). Government efforts to improve access to health care and education, and combatting poverty, will thus help manage our population growth.

Box 1.3 Human fertility in Namibia

Mean total fertility	(children / woman)
Rural	6.8
Urban	4.7
All women	6.1
No education	8.8
Completed grade 7	7.2
Completed grade 10	4.2
Completed grade 12	3.1

Source: NPC[1]


Fig 1.11 Water is often trucked to rural settlements with no potable surface water. Courtesy Ministry of Information and Broadcasting (M Namundjebo)

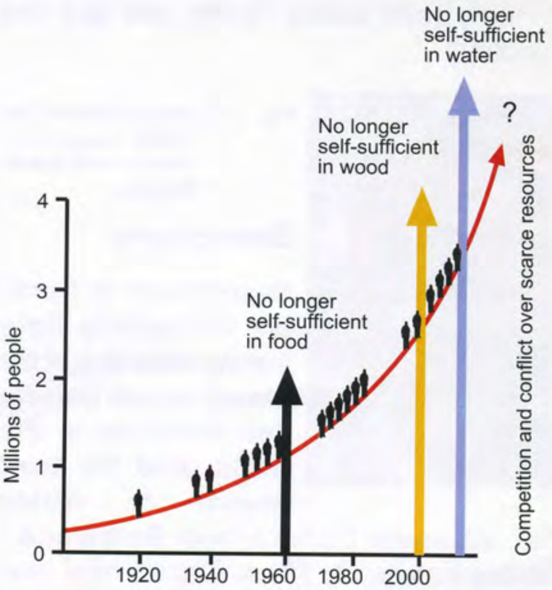


Fig. 1.12 Projected human population growth and postulated resource crises facing Namibia Courtesy C Ashley

Fig. 1.13 Primary health care services have made significant strides. Courtesy Ministry of Information and Broadcasting

Fig. 1.14 A rural primary school. Courtesy Ministry of Information and Broadcasting

Box 1.4 Human mortality in Namibia

The three major causes of human death in Namibia are AIDS, malaria and tuberculosis. AIDS overtook other diseases as the top killer in late 1996. It is greatly under-reported and is not usually listed on death certificates.

Cause (all ages)	*% of total deaths*
AIDS	12.4
Tuberculosis	7.5
Malaria	6.7
Gastroenteritis	6.4
Cancers	6.2
Pneumonia	5.2
Premature birth	4.4
Chronic cardiovascular failure	4.3
Malnutrition	3.3
Cardiovascular accident	2.7
Other causes	41.3

N = 7472 deaths

Source: UNDP[37]

Land use and the economy

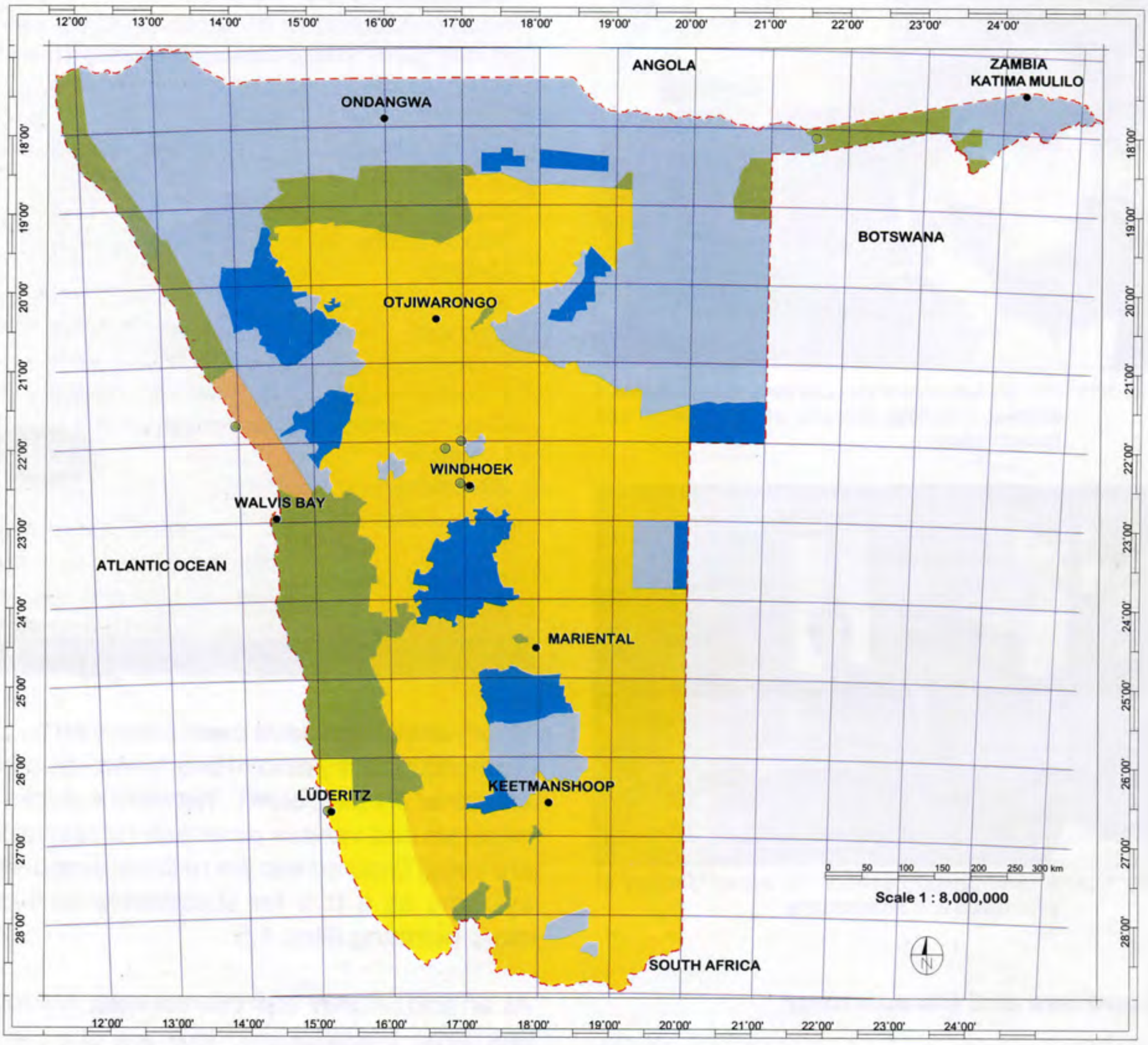
Namibia is mainly an agricultural and mining nation, with important marine fisheries. It depends heavily on both imports, such as food, manufactured goods, and technology, and exports such as beef, fish and minerals. Like many other arid developing countries, Namibia's economic output is highly sensitive to fluctuations in climate and world market prices[38] (see also Chapter 4).

Prior to Independence in 1990, mining and commercial agriculture jointly accounted for about 30% of Gross Domestic Product (GDP) and 75% of total exports.[2] The mining sector has remained extremely influential, with diamonds, uranium and base metals mined mainly for export.[2] This sector is a major landholder. Large areas on Namibia's arid southwest coast have been controlled by the diamond industry since 1908[16] (see *Protected industrial areas,* below). Namibia's stocks of minerals and various other natural resources are being factored into the national accounting systems as a tool for sustainable development planning (Box 1.5).

As an arid country with infertile soils, Namibia has large tracts of land that are unsuitable for livestock or crop production, and almost no potential for the expansion of irrigation. Food self-sufficiency by the year 2020, an oft-cited policy goal, is therefore conceivable only for specific items such as beef, mutton and fish. The subsistence farming sector produces only 1.5% of GDP, but is an essential means of livelihood for about 70% of the population.[2] GDP statistics are therefore not a very meaningful index of economic activity for most Namibians. The gap between rich and poor is desperately large: income inequalities are believed to be the highest in the world.[2]

Map 1.9 summarises the distribution of Namibia's major land tenure systems, which are outlined below.

Map 1.9 Major land uses in Namibia



Land Tenure

- State protected nature area
- Open communal area
- Sub-divided and surveyed communal farmland
- Tourist recreational area
- Restricted area for mining
- Commercial farmland

- • Major towns
- • Small state protected areas

Source:

Various Government Gazettes published by the Government of Namibia.

Ministry of Lands, Resettlement and Rehabilitation Division of Survey and Mapping 1:250000 maps.

Box 1.5 Natural resource accounts

Stocks and flows of natural resources are rarely reflected in national accounting systems, despite the overwhelming dependence of most countries on their natural resource base. Namibia, like many developing countries, depends on exports of natural resources. Ensuring that our national decision-making adequately reflects the true costs and benefits of natural resources requires a system of ***natural resource accounting****, or NRA.*

Together with support from New York University, Namibia's environmental economics unit at the Directorate of Environmental Affairs (DEA) has embarked on a programme to integrate NRA principles into the national accounting system by building 'satellite accounts' for natural resources. These accounts have many uses, such as helping the government assess whether it is maximising revenue from individual resources, or which uses of water are most valuable to the national economy. NRA analysis can also help governments plan for the ultimate obsolescence of industries based on non-renewable resources, such as minerals,by investing profits in sustainable industries. The Namibian NRA project began in 1996 and has already completed several valuable analyses for policy-makers.

— Rob Blackie

Land use practices in Namibia today, towards the close of the 20th century, stem directly from the massive social-engineering policies of the colonial past. The *apartheid* 'homeland' policies of the South African administration, and the German administrative distinction between 'Native Reserves' and 'Crown Land,' played dominant roles whose shadows are still cast on the country today.[39] By reserving prime land for white settlers, both colonial powers gradually squeezed black Namibians onto land that was agriculturally marginal, prone to human or stock diseases, or both. This grim pattern was repeated throughout Africa wherever European settlers were a powerful political and economic force, but reached a zenith in South Africa and Namibia. Despite wartime disruption to South Africa's costly resettlement scheme for white farmers in Namibia, an ethnically based policy of land exclusion was well established by the 1930s.[34]

Increasingly ostracised by the UN and world community for its *apartheid* policy and illegal occupation of Namibia, South Africa in 1971 went ahead to implement recommendations of the notorious Odendaal Commission report.[34,39] This was Pretoria's most ambitious blueprint for 'separate development' in Namibia. It set up ethnic 'homelands' along the South African model, mostly at the edge of the commercially-farmed, white-occupied central highlands. The per capita allocation of land was 54 ha for blacks and 'Rehoboth Basters,' people of mixed racial descent, and 444 ha for whites.[39] These homelands were never viable in structural or economic terms, but were a way of controlling a cheap labour pool for white-owned enterprises.[34]

By the late 1970s, Namibia had a core of heavily subsidised ranching land in the 'white heartland,'[39] surrounded by much more densely settled homelands which often had poorer soil or groundwater. This state of affairs is still largely intact today. Of the roughly 6100 commercial farms in Namibia, mostly large cattle and sheep ranches, about 89% are owned by local white farmers, 9% by non-Namibians, and 3% by black Namibians.[2]

Other than mining and agriculture, conservation and tourism are collectively increasingly important in terms of land surface and GDP (see below and Chapter4). Finally, urban development is a rapidly growing land use in Namibia, albeit on a smaller scale than in many countries (below).

Agriculture and traditional land uses

Namibian agriculture is in many ways typical of dryland farming throughout the world, with heavy emphasis on livestock production. Most farmers keep goats, cattle, sheep, ostriches, game mammals or a combination thereof. Much of the land zoned for agriculture in Namibia is suitable only for nomadic or rotational grazing due to poor surface water availability, erratic rainfall and thin, infertile soils in much of the country. Only about 6.5% is suitable for mixed arable farming, where soils are suitable and mean annual rainfall exceeds 500 mm.[1,34] Less than 5% of Namibia is under irrigation.[40] This is at or near the theoretical maximum due to water availability and salinisation risk.[18] Namibia is thus essentially a range country, with reasonably diverse rangeland uses.

An extremely important sector in terms of human livelihoods is non-commercial or subsistence farming on communal land. Most communal farmers, in addition to stock management, plant small seed crops such as millet (*omahangu*) *Pennisetum glaucum*, sorghum *Sorghum bicolor*, beans *Vigna unguiculata*, pumpkin *Cucurbita moschata*, and melons (*Citrullus lanatus* and *Cucumis melo*). Many people also gather wild foods and keep poultry (Chapter 4).

Traditionally, many of Namibia's people were nomadic pastoralists, moving animals long distances to find water and grass where it was available.[15] Pastoralism or 'transhumance' was widely practised in catchments of the western ephemeral rivers for at least 4000 years, but started to disappear with the arrival of Namibia's first colonists in the nineteenth century.[17] Movements of the OvaHimba people within the Khumib catchment were an excellent example of an appropriate rotational grazing system in arid rangelands.[17]

The introduction of communal land areas as outlined in the Odendaal Commission report[41] has interfered with this transhumance system, leading in some areas to environmental degradation. As a direct consequence of this, indigenous farmers lost their traditional ability to defend and manage their seasonal pastures or grazing areas.[42] Historically many Namibian farmers were forced to live under reserve conditions, and those who worked as labourers on commercial farms had little or no land or livestock. The traditional management practises and ecological knowledge of communal farmers can greatly assist agararian reform.[34] While some traditional practices and knowledge may be incompatible with new technologies, it is better to foster the wisdom and knowledge contained in these practises, and accept them as an integral part of modern, environmentally sustainable range management.[42]

Agricultural development in communal areas was neglected for many years. Formal extension services did not exist until recent decades, and trainers appointed to extension posts did not receive adequate guidance or supervision.[34] Financial credit and agricultural extension assistance to communal farmers has greatly improved since Independence.

Beginning in the early 1960s, veterinary cordon fences known as the 'Red Line' were erected to restrict the southward movement of cattle raised on communal farmlands.[43] These cordons were prompted by the risk of transmission of stock diseases such as bovine lungsickness (CBPP) and foot-and-mouth disease (FMD, see Appendix 6), and followed directly from a major outbreak of FMD in 1961. Discussions have gone on for some years about the possible removal of these fences to allow equal marketing opportunities for communal stock farmers, but the issue is highly controversial.

Fig. 1.15 The 'Red Line' veterinary checkpoint at Oshivelo. Courtesy Ministry of Information and Broadcasting (Asser Kangootui)

Fig. 1.16 Communal farming extension services. Courtesy B Kruger

The livestock export industry is based almost entirely in the commercial sector, south of the Red Line, and earns considerable foreign exchange. Currently, it is worth about N$800 million annually, with increasing export volumes making up for short term drops in meat prices. Eighty percent of commercial animal production (meat, meat products, live animals) is exported. Most meat exports have been to South Africa and the European Union.[43,44] Trade in canned meat from communal areas north of the Red Line has been previously been authorised under EU regulations,[43] but stringent hygiene and veterinary disease controls are more difficult to maintain in the less-developed communal farmlands.

Karakul sheep production, mainly in southern Namibia, has historically been the second most important branch of commercial agriculture after beef, but sensitivity to fluctuating international market prices for pelts has harmed the industry and greatly reduced its contribution to GDP. During the same period, wildlife farming has become increasingly important, as it is linked to the fast-growing tourism sector (see below).

Mining

Charles Darwin's cousin, the explorer Francis Galton, in 1851 noted Ovambo tribesmen smelting copper from surface deposits near Otavi.[45] Commercial mining was established at about the same time in 1854-55 with the formation of the Walvisch Bay Mining Company to exploit copper.[46]

Mining has long been the backbone of the Namibian economy, and remains the major contributor to the country's GDP and export revenues.[47] Revenues are highly sensitive to world market prices and fluctuate accordingly,[48] but commonly account for over 70% of export earnings, 11-25% of GDP, and roughly 25% of government revenues.[48,49] Although in the early 1980s mining strongly dominated the economy, contributing over 40% of GDP, economic diversification and global market prices have gradually reduced this rate to about 11% in 1995.[47,49]

Small to medium mineral deposits and mining claims occur throughout much of Namibia. The two main operations, NAMDEB Diamond Corporation in the *Sperrgebiet* (see below) and Rössing Uranium in the central Namib currently earn the country most of its minerals-related foreign exchange.[50] The *Sperrgebiet* is by far the largest mining area and the only one legally proclaimed and restricted for mining. The 186 km^2 Rössing mining area, east of Swakopmund, was historically the major water consumer of the central Namib. It has significantly decreased its consumption and now features corporate measures to limit and monitor negative environmental and health impacts of mining.

Copper and other base metals are mined from several sites and smelted at Tsumeb, and gold is mined at the Navachab site near Karibib. A major copper mine at Haib in southern Namibia may commence operations in 1999, and the feasibility of exploiting extremely pure cathode zinc deposits at the Skorpion mine is under study.[45] About 40 formal mining operations are active in the country, producing 30 commodities such as diamonds, uranium, semi-precious stones, base metals such as copper, gold and zinc, industrial minerals such as petalite and fluorspar, and dimension stones such as granite and marble.[46,50,51] Other resources of significance which are mined in Namibia include seabird guano and salt (Box 1.6). There are also sizeable offshore reserves of natural gas and oil,[52] for which extensive prospecting has taken place.

Historical links between mining and abuse of the environment are clear. Namibia is littered with the rusting remains of abandoned and unrehabilitated mines.[51] Although mining activities need not be contrary to the aims of environmental conservation, mines in Namibia were historically the realm of entre-preneurial frontiersmen who often worked the mines in conditions of great hardship and abandoned them in bankruptcy.[53] Modern mining activities rely on increasingly sophisticated technologies. Although they are increasingly accompanied by environmental assessment and monitoring programmes, certain mining activities which may significantly threaten biodiversity.

Box 1.6 The guano harvesters

The guano mining industry of the past is an instructive example of the boom and bust exploitation of a natural resource. It has also become an example of a modern industry successfully integrating economic activity and environmental conservation. After the 1828 discovery of Namibian guano deposits and the 1840s 'guano rush,' it took less than 18 months to strip centuries-old deposits which lay 15 m thick in places. Guano mining threatened breeding red data seabirds such as penguins, cormorants, and gannets. In 1987 all islands were declared nature reserves to protect their seabird populations. Harvesting of guano off mud banks at Sandwich Harbour and Walvis Bay led to a dramatic drop in the cormorant population, and a corresponding decrease in the guano that could be collected at these sites. The balance between guano harvesting and seabird roosting was restored with the erection of artificial guano platforms which offer protection from human disturbance and predators. Today, the Namibian guano enterprise has evolved into a flourishing industry which balances economic development and conservation.

— Sources: Brown[54] and J Tarr[55]

Marine diamond mining involves perhaps the most extensive threats (Chapter 3), which are real but currently difficult to quantify.[16,56] Beach mining for diamonds affects large coastal areas in southern Namibia, and threatens the range of species such as the Namaqua dwarf adder.[54] Tailings pumped into the sea from off-shore and on-shore operations smother rock-dwelling organisms, sand-living invertebrates and rock lobsters *Jasus lalandii*[54,56] (see Chapter 3). Heavy sediment loads in the water cause physical harm to seabed-dwelling (*benthic*) species,[56] especially at the egg and larval stages.

Offshore oil and gas exploration may pose threats to the marine ecosystem. Primary impacts of exploratory work may be the deposition of drill cuttings and mud on the seabed around the rigs,[56] smothering benthic organisms on a small scale and introducing potentially toxic compounds. These activities are discussed further in Chapter 3.

Fig. 1.17 Courting gannets. Courtesy C Beyers

The Namibian Government's stated aim is to create real wealth through environmentally acceptable and sustainable mining development, and to minimise threats posed by mining activities to the environment and biodiversity. Therefore a new Prospecting and Mining Act (33 of 1992) was formulated, with provisions to ensure good mining practices which protect the environment during prospecting and mining. Combined with new fiscal incentives for operators to rehabilitate mines and repair environmental damage, these provisions now provide a basis for environmental protection.[50] All mineral licenses require licensees to prepare an Environmental Assessment (EA), indicating the extent of any environmental pollution prior to the onset of prospecting or mining activities, together with an estimate of any potential impacts.
— Sem Shikongo

Fisheries

Commercial marine fisheries and subsistence inland fisheries are both important in Namibia (Chapters 2 and 3). In terms of the national economy, the marine sector is vastly more important, although freshwater fisheries form an essential component of many rural people's livelihoods.[57]

The marine fish resources of Namibia were, until recently, among the richest in the world.[56] The Benguela Current off Namibia and South Africa is one of the world's most powerful and productive upwelling systems, supporting lucrative marine industries (see Chapter 3).

Following an all-too-familiar trend, however, heavy overexploitation of pelagic fish off Namibia in the 1960s and 1970s led to the collapse of populations of several economically important fish, especially pilchard or sardine *Sardinops sagax*. This was due to a potent mix of factors, including free-for-all exploitation by increasingly large fleets from countries such as South Africa, the former Soviet Union, and Spain; lack of local control and enforcement; inadequate scientific data for the accurate estimation of fish stocks; and lack of foresight or responsibility by individual authorities in the colonial period.[58]

This history badly crippled the potential for subsequent development of the industry. Even with moderate continued exploitation, many fish species take decades to recover from population bottlenecks (see also Chapter 3). The greatest prudence is thus needed to protect stocks sufficiently in order to free the industry from the effects of past greed and overexploitation.

Despite this history, marine resources remain an important, indeed increasingly important, sector of the Namibian economy. From 1980 to 1997, fishing and its associated secondary industry of fish processing grew, as a percentage of GDP, from 1.8% to 8.5% at current prices.[48] Efforts in 1990 to secure protection of a 200 nautical mile (nm) exclusive economic zone have greatly reduced the uncontrolled overexploitation of fish resources. Resource protection could be further secured by a proposed convention to cede management control over the entire marine area between Angola, Namibia, South Africa and the mid-Atlantic islands of St Helena, Ascension and Tristian da Cunha to these governments.[59] Regardless of the size of the area under local or regional management, however, the fishing industry remains highly vulnerable to environmental variability, as well as to local overharvesting.[56]

Inland fisheries play a lesser role nationally, but are extremely important in the subsistence economies of many people in northern and northeast Namibia (section 2.9, Freshwater fish diversity). Fish from perennial and seasonal wetlands are harvested, in some cases probably unsustainably, mainly for subsistence, and are sold commercially only on a very limited basis. Aquaculture in freshwater systems has been little developed, but recent legislation is currently being drawn up by the Ministry of Fisheries and Marine Resources (MFMR), and a White Paper on inland fisheries policy was recently published.[60]

Forestry and watersheds

Namibia has a relatively long, if chequered, history of forestry management. Before the colonial era, traditional leaders in many areas exercised control over the harvesting of trees. These controls may have been effective for many centuries, judging from oral records, although they depended on individual wisdom (see Box 1.7).

The first written regulations for woodland management date from the late 19th century.[61,62] During the German colonial period (1884-1915), forest advisors such as government botanist Kurt Dinter developed management policies to support the increasing demand for timber and other wood products. A research station was started near Windhoek as early as 1900. Once South Africa took over the administration of Namibia in 1915, however, forest legislation enacted by the Germans was replaced with laws widely seen as weaker and virtually unenforceable.[62] During South African rule foresters were answerable to Pretoria, not Windhoek, and were housed in numerous ethnically-based regional administrations.

Fig. 1.18 Charcoal production. Courtesy HH Kolberg

Box 1.7 Protected forest groves: the history of Chongo- camasaku Kakambi

The Chongo-camasaku Kakambi forest lies on the southern Chobe floodplain of east Caprivi, within the territory of the Subiya villages of Mahundu and Ibbu. It is a 15 ha hummock forest, typical of the landscape patches between wet floodplain and drier hillocks. Its main trees are *Hyphaene petersiana* (*Munganda* in the Silozi language), *Lonchocarpus capassa* (*Mupanda*), *Dichrostachys cinerea* (*Muselesele*), *Piliostigma thonningii* (*Mubabama*), *Ficus sycomorus* (*Muchaba*), *Adansonia digitata* (*Mubuyu*), *Faidherbia albida* (*Muunga*), *Trichilia emetica* (*Musikili*) and *Kigelia africana* (*Mupolota*). These all occur in a range of ages.

Old people in the villages say that 70 years ago this was not a forest, but a patch of bushes only as tall as a man. At that time, flooding in the Chobe was more regular and extensive than now, and this checked the growth of vegetation. Only on small islands could the more flood-sensitive species survive. As the floods diminish in extent, woodlands are expanding. In Chongo-camasaku Kakambi, what was 'bush' has now developed into a small forest grove. People have increased the species richness of the forest. Local people say that *H. petersiana* palms were introduced using seed brought from Mbalakalunga in Botswana.

The forest was also afforded protection for its very strong cultural significance. The traditional use of Chongo-camasaku by people of Mahundu and Ibbu villages was restricted because the area was historically a burial ground for Subiya families and a site for spiritual rain ceremonies. Traditionally, only one family was allowed to enter the forest — others who did would become lost. During the second Lozi empire in east Caprivi (1864-1909), Chief Chika Liswani authorised the Kakambi family to settle in the area to protect the centre of the Subiya territory from roaming Zulu and Ndebele groups. Before he died, people would gather at his homestead, and thereafter his burial site in the forest, to ask him to bring rain.

Restrictions on use of the forest were limited. People could collect fruit and fibre as they needed. However, they could only use the forest by day, and would suffer if they entered by night. With time, though, some of the traditional restrictions eroded. Fearing that traditions would be lost altogether, the Ibbu community decided to keep the history of the Chongo-camasaku alive and to revive protection of the forest. Headman James Munihango explains:

> *'Now we are deciding to re-originate our traditional culture as well as to secure this place. We have decided to protect this area on condition that it is important for our history and because of certain plant species like Munganda and Mubuyu trees, which can be found within the forest. Sometimes, also animals are found in this Chongo-camasaku.'*

The community has decided to designate the site as a community forest. At present they are awaiting new legislation, which they hope will enable them to secure its legal protection.
— *Charlotte Flower*

The early German foresters had attempted to establish alien plantations to meet the demand for timber. However, even then, unsustainable timber exploitation in natural forests continued. Huge areas of woodland in the Okavango, Caprivi and Otjozondjupa regions (map 1.10) were heavily logged in the past. A good example is the virtual extinction in the mining region of Tsumeb and Otavi of tamboti *Spirostachys africana*, a tree exploited for use as mine props.

In places where tamboti was cut, encroachment by blackthorn *Acacia mellifera detinens* and sicklebush *Dichrostachys cinerea africana* occurred. Bush-encroached land has more recently been extensively cleared in some areas for the production of charcoal sold to the Tsumeb Corporation copper smelter, which burns about 450 tonnes per month.[63,64] Yet bush encroachment remains a significant form of land degradation on nearly 12% of Namibia's land, and carries huge costs in terms of lost productivity[63] (Chapter 4).

Box 1.8 Indigenous fruit tree development

Little is known of the ecology and physiology of indigenous fruit trees in Botswana and Namibia, despite their importance to rural people. Most species produce fruit even under harsh conditions, through adaptations to drought and marginal soils. Given present overharvesting in many areas of Namibia, fruit trees will no longer be abundant in a few years' time.

Development of indigenous fruit trees could improve food security, reduce dependence on arable agriculture, help arrest soil erosion, and contribute to sustainable management of marginal areas in developing countries. With this in mind, a European Community-funded project called 'Sustainable domestication of indigenous fruit trees: interaction between soil and biotic resources in some drylands of southern Africa' began in 1997. The aim is to domesticate indigenous fruit trees and to study their effect on soils. Six species, promising both for their nutritional value and cultivation potential, have been selected in Namibia and Botswana: marula *Sclerocarya birrea*, manketti *Schinziophyton rautanenii*, monkey oranges *Strychnos spinosa* and *S. cocculoides*, wild medlar *Vangueria infausta* and raisin bush *Grewia flava*. Researchers from different disciplines in Botswana, Israel, italy, Germany and Namibia are studying germination requirements, nutritional value, nutrient uptake and growth enhancement through natural fertilisers such as seaweed extracts. The Namibian contribution will be done by University of Namibia MSc students.

— Sem Shikongo

The Directorate of Forestry (DF) in the Ministry of Environment and Tourism has just completed a forest cover mapping exercise and initiated a follow-up National Forest Inventory, surveying all woodlands on communal land north of 20°S. These two projects will allow the development of an important database for forestry, biodiversity and desertification applications, and generate a quantitative assessment of forest resources. The DF has also developed an incipient Community Forest Project, and houses the Tree Seed Centre, a project to collect, store and regenerate genetic material from economically valuable indigenous trees (see also Box 1.8; section 2.7).

Fig. 1.19 Sales of woodcarvings at Okahandja. Courtesy HH Kolberg

Woodlands of course contribute directly to the national economy in numerous ways. The craft industry is a rapidly increasing source of income for rural craftspeople, with an annual sales turnover of tree-based crafts of over N$20 million.[65,66] Okavango wood carvings, for example, may earn individual carvers N$1000-2000/yr. Woodlands contribute significantly to the economy through the charcoal industry,[63] valued at approximately N$8 million/yr,[66] and play an important role in the tourism industry in terms of wildlife habitat and forage as well as their inherent aesthetic value.[66]

The Directorate of Forestry's Strategic Plan[67] holds as priorities:

- *conserving natural ecosystems for their biodiversity and other values;*
- *enhancing agricultural productivity through soil and water conservation;*
- *supporting national efforts aimed at poverty alleviation and equitable development;*
- *restricting potential climate change.*

One of the most significant functions of indigenous woodlands is the support they provide to the subsistence economy of people living on communal land. As a large majority of Namibians depend on woody plants for fuel, construction materials, tools, food and medicine (Chapter 4), the focus on eco-system functioning, land productivity and human development in the Forestry Strategic Plan reflects that poverty cannot be alleviated in degraded environments.

The most significant environmental functions of woodlands, in a global sense, are their role as repositories of genetic and other biological diversity, and their potential impact on global and regional climate by sequestering carbon and moderating humidity.[67] Watershed (or catchment) forests play an extremely important role in the prevention of soil erosion and the regulation of water flow and quality. Where droughts and destructive floods frequently follow each other, as in many parts of Asia and Africa today, this is evidence of environmental damage to watersheds and riverine woodlands following deforestation and overgrazing. If Namibia is to avert the fate of countries such as Madagascar, Mauritius, Tanzania and Indonesia, it is essential that we protect our catchments carefully through enlightened management practices.

Woodlands in central Namibia are important protectors of the upper catchments of the west-flowing ephemeral rivers. Ephemeral rivers such as the Kuiseb, Swakop, Omaruru, Ugab, Huab and Hoanib drain the central plateau and bring life to the desert in one of Namibia's most dramatic natural processes.[17] Riverine woodlands are also important dry season grazing areas. They support an impressive variety of plants, animals and fungi (Chapter 2), as well as human and livestock populations. The perennial Kunene, Kwando, Okavango, Chobe and Zambezi Rivers in the north support dense human populations and many species of aquatic plants and fish[68] (see below, and Chapters 2 and 4).

Namibia's forest resources have, up to now, helped satisfy the basic needs of the country's low-income rural and urban households for forest products. As human populations increase, however, there is an increasing need for vigilance to ensure that woodlands are protected and developed in a sustained way, so that they meet the diverse needs of present and future generations.

— Moses Chakanga & Phoebe Barnard

Fig. 1.20 Elephants in Caprivi Region. Courtesy P Tarr

Conservation and tourism

Environment-centred tourism is a significant and rapidly increasing industry in Namibia. The country boasts an unusual blend of stark scenic grandeur, rich wildlife, diverse habitats and excellent infrastructure. Overall, tourism expanded by 166% annually[69] in the early-mid 1990s (Chapter 4). Before 1990, tourism was largely oriented towards self-catering South Africans in state-owned and -run resorts and angling spots. After Namibia's Independence, the profile of foreign tourists began to shift towards wealthier, cosmopolitan visitors. Currently, a third of all foreign arrivals in Windhoek are South African, a third are German, and a third are a diverse mix of other nationalities.[70] Many visit other countries in southern Africa as part of a regional ecotourism package.

Namibia's Tourism Development Plan predicts 540 000 foreign tourists annually by the year 2000, with the creation of 20 000 jobs and gross foreign exchange earnings of N$1 billion.[70] The Tourism and Safari Association of Namibia (TASA) in 1997 had 140 registered operators in Namibia catering for ecotourism, hunting safari and general tourism markets.[71]

Fig. 1.21 Luxury tourism lodge. Courtesy P Tarr

Fig. 1.22 Small private bush lodge. Courtesy P Tarr

While capital-intensive tourism ventures have sprung up in Namibia from both foreign and local investments, these cater mainly for the wealthier foreign tourist. More recently, private individuals and rural communities are beginning to diversify their livelihoods into small-scale ecotourism ventures for the lower budget, more adventurous tourist (Chapter 4). Private guest farms, bed-and-breakfast concerns, small private lodges and community-run campsites have helped create a very diverse tourism industry based on scenic attractions and wildlife (Fig. 1.21).

How do these different ventures influence biological diversity conservation in Namibia? Indirectly, they have a strong positive effect in terms of income and job creation in environment-related fields at the private, community, or national levels (Chapter 4). Directly, they increase the proportion of habitats being protected in a relatively undisturbed state, considerably augmenting the network of state protected areas[72] (Chapter 2). The Namibian government has long recognised that tourism depends heavily on a pristine and attractive environment, as reflected in the combined Ministry of Environment and Tourism (MET). More recently, associations such as the Namibian Community-based Tourism Association (NACOBTA) have been founded by private and community operators in the expanding environmental tourism market (Fig. 1.22).

For rural communities, small-scale tourism initiatives can mean the difference between a life of poverty exacerbated by drought, and one of enterprise, pride and modest financial success. People in communally-held areas of Namibia used to be alienated from rights to wildlife and other natural resources on that land. Since 1996, amendments to the Nature Conservation Ordinance have allowed well-defined communities to regain the rights to manage, use, and benefit financially from wildlife (Chapter 5).

Ecotourism has been one such avenue of benefit for rural people, and can potentially flourish even faster than private tourism ventures on commercial farmland.[73] The advantages to communities are considerable, in terms of economic diversification, financial buffering against drought, job creation, use of local skills and knowledge, and training in new skills such as management, hospitality, and languages[73] (Chapter 4). However, the direct influence on biological diversity of tourism ventures, and land management practices associated with them, is much less easily quantified. Where land is protected from other forms of development for overall scenic and prisitine attractiveness to tourists, biological diversity is likely to be effectively conserved. Where game-viewing or hunting are specifically offered to tourists, however, the potential exists to manage land for the benefit of large,sought-after species, and not necessarily for the benefit of biodiversity as a whole (Chapter 4).

• *The state protected area network*

Namibia's state-controlled **protected area network (PAN)** consists of 21 parks and reserves proclaimed under section 14 of the Nature Conservation Ordinance (map 1.9; Box 1.9). These state parks alone make up about 13.8% of Namibia's land area. Two of our national parks, Etosha and Namib-Naukluft, are among Africa's biggest and most important parks. Etosha National Park (previously 'Game Reserve no. 2') was dramatically reduced in size by over 70% to gain land for ethnic partitioning under the terms of the 1964 Odendaal Commission report.[41] Prior to that, it was among the biggest parks in the world, with at least 88 000 km^2 protected in a rugged and endemics-rich area stretching from Etosha Pan to the coast (Box 1.9).

Fig. 1.23 Mountain zebras at Namib Naukluft Park. Courtesy P Tarr

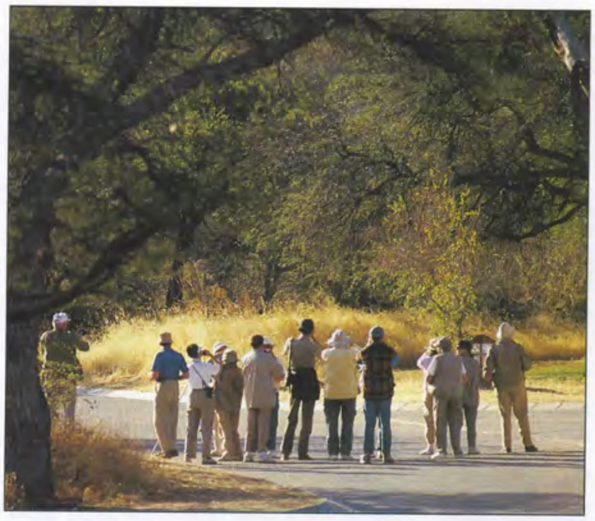


Fig. 1.24 Birdwatching at Waterberg Plateau Park. Courtesy P Tarr

Box 1.9 Namibia's state-controlled protected areas[a]

	Park	Area (km^2)	Established	Comments
1	Etosha National Park[b]	93 240.00	1907	
	amended	89 834.00	1947	
	amended	99 526.00	1958	
	amended	27 554.00	1963	Odendaal report[41]
	amended	22 912.00	1975	1997 measurements (ODA)
2	Namib-Naukluft Park	49 768.00	1907	amended 5 times 1968-1990
3	Gross Barmen Hot Springs	0.10	1968	
4	Caprivi Game Park	5 715.00	1968	
5	Hardap Recreation Resort	251.77	1968	
6	Daan Viljoen Game Park	39.53	1968	
7	Cape Cross Seal Reserve	60.00	1969	
8	Ai-Ais/ Hunsberg Reserve Complex	461.17	1969	then called Ai-Ais Hot Springs
	amended	3 461.17	1988	Huns Mts incorporated
9	South West Nature Park	0.04	1970	
10	Skeleton Coast Park	8 000.00	1971	
	amended	17 450.00	1973	
11	Waterberg Plateau Park	405.49	1972	
12	Von Bach Recreation Resort	42.85	1972	
13	Nat'l West Coast Recreation Area	13 000.00	1973	
	amended	7 800.00	1974	
14	Nat'l Diamond Coast Recreation Area	50.49	1977	
15	Naute Recreation Resort	224.62	1988	
16	Mangetti Game Camp	482.92	1988	
17	Popa Game Park	0.25	1989	
18	Mahango Game Park	244.62	1989	
19	Khaudum Game Park	3 841.62	1989	
20	Mudumu National Park	1 009.59	1990	
21	Mamili National Park	319.92	1990	
Total		114 079.98		

[a] Updated from Baker.[74] As not all parks have been precisely measured with modern techniques, size data for some are not yet definitive.

[b] Pre-1963 data for Game Reserve no. 2 (now Etoshā National Park) are probably inaccurate; the park may never have been larger than *c.* 88 000 km^2.[75,76]

On its own, Namibia's large, relatively very well-managed state protected area network is ecologically unrepresentative, and is thus not wholly adequate as a basis for protecting our biological diversity. In some cases, private and community conservation efforts help fill this gap, but additional protection measures are needed in others. Chapters 2 and 3 identify areas of unusual ecological value, many of which need additional protection.

- *Conservancies*

Conservancies are land units managed jointly for resource conservation purposes by multiple landholders, with financial and other benefits shared between them in some way. They occur on both commercial (private) and communal (tribal) land. Most aim to enhance habitat for, and numbers of, game species such as ungulates or gamebirds, and many draw income from tourism ventures.[77] Over 10 000 km^2 of farmland has so far been consolidated into nine commercial conservancies, ranging in size from 600 km^2 to 2 300 km^2 and bound by constitutions and ecologically-sensitive land management plans.[78] Other commercial conservancies are now being formed. Many are increasing in size, as previously skeptical landowners agree to join existing conservancies.

Communal land conservancies are also being developed by some rural communities, and will mainly be very large. As of late 1997, five large communal conservancies have submitted formal proposals for gazetting. One of these is an area of about 9 023 km^2 managed by Ju' //Hoan (San) people at Nyae Nyae in the ecologically diverse Tsumkwe pan region.[79] Another is an arid region of almost twice this size in the former western corridor of Etosha National Park, stretching along the eastern boundary of the Skeleton Coast Park. The proximity of state protected areas offers rural people in these regions considerable potential for financial and economic gain,[80] making ecotourism and conservancy management very attractive land use options.

Conservancy management is a land use which complements, and does not necessarily exclude, traditional farming. It can thus diversify people's livelihoods, broaden their resource dependence as a means of coping with drought, and potentially double household incomes.[81] Many rural communities have been stimulated to form conservancies by the government's recent policy to return resource management rights and responsibilities to carefully defined conservancy committees with an approved constitution.[82] Most communities which have expressed a desire to form conservancies are expected to have formalised them by the year 1999. To compete with other land uses, however, all wildlife-based initiatives must remain financially and economically competitive,[83] which means making optimal and sustainable use of wildlife resources. Any actions undermining the principle of sustainable wildlife use may therefore jeopardise biodiversity conservation aims in Namibia.

- *Private reserves and game farms*

Privately owned **nature reserves and game farms** can play a significant role in biodiversity protection in Namibia. Some are extremely rich in endemic species, unique landscape features, or both (Fig. 1.25). Both categories are fairly abundant on commercial farmland. As of 1995 there were 148 private nature reserves totalling 7642 km^2, or 0.9% of Namibia's land area, registered with the Ministry of Environment and Tourism.[84,85] Statistics for the number and extent of game farms are unavailable, but game farming has become a multi-million dollar local industry[77,86] since 1967, when commercial landowners were granted rights to use and benefit from wildlife on their farms, subject to certain conditions.[86]

Private reserves and game farms differ in legal status and management system (see also Chapter 5) and their success in conserving biodiversity has not yet been formally evaluated in Namibia. Regulations applying to private nature reserves are generally stricter than those for game farms, so private reserve owners who wish to hunt game for commercial purposes must first deproclaim their land. Largely for this reason, there has been an average annual loss of about 3% of all private reserves between 1979 to 1994.[85] Game farming can be both very lucrative and effective at conserving habitats. Yet because it involves deproclaiming conservation sites in the private network, it renders land less secure for conservation. Furthermore, management for desired game species may not necessarily conserve biodiversity in the broader sense.[83]

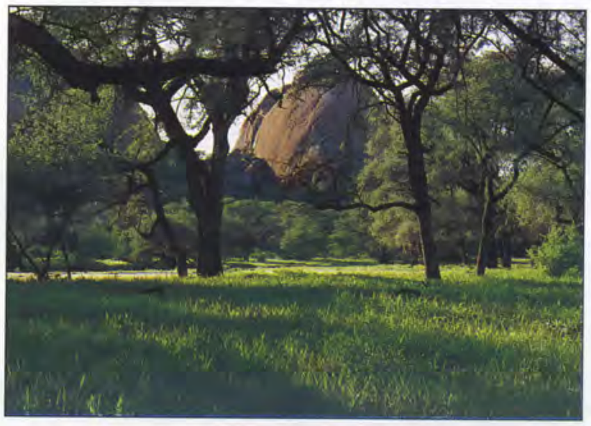


Fig. 1.25 Private nature reserve, Otjume Ost. Courtesy R Simmons

• *Protected industrial areas*

Namibia is unusual in having a vast tract of land protected by the mining industry for its own activities (Map 1.9). The 26 000 km^2 *Sperrgebiet* or 'Forbidden Area' is by far the largest of these areas, and has been covered by various temporary industrial concessions for nearly 90 years. Not long after diamonds were found near Lüderitz in 1908, large areas were declared strictly off-limits to anyone other than the companies granted prospecting and mining rights, which were bought up by Sir Ernest Oppenheimer after World War I to become the Consolidated Diamond Mines of South West Africa Ltd.[16]

Although mining occurs only in a narrow strip along the southern Namib coast and Orange River, a strip of desert about 100 km wide and over 300 km long was included in this prohibited area. This not only helped protect the coastal diamond areas from unauthorised access, due to the harsh terrain that would have to be crossed to reach them, but coincidentally protected some of the country's most pristine and specialised ecological communities from disturbance (Figs. 1.26-1.28). It has also kept intact many sites of high geological, palaeontological, historic and archaeological value.[16]

Environmental conservation has only recently been recognised by the mining industry as an important by-product of its land tenure. The remoteness and prohibited status of the *Sperrgebiet* have kept large inland areas from being developed inappropriately. Coastal and intertidal habitats, however, have suffered major, if localised, ecological damage from mining (Chapter 3). Three *Sperrgebiet* habitat types or areas have been identified as environmentally most sensitive:[16]

- **the Orange River valley** along the southern border is a scenically dramatic 'linear oasis' through arid terrain. It supports many succulent and fog-dependent species which occur nowhere else in the Namib or Namibia. The river mouth is a wetland of international significance, and the valley is immensely rich in marine and terrestrial fossils.

- **the Atlantic coast, offshore islands and coastal dune hummocks** harbour many endemic animals, breeding seabird colonies, and specialised fog-dependent lichens and hummock vegetation, as well as sites of historical, archaeological and palaeontological value.

- **the inland inselbergs, mountain ranges and rocky outcrops** are important ecological refuges for many highly restricted-range plant species and some rare or threatened animals. Once degraded, they are effectively impossible to rehabilitate. Mountains such as the Aurusberg and Roter Kamm meteorite crater combine unsurpassed scenic grandeur with a diverse and unique succulent flora.

These three zones must be stringently protected to ensure that biodiversity loss and other forms of habitat degradation cannot occur[16] (Box 1.10).

Box 1.10 Options for the Sperrgebiet

How can the Sperrgebiet — unique, spectacular, largely undisturbed, agriculturally unproductive, with immense unrecognised value — best be used for Namibia's present and future benefit? Currently, an agreement between the Namibian Government and NAMDEB restricts access as long as present mining operations continue, and until the possibility of further diamond reserves has been ruled out. What will then happen to the Sperrgebiet? Development strategies must be carefully scrutinised due to the vulnerability of the area. Any future mining and prospecting for diamonds or other minerals must be carried out with minimal damage to the environment. In the short term, Namibia can reap benefits from mining activities, but these accrue from non-renewable resources. A better alternative is to encourage sustainable ecotourism, thus drawing on the wilderness, scenic grandeur, scientific and historical value of the Sperrgebiet while protecting its largely pristine character. In the long run, this would be more compatible with the sensitivity of the area, and could generate considerably more revenue. Discussions about a sustainable management plan for the area have begun between the MET, MME, NAMDEB and other parties. Whichever paths are taken, Namibia should be careful not to forfeit the potential of the Sperrgebiet for future generations.

Sources: Pallett,[16] P Tarr & L van Rooyen[87]

Fig. 1.26 Central *Sperrgebiet* plain. Courtesy G Williamson

The vast natural terrarium of the *Sperrgebiet* is of extraordinarily high value in terms of biodiversity and tourism. The area forms one of the last major refuges for red data mammals such as water mongoose *Atilax paludinosus*, grey rhebok *Pelea capreolus*, African wild cat *Felis sylvestris*, cheetah *Acinonyx jubatus*, aardwolf *Proteles cristatus*, Cape clawless otter *Aonyx capensis*, brown hyaena *Hyaena brunnea*, spotted hyaena *Crocuta crocuta* and bat-eared fox *Otocyon megalotis*.[16] Many important red data wetland and seabirds rely on the Orange River mouth and islands off the *Sperrgebiet* coast. Over 700 plant species are believed to occur in the area, of which about 50 species (8%) are endemic to the *Sperrgebiet*.[88] Dozens of highly restricted plants, some endemic to single mountains, may remain unclassified.[88] We may expect this high plant endemism to be correlated with high insect endemism, through coevolutionary associations such as pollination and herbivory.[16] Ninety lichen species, all highly fog-dependent, are found there. The area also has fascinating and impressive fossil deposits dating from the Cretaceous period about 85 million years ago.

Fig. 1.27 South Elizabeth Bay dunes. Courtesy G Williamson

Fig. 1.28 *Conophytum taylorianum ernianum, Sperregebiet.* Courtesy G Williamson

Wetlands

As Namibia is so arid, its wetlands have an ecological, economic and social impact greater than one might think. Most of its wetlands are ephemeral. Only five rivers, all with their headwaters in other countries, are perennial: the Kunene, Okavango, Zambezi, and Kwando Rivers, shared with Angola, Zambia or Botswana, and the Orange River, shared with South Africa. Almost 5% of Namibia's land area is classified as wetlands,[89] both coastal and inland (section 2.1).

Inland wetlands are concentrated mainly in the northeast of Namibia, where rainfall is much higher. The Okavango, Kwando and Zambezi Rivers are located here, with their associated tropical wetlands covering over 5000 km^2.[90,91] Further west is Namibia's famous ephemeral wetland, the Etosha Pan/ Cuvelai inland delta complex with its *oshana* drainage channels. Many of the *oshanas* are fed by seasonal *efundja* floodwaters, originating in the Angolan highlands and sometimes flowing as far south as the Etosha Pan. *Oshanas* are ecologically and economically important, receiving irregular seasonal influxes of water and nutrients. They are a key source of fish and other wetland resources for rural people in the Cuvelai Basin.[92,93] The seasonal Tsumkwe or 'Bushmanland' Pans in eastern Otjozondjupa Region are a stopover for migratory birds on their flights to and from overwintering grounds. Namibia's other very important group of ephemeral wetlands is found in the catchments of the west-flowing rivers,[17] which drain the central highlands through hyper-arid western Namibia to the Atlantic Ocean. These rivers are, in essence, linear oases for humans and many other species in the otherwise inhospitable desert.

Namibia's coastal wetlands are few in number, but highly important ecologically. As the coastline is bleak, hyper-arid and forbidding to most non-marine life, the few sheltered bays and freshwater intrusions along its 1470 km length have assumed a disproportionate ecological significance.[94,95] Coastal wetlands consist mainly of extensive mudflats, sheltered marine waters and small estuaries. Due to the productive marine upwellings of the Benguela Current (Chapter 3), and the inhospitable terrain between isolated wetland sites, Namibia's coastal wetlands are rich in species and nutrients. Productivity of the central coast in terms of intertidal life is higher than that of the north and south.[96]

Unfortunately, rather little is known of coastal wetland biota, with the exception of birdlife.[94,97] Two coastal sites, Sandwich Harbour and Walvis Bay, host almost 200 000 migratory shorebirds during peak migration periods, and are the most critical coastal wetlands for birds in the entire southern African region.[98] At our northern border with Angola, the Kunene River slices through extremely rugged and arid terrain to form a small but unusually rich estuary in the tropical warm-water zone. This lagoon is Namibia's second most species-rich coastal wetland for birds, and fourth in importance for bird densities.[95] It supports breeding Nile crocodiles *Crocodylus niloticus*, and two tropical turtles may breed there.[99,100] The high avian species richness, tropical reptile fauna, and extreme isolation from other coastal wetlands make the Kunene mouth a unique and important site. It faces a significant threat from proposed upriver hydroelectric development.

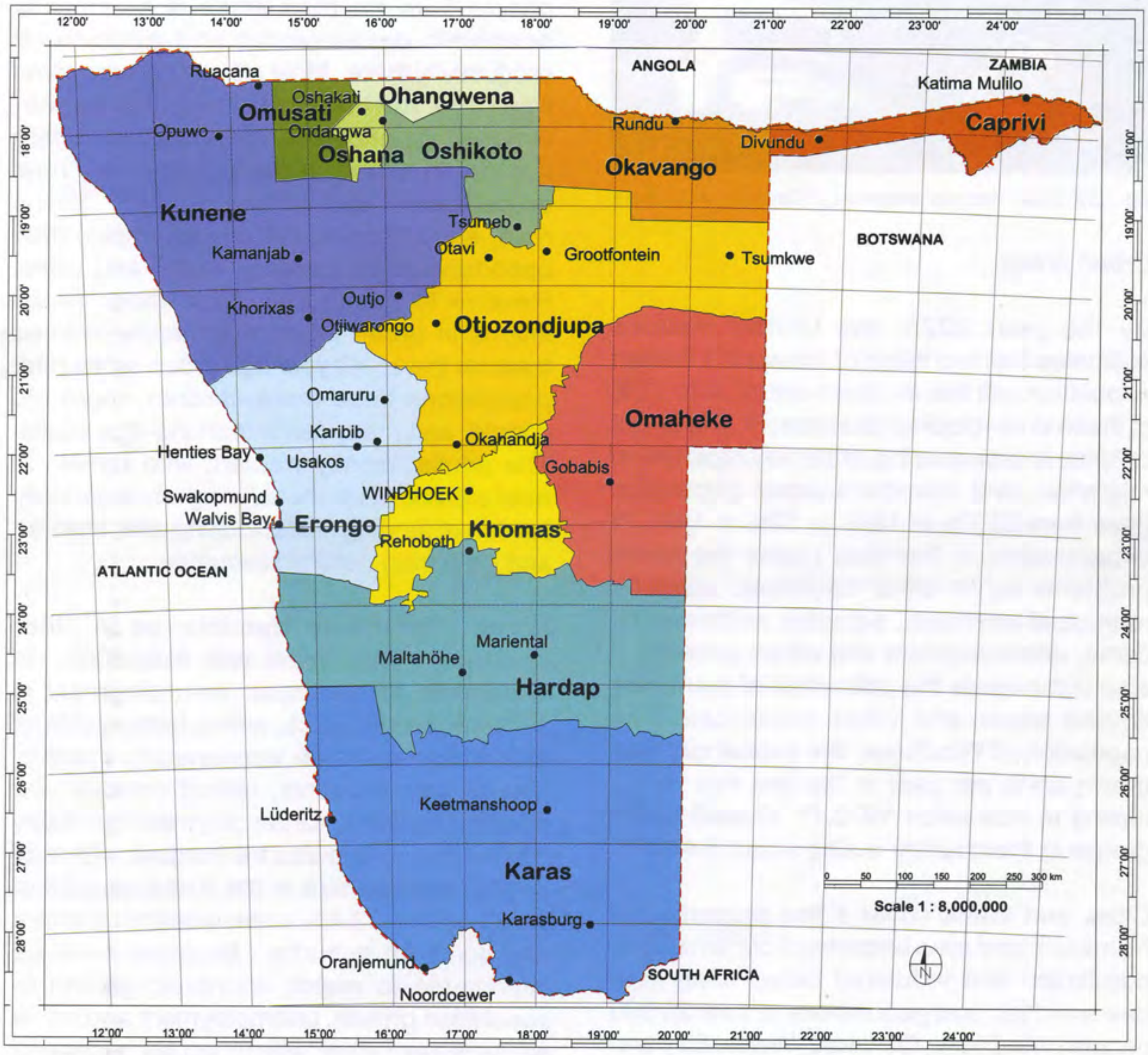
Major threats to inland wetlands include habitat alteration through agriculture and intensive settlement, overfishing in perennial rivers, invasive alien species, and livestock overgrazing in floodplain vegetation. Main threats to the biological diversity of coastal wetlands include beach disturbance from intensive angling and motor vehicle use, pollution from offshore oil exploration, and other industrial or harbour development. In the west-flowing rivers, including the Kunene and Orange, imprudent disruptions of hydrological flow through dam construction will almost certainly cause local or national extinctions of organisms adapted to these very variable rivers.[95]

Namibia acceded to the Ramsar Convention on wetlands of international importance in December 1995. It initially designated four wetlands as Ramsar sites: the Walvis Bay wetlands, Sandwich Harbour, the Orange River mouth (shared with neighbouring South Africa), and the Etosha Pan/ Cuvelai inland delta complex.[101] A further eight wetlands have been proposed for the list, as well as three of Namibia's offshore islands.

Wetlands and riparian habitats are discussed in detail in section 2.1, Ecological diversity.

—Holger Kolberg & Rob Simmons

Map 1.10 Regions and major towns of Namibia



Regions and Towns

- Okavango
- Caprivi
- Kunene
- Ohangwena
- Omusati
- Oshana
- Oshikoto
- Otjozondjupa
- Omaheke
- Erongo
- Khomas
- Hardap
- Karas

--- Border

• Major Towns

Source:

Various Government Gazettes published by the Government of Namibia.

Ministry of Lands, Resettlement and Rehabilitation Division of Survey and Mapping 1:250000 maps.

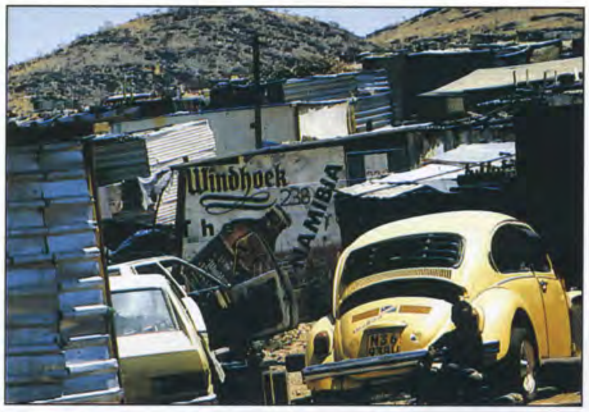


Fig. 1.29 Urban 'informal settlements.' Courtesy M Goldbeck

Urban areas

By the year 2025, the United Nations estimates that two thirds of the world's human population will live in urban areas, with 75% of these in developing countries.[102] The whole of Africa is experiencing extremely rapid urban migration, and Namibia's urban population grew from 22.7% in 1970 to 32% in 1991.[103] Urbanisation in Namibia poses the same problems as in other countries: strained municipal services, squatter settlements, crime, unemployment and urban poverty. It also compounds the difficulties of managing limited water and other resources. The population of Windhoek, the capital city, has grown 5.4% per year in the last five years, tripling in size since 1970.[103] Overall urban growth in the country is also about 5.4%.[104]

Cities and towns cover a tiny proportion of Namibia's land area because of our small total population and industrial base. Only four towns in 1991 had populations of over 20 000 people: Windhoek, Oshakati, Walvis Bay and Rehoboth (map 1.10). Rapid urbanisation may therefore seem to pose less dramatic environmental, social and economic problems than in some nations. However, due to the country's aridity and already overextended water resources, some water-thirsty towns are already effectively overpopulated at current consumption levels.[17,103] Many towns are developing in sensitive or marginal areas, including riparian zones, and on diminishing or saline aquifers. Coastal development, especially at the rapidly growing port of Walvis Bay, has led to a 10 m drop in some areas of the Kuiseb alluvial aquifer.[17] The western town of Khorixas has had an astonishing mean daily water consumption of nearly 500 litres per person, lowering water levels in its aquifer by 50 m in recent years.[17]

From a different angle, the drain of working people from the rural areas is a barrier to economic development and agricultural productivity there. Most urban migrants come from the northern regions of Oshana, Omusati, Ohangwena and Oshikoto, where population density is the highest of any rural or 'peri-urban' area in the country.[103] Young men, especially, perceive their employment opportunities as better in towns and cities. Relative to the country as a whole, populations in urban areas are heavily skewed towards the 15-40 year age group, while rural populations have more children, more old people, and many fewer working-age adults. The adults, mostly women, who remain in rural areas end up shouldering a heavier daily burden of tending fields, looking after children and gathering natural resources.

Urban migrants in Namibia, as in other countries, mainly meet with frustration. In Windhoek, for example, unemployment is currently around 22%, with a further 19% of residents classed as 'economically inactive' housewives, students, retired workers and disabled persons. Unemployment inevitably hits the poorer suburbs the hardest, with over 33% unemployment in the Katutura area of Windhoek and 3.4% in the wealthier eastern and southern suburbs. Because it will be impossible to match economic growth to population growth, unemployment and crime will increase further, with urban tax bases and municipal services declining rapidly unless urban migration can be slowed.[103]

Fig. 1.30 Windhoek urban sprawl. Courtesy P Tarr

1.3 Key issues affecting biodiversity conservation in Namibia

This chapter has sketched a brief picture of Namibia's physical, social and economic environment, as well as its often grim history of natural resource conflict and political self-determination. In one way or another, each of these aspects has shaped the difficulties we in Namibia face today. It is a daunting challenge to find effective and lasting ways of safeguarding the country's superb and unique environment, so that people and their grandchildren can share in the wealth of a country which was for so long denied. These challenges become more daunting each year, as the admirable gains made by Namibia's new leaders in establishing a sound footing for development become strained by increasing population growth and unemployment.

We have tried to weave three major threads through this chapter. The first is the thread of environmental constraints. Namibia is an arid country, with thin and infertile soils, and will (from a human perspective) always be so. Development options for the country which do not recognise this fundamental reality may bring only hardship, wasted money, dashed expectations and perhaps lasting environmental damage. By contrast, development decisions and projects which make effective use of the country's natural beauty, renewable resources and human wisdom can help ensure that our children lead lives of pride and self-determination, rather than of hardship, despondency, poverty and dependency. Namibia's constitution obliges us to use our environment and resources wisely, without degrading or depleting them. Unfortunately, not all decisions are made with the necessary circumspection that our constitution requires of us, but hopefully we are learning from our mistakes.

The second thread is that of injustice in natural resource distribution and access. Namibians have fought hard for political independence and self-respect through generations of an often harrowing colonialism. Land, minerals, water, fish stocks and other resources have been developed in many ways, and squandered in others, by many different parties in Namibia's past. Our colonial history has left at least three direct legacies. One is a frontier country's legacy of boom-and-bust natural resource-based industries, some of which still suffer from past overexploitation. A second legacy is a deep mistrust among many ordinary Namibians of the aims and means of environmental conservation, since in the past, conservation often meant removal from traditional lands, denial of access to essential resources, and deepening poverty and dependency.[72] The moves Namibia has made since Independence to redress these wrongs are a good start in healing this mistrust.

However, a third legacy, and a much more positive one, is the legacy of scientific enquiry created by Namibia's colonial rulers. Important data on our biological resources, so necessary for insights on environmental change and biodiversity management, stretch back decades, and sometimes generations. These data may often be patchy, often anecdotal, and often seemingly directionless, but more often than not they are useful. Our challenge now is to build on this scientific legacy in Namibia, to focus it, and to make it more cost-effective in the support of environmental planning and management.

Finally, the third thread raised in this chapter is more fully developed in those to follow. This is the degree to which human development in Namibia is underpinned by environmental health, particularly biological diversity. The vast majority of our people live directly from the land and rely heavily on its biological resources and habitats for food, housing materials, tools, medicines, and livelihoods. Unseen biological diversity in our soil, for example, is the slim thread that keeps our rangelands, croplands and woodlands functioning. We have little idea of how this happens, nor of how our land management practices safeguard or jeopardise these essential ecosystem 'services' to humankind. Research and information on these processes deserves the most urgent support.

Although many people may regard the aims of 'nature conservation' with disdain, and equate 'biodiversity' with large huntable game, it is our hope that this book, and the lay publications to follow, will convince people that their health, their survival, and their livelihood lies in the protection of our brittle, spectacular natural environment.
— *Phoebe Barnard*

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Biodiversity of terrestrial and freshwater habitats 2

Coordinated by Phoebe Barnard with Shirley Bethune (wetlands) and Herta Kolberg (genetic resources)

Courtesy P Tarr

What do we know so far about the biological diversity of our land and freshwater habitats? What are the most pressing conservation priorities for these habitats and the species they support? How can our terrestrial and aquatic diversity be safeguarded in the natural environment, and what facilities exist for *ex situ* conservation of material in gene banks and biological gardens? This chapter addresses these questions, and summarises taxonomic richness, endemism, conservation status, and related issues for terrestrial and freshwater species.

2.1 Ecological diversity in Namibia

The search for patterns is a basic aim of any science, indeed of most human endeavours. Ecologists have long tried to classify species, communities, habitats, ecosystems and biomes as a way to simplify the complex natural world.

Ecological diversity is often described broadly in terms of *biomes* or *ecosystems*. Namibia's four main terrestrial biomes (below) are a broad-brush representation of the country. Ecosystems, a middle level of organisation, are generally regarded as self-contained groups of organisms and their physical environment which together form a recognisable entity.[1] However, Namibia has no scheme for classifying ecosystems, and the Biodiversity Task Force opted not to develop one afresh, finding the concept ill-defined. Existing classification schemes for biomes, vegetation types and wetlands were felt to summarise Namibia's terrestrial and freshwater variety adequately, even if they need fine-tuning in specific areas. This chapter therefore summarises the most widely used classifications at these three levels, as indices of Namibia's ecological wealth and variety on land and water. A wetland classification has not previously been published for Namibia, so the following wetland section is longer than the terrestrial summaries.

Biomes

The most widely used classification of Namibian terrestrial biomes is that of Irish,[2] portrayed in map 2.1a. This uses an 'objective categorisation' approach[3] based on dominant and codominant vegetation life forms or structures, correlating with indices of summer aridity and rainfall seasonality (Figs. 2.1-2.8). The scheme distinguishes four major terrestrial biomes (desert, Nama-Karoo, succulent Karoo and savanna). Although animal distribution data on their own cannot realistically be used to delineate biomes, insect distribution data have helped confirm the general validity of this objective categorisation method.[2] Distributions of sedentary and non-

Fig. 2.1 Semi-arid savanna (HH Kolberg)

Fig. 2.2 Moist savanna (J Irish)

Fig. 2.3 Typical Nama-Karoo (J Irish)

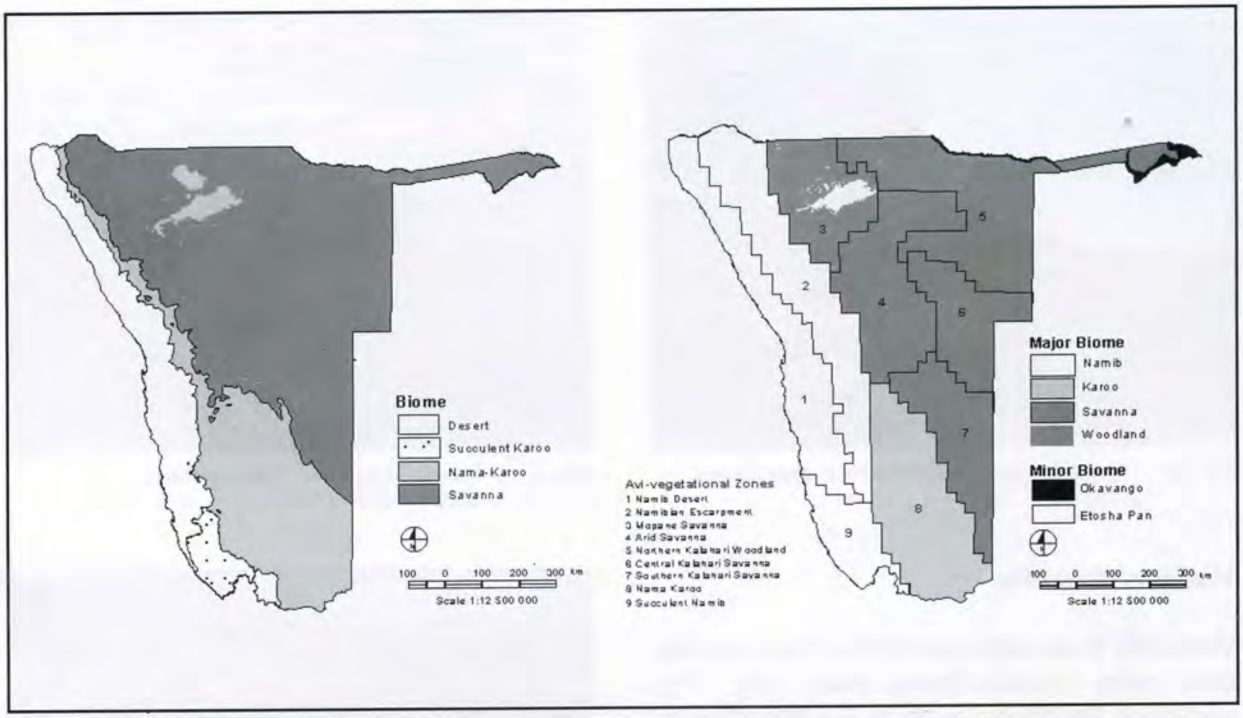
Fig. 2.4 Edaphic Nama-Karoo of Etosha Basin (J Irish)

Fig. 2.5 Lowland succulent Karoo (J Irish)

Fig. 2.6 Succulent Karoo (M Müller)

Fig. 2.7 Southern Namib (J Irish)

Fig. 2.8 Central Namib in fog zone (J Irish)



Map 2.1 Terrestrial ecological classifications of Namibia: (a) Irish's[2] biome scheme and (b) the SABAP scheme[6,7]

host-specific insect families correspond to these biome patterns better than to previous classification schemes.[4,5] Irish's scheme is a very useful framework on which more detailed analyses can be done of certain regions. Classification of the endemics-rich northwestern Namib escarpment as Nama-Karoo, for example, is debated by some biologists, but the overall validity of the scheme is agreed. A similar biome classification (map 2.1b) has been used by Africa's largest biodiversity project, the Southern African Bird Atlas Project (SABAP),[6] and by a recent diversity analysis of Namibian birds[7] (see sections 2.6 and 2.9).

Vegetation communities

At a finer scale, most botanists in Namibia use the system of vegetation types proposed over 25 years ago by Giess,[5] who divided the country into fourteen zones in three broad categories (map 1.8, summarised in section 1.1). As floral diversity and phytogeography underpin the diversity and geography of so many other taxa, many of the conservation status accounts for taxa in this chapter are based on Giess' vegetation types as an index of habitat diversity.

Giess' influential scheme is broadly endorsed today, although he regarded it as preliminary and based on patchy data in some areas. The escarpment also requires more detailed analysis in this scheme: it is categorised as Semi-desert and Savanna Transition in central-western Namibia, but is misclassified as Mopane Savanna in its northern sections. Ongoing work at the National Soil Laboratory and National Botanical Research Institute to develop an agro-ecological zone system may help clarify the floristic nature of some areas.

The SABAP scheme also uses nine 'avi-vegetational zones' to explain patterns of bird distribution and abundance: Namib Desert, Namibian Escarpment, Succulent Namib, Nama Karoo, Mopane Savanna, Northern Kalahari Woodland, Central Kalahari Savanna, and Southern Kalahari Savanna. The SABAP scheme attempts to merge avifaunal and floristic distribution patterns, and differs from Giess' scheme where bird distributions warrant amalgamation of vegetation types. Other minor differences appear in the classification of the northern escarpment and mopane belts.[6,7]

Fig. 2.9 Riverine systems: Kunene River near Epupa. Courtesy P Tarr

Fig. 2.10 Lacustrine systems: Lake Liambezi. Courtesy S Bethune

Wetland habitats

Wetlands in an arid country like Namibia can take many unusual forms (map 1.7). The Wetlands Working Group of the Biodiversity Task Force uses the Ramsar Convention on Wetlands definition of wetlands: *areas of marsh... or water, whether natural or artificial, permanent or temporary (ephemeral), with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.*[8] The classification of wetlands used by the Ramsar Convention has been adapted for Namibia in a previously unpublished scheme (Table 2.1; Figs. 2.9-2.11):

Riverine systems: flowing or *lotic* systems such as rivers and their floodplains and estuaries, including river mouths and freshwater lagoons.

Lacustrine systems: standing or *lentic* open water systems such as lakes, pans and impoundments.

Palustrine systems: well-vegetated lentic systems such as swamps, marshes, *vleis* or *mulapos*, springs and seeps.

Marine systems: shallow ocean overlaying the continental shelf and coast, such as mudflats, lagoons and rocky shores. Namibia has no mangrove swamps or coral reefs.

Since this chapter focuses on terrestrial and freshwater systems, Table 2.1 does not deal with marine wetlands (see Chapter 3).

Fig. 2.11 Palustrine systems. Courtesy P Tarr

Riverine systems

River systems in Namibia include both perennial rivers and their floodplains as well as the more typical ephemeral rivers, called *omiramba* in the northeast (maps 1.5, 1.7). Perennial rivers occur only on our national borders and are shared with neighbouring states. The Kunene River originates in Angola, the Okavango is shared with Angola and Botswana, the eastern Caprivi rivers (the Zambezi, Kwando, Linyanti, Chobe) originate in Zambia, and the Orange originates in Lesotho and is shared with South Africa. These rivers carry large volumes of water. Most of the mean annual runoff of the Zambezi (40 000 million m^3), Orange (11 000 Mm^3), Okavango (10 000 Mm^3), Kunene (5500 Mm^3), and Kwando-Linyanti rivers (1300 Mm^3) originates in the upper catchments in neighbouring countries, and local rainfall contributes very little.

Table 2.1 Freshwater wetland systems of Namibia

Classification	Defining characters	Namibian examples
Riverine		
Perennial rivers	Rivers that flow throughout the year	Kunene, Okavango, Zambezi, Orange, Kwando-Linyanti-Chobe Rivers
Floodplains and backwaters	Low-lying areas and depressions next to rivers	Okavango and eastern Caprivi floodplains
River mouths	Predominantly freshwater wetlands which form where rivers meet the sea	Kunene and Orange river mouths
Ephemeral rivers or omiramba	Rivers flowing only after heavy rains, sometimes not for several years	Kuiseb, Nossob, Ugab, Huab rivers, Omatako Omuramba
Oshanas	Seasonal, shallow, interlinked pans with inflow from rain and seasonal floods	Cuvelai drainage area
Lacustrine		
Floodplain and oxbow lakes	Shallow lakes in depressions or old rivercourses in floodplain areas	Lake Liambezi (now dry), small lakes in the eastern Caprivi floodplains, *e.g.* Lake Lisikili
Sinkhole lakes and caves	Small, deep, permanently filled caverns and sinkholes	Otjikoto and Guinas Lakes, Aigamas and Dragon's Breath Caves
Pans	Shallow, ephemeral, unvegetated pools in depressions filled by local rainfall or endoreic rivers	Nyae-Nyae Pan, Etosha Pan, Kalahari *pannetjiesveld*,' Sossusvlei, Tsondabvlei
Dams and impoundments	Man-made lakes formed when rivers are impounded by a dam wall	Hardap, von Bach, Olushandja Dams and numerous small farm dams
Palustrine		
Swamps	Well-vegetated wet areas with open standing water associated with perennial rivers	Linyanti Swamp
Marshes	Well-vegetated, water logged areas with little visible open water, found along perennial rivers	Confluence of the Okavango and Cuito Rivers
Vleis or *mulapos*	Seasonal or permanent shallow, vegetated pools dependent on local rainfall or fed by groundwater rising to the surface	Tsumkwe *vleis*, *e.g.* Makuri Pan
Seeps and springs	Permanent vegetated pools and streams formed by artesian waters	Sesfontein, Karstveld, Naukluft springs
Geothermal springs	Small permanent pools fed by hot groundwater rising to the surface from a great depth	Ai-Ais, Gross Barmen, Rehoboth, Warmquelle, Klein Windhoek springs
Estuarine		
Estuaries	Wetlands at the mouths of perennial rivers subject to both tidal and river inflows	Kunene River mouth

Most of Namibia's rivers, however, are ephemeral (map 1.7). They flow only for a few days each year, and often not for several years, but may store important volumes of surface- and groundwater (Box 2.1). Subsurface flow and water stored in sediments can support vegetation.

The west-flowing ephemeral rivers drain higher rainfall areas inland, channelling runoff across the Namib Desert to the Atlantic in 'linear oases' which support species normally found only in wetter areas.[9,10] Omuramba Omatako is the largest north-flowing *omuramba* (maps 1.5, 1.7), but its waters have not reached the Okavango River in living memory due to blockage by dunes and vegetation. The east-flowing Nossob River and its tributaries historically fed into the eastern Orange River catchment, but have not done so since 1934. By contrast, the south-flowing Fish River and its tributaries regularly feed the Orange.

These rivers are the focus of human settlement in otherwise dry regions.[10] Sandy rivercourses and alluvial aquifers provide year-round groundwater to riparian forests, people, their stock, and wildlife. Groundwater seeps to the surface in some places; in others the water table can be reached by digging. Gemsbok, zebra and elephant are adept at this, and the holes they dig are used by a myriad of other wildlife.

Floodplains are seasonally or periodically flooded areas adjacent to perennial or ephemeral rivers (Box 2.2). Three types occur on our rivers: The most common are *fringing floodplains*, found along rivers where flat terrain allows seasonal inundation with rising floodwaters. Less common are *riverine swamps*, more permanent wetlands found at river confluences such as the junction of the Cuito and Okavango rivers. The Okavango Swamps in neighbouring Botswana are a good example of an *endoreic floodplain* (one with no outflow).

Box 2.1 Ephemeral river dynamics

Unlike perennial rivers, in which a 'flood' is a dramatic rise in water levels, spilling the banks and inundating surrounding areas, in the normally dry ephemeral rivers a flood is any flow at all. The frequency, intensity, duration and distance of floods vary greatly. Runoff in the catchment is influenced by topography, land use, soil types and vegetation cover as well as the intensity and duration of rain.

Strong localised thunderstorms can cause very sudden floods, characterised by a wall of water which moves rapidly down a dry rivercourse, often sweeping away plants and animals. Longer periods of rain bring about more sustained floods, with single or multiple peaks. Multiple peak floods can occur with consecutive rains over many days, or rains in different parts of the catchment. Ephemeral river floods redistribute sediment, nutrients and organic debris which have accumulated in dry rivercourses and deposit these downstream or, in rare events, in the sea. Much of the water transported in an ephemeral river soaks into the sandy riverbed or evaporates, and water volumes tend to decrease with distance downstream. The recharge of alluvial aquifers beneath the rivers is vital for sustaining the ribbon of riverine vegetation associated with ephemeral rivers in Namibia. A cross-section of a typical ephemeral river shows the interdependence of surface flow in the river channel, recharge into the alluvial aquifer, and the availability of this groundwater to trees and via boreholes to man.

— Source: Jacobson et al. (1995)[10]

Fig. 2.12 Sinkhole lakes: Lake Otjikoto. Courtesy K Roberts

Box 2.2 Floodplain dynamics

Annual or periodic floods are essential to the productivity of floodplains. Floodplains typically have a dry period followed by inundation as rivers rise and spill their banks. A highly productive flooded period follows, and then the floodplain gradually dries. In the dry season, floodplains provide lush grazing and fertile soil for crops. When inundated, they provide rich nursery and feeding areas for fish, amphibians, birds, and other aquatic fauna, and support a diverse flora.

As both the Okavango and Zambezi rivers receive most of their flow from the Angolan and Zambian highlands respectively, it takes some time for the floodwaters to reach Namibia. The flood peak caused by Angolan rains in January/February only reaches Rundu in March/April, and Maun, Botswana, in June/July. The delay in flooding allows the floodplain depressions to fill with rainwater and support the life cycles of ephemeral pool fauna such as ostracods, fairy shrimps, snails and tadpoles. These must complete their life cycles before the pools are linked by flooding and predatory fish can enter. During annual floods, fish migrate from the river into the newly inundated floodplain which provides ideal breeding and feeding habitat. Floodplain fish typically include small species such as the Zambezi parrotfish Hippopotamyrus discorhynchus, *the larger African pike* Hepsetus odoe, *several cyprinids and the unusual many-spined climbing perch* Ctenopoma multispinis. *As the floodplain waters recede, the fish return to the mainstream. This is when they are most easily caught, and fish traps and fences set across side channels are a common sight at this time.*

Fig. 2.13 Kwando floodplain, Caprivi. Courtesy K Roberts

Estuaries and river mouths are found at the lowest part of a river and usually contain a mixture of fresh and salt water. River mouths are predominantly freshwater, while estuaries are subject to both tidal and river inflows. Water, nutrients and sediment flow out with river floods and in with the incoming tide. Sediments deposited as the water meets the resistance of the sea form wide mudflats.

Although dominated by river water inputs, the river mouths of the Orange and Kunene rivers have been termed estuaries, and are indeed subject to some tidal influence.[11] The Kunene River mouth and lagoon are vulnerable to flow alteration caused by the proposed Epupa Hydropower Scheme. A dam built upstream would reduce the volume of river water reaching the mouth, as well as the duration and intensity of floods. This will, in turn, reduce the scouring necessary to keep the river mouth from silting shut, and decrease essential nutrient inputs.[11,12]

Lacustrine systems

Most large standing waterbodies in Namibia are man-made, including 12 government dams on ephemeral rivers and numerous smaller farm dams. The proposed Epupa Dam, at 280 km^2, would be by far the largest of these. Namibia has few natural lakes, of three main types:

- small, deep, permanent sinkhole lakes and caves (*e.g. Lake Otjikoto, Lake Guinas, and Aigamas Cave)* (Fig. 2.12);
- larger, relatively shallow ephemeral floodplain or oxbow lakes on seasonally flooding rivers (*e.g. Lake Liambezi, now dry, in eastern Caprivi*) (Box 2.3, Fig. 2.15);
- very shallow ephemeral lakes and pans (*e.g. Etosha Pan, Lake Oponono, Sossusvlei, Tsondabvlei, Tsumkwe Pans such as Nyae Nyae, and Kalahari 'pannetjiesveld' pans*).

Sinkhole lakes and caves are characteristic of dolomite, and form as water penetrates cracks in the dolomite and leaches away the rock. This process gradually forms larger water-filled underground caves; sinkholes form when the roof of an underground cave collapses. The sinkholes and caves of the Mountain Savanna and Karstveld vegetation type (map 1.8) near Otavi, Grootfontein and Tsumeb are ecologically extremely important due to the presence of endemic invertebrates and fish (see section 2.9). For example, southern Africa's only true cave fish, the endangered cave catfish *Clarias cavernicola*, is found only in Aigamas Cave.[13,14,15,16] These habitats and their unique fauna are especially vulnerable to pollution and groundwater level changes, and great care must be taken when planning large scale abstraction.

Box 2.3 The vanishing lake: Liambezi

Lake Liambezi in eastern Caprivi is Namibia's best known temporary floodplain lakes. The explorer Selous reported a large water-filled lake in 1879. Large floods in the Zambezi in 1952 and 1958 filled the previously-dry lake, but throughout the 1980s lake levels steadily declined until the lake dried up in 1989.[17] It has not filled since then. In 1986 the lake covered 406 km², of which 189 km² was open water and the rest well-vegetated marginal marsh.[18] At this stage the lake was about 3 m deep and mostly covered by a variety of submerged plants. Phragmites *reedbeds and stands of cattail (*Typha*) and papyrus (*Cyperus*) lined the lake margins and shallower areas. Water lilies* Nymphaea capensis *and* N. lotus *shaded the water surface, along with dense mats of the invasive aquatic weed* Salvinia molesta. *The lake supported a wide diversity of species including 54 types of algae, 28 of zooplankton[19] and 43 species of fish[20,21] in the open water. For a short time a small commercial fishery of about 60 fishermen on the lake supplied the Katima Mulilo market.[20]*

Fig. 2.14 Oshanas are important in groundwater rechange. Courtesy K Roberts

Fig. 2.15 Lake Liambezi, 1982. Courtesy S Bethune

Pans are shallow depressions periodically filled by rain or discharge from endoreic rivers (map 1.5), which dry out too rapidly to sustain much plant growth. For example, the Etosha Pan fills via the Cuvelai Drainage System only after very large floods (*efundja*) once every 7 - 10 years. On these occasions, it is briefly transformed into important habitat for aquatic invertebrates such as fairy shrimps which are adapted to ephemeral habitats, and for amphibians and wetland birds, particularly breeding flamingos and pelicans.[22,23] The *oshana* system (Fig. 2.14), which is classified as riverine, is a series of smaller, linked pans in the Cuvelai system, which when inundated support up to 151 plant, 43 crustacean, and 19 fish species.[24,25] The largest *oshana* is Lake Oponono, which receives floodwaters about twice every three years. The flooding *oshanas* recharge groundwater, supply both surface and shallow groundwater to people, wildlife and livestock, renew grazing, and bring fish southwards (see section 2.9 and Chapter 4). The Cuvelai system supports more people per unit area than any other non-urban region in Namibia.[26]

Sossusvlei, in the central Namib dunefields, forms the end of the Tsauchab River. The catchment receives less than 200 mm of rain a year; floodwaters only reach this endoreic pan after exceptional rains. The 15 km² pan is surrounded by some of the world's highest dunes, as well as camelthorn trees *Acacia erioloba*, spiny *Cladoraphis spinosa* grasses, and *!nara* plants, *Acanthosicyos horridus*. During the brief wet periods, several types of algae, copepods, ostracods, cladocerans and wetland birds have been recorded.[27]

Fig. 2.16 Epupa Falls. Courtesy P Tarr

The many smaller ephemeral pans scattered across Namibia are of ecological importance as a temporary water source for people and as habitats for unique communities of aquatic biota. When wet, they support a variety of desiccation-resistant crustaceans with rapid life cycles.[28] The harsh conditions have led to speciation: 42 ostracod species have been collected from ephemeral pans or pools in the northern Namib, 18 of which are thought to be endemic to Namibia. There is still much to learn about these very arid ephemeral pans.

Impoundments are created by the damming of rivers for water storage or hydroelectricity generation. All large state dams in Namibia are water storage reservoirs built on ephemeral rivers (map 1.7). Many central Namibian towns depend on this water; for example Windhoek is supplied by the von Bach (50 million m^3) and Swakoppoort Dams (69 Mm^3) on theSwakop River, and the shallow Omatako Dam (45 Mm^3) on the Omuramba Omatako. The largest dam is Hardap Dam (300 Mm^3) on the Fish River, which supplies the town of Mariental and the Hardap Irrigation Scheme. Much of this water is wasted by extremely inefficient flood-irrigation practices.

Aside from storing water, impoundments support a variety of aquatic and wetland biota. Unlike natural lakes, there is often no marginal zone of plants, due to water level fluctuations caused by water withdrawals and irregular inflows. Rooted plants never become established since water levels rise and fall unpredictably. This has profound ecological effects, as it prevents the establishment of sheltered areas for young fish and invertebrates.

The creation of an impoundment can have serious environmental consequences. A dam creates a water body where none existed, such as on an ephemeral river, or alters a perennial river into a lake, in which case the river biota must either adapt to non-flowing conditions or die. New dams are often extremely unstable ecosystems. Nutrients from decaying, previously terrestrial plants may promote nuisance plant growth, such as the explosive growth on Lake Kariba of *Salvinia molesta* in the 1960s, which characterised a 14-year unstable phase.

Namibia is one of very few countries in the world which builds dams on ephemeral rivers. Although extremely valuable for water supply, impoundments have two main drawbacks. First, they effectively cut off the natural supply of water, nutrients and silt essential for downstream ecological functioning. Second, the long retention times of water in the dam can cause water quality problems.

Palustrine systems

Palustrine systems or well-vegetated standing waters include permanent marshes and swamps, less permanent *vleis* or *mulapos*, and seeps and springs fed from groundwater. They occur mainly in wetter parts of Namibia, and are associated with perennial rivers, higher rainfall, or shallow groundwater.

Marshes and swamps are well-vegetated lentic wetlands with permanently waterlogged soils, often found alongside perennial rivers and lakes. They are very important in terms of high biodiversity and productivity, nutrient cycling, and moderation of floods. Marshes typically have little visible surface water, while swamps have visible open water or lagoons, as in the case of Botswana's Okavango Delta.

The ecologically valuable marsh at the confluence of the Cuito and Okavango rivers resembles a vegetated floodplain at the peak of productivity. In the dry season the water is shallow, stagnant, and often oxygen-poor due to rotting organic debris. Such marshes support dense stands of reeds and some papyrus, and a variety of sedges and trees adapted to waterlogged soils, such as the forest waterberry *Syzygium gerrardi*. They serve as refuges for floodplain fish such as African pike *Hepsetus odoe* and blackspot climbing perch *Ctenopoma intermedium*, and are habitat for bilharzia and malaria vectors.[29]

The little-known Linyanti Swamp in eastern Caprivi closely resembles the much better-known Okavango Delta, with a 'permanent swamp' section supporting a rich array of species, and a 'seasonal swamp' or floodplain which fluctuates between terrestrial and aquatic phases. Vegetation includes emergent plants such as reeds and papyrus, rooted submerged plants such as oxygen weed (*Lagarosiphon*), rooted plants with floating leaves such as water lilies (*Nymphaea*), and free floating plants such as duckweed (Lemnaceae).

Vleis or *mulapos* are shallow, well-vegetated lentic pools, seasonally filled with water and covered with grass. They are usually smaller than swamps and marshes, and often depend on local rainfall. Namibian examples include the rainwater pools in forests of the Caprivi, Okavango and Otjozondjupa Regions (map 1.10) and the Kalahari sandveld (map 1.3). These are analogous to the *dambos* of Zambia and Zimbabwe. Although temporary, these wetlands support a wide variety of animals adapted to surviving dry periods. For example, the rainwater pools of eastern Caprivi support a remarkable endemic fish, the Caprivi killifish (*Nothobranchius*). Like the invertebrates of temporary ponds, these fish reach maturity before the ponds dry out, and lay drought-resistant eggs which survive in the dry mud until the ponds fill again.

Springs and seeps form small permanent or semi-permanent wetlands, fed by groundwater which rises to the surface and flows away. They are scattered throughout the arid and semi-arid areas of the country, such as Sesfontein and Orupembe in the Kunene Region, where they provide the only permanent source of water to wildlife and people. Typical springs and seeps have a freshwater "eye" where the water surfaces, but water becomes more saline with distance from the eye. As water evaporates rapidly, the edges of these wetlands are often encrusted with salt. The animal communities living in these springs vary along these salinity gradients. Some more permanent seeps, such as those along tributaries of the Kunene River, support endemic fish such as *Kneria maydelli* (see Appendix 13).

Fifty-seven geothermal (hot water) springs are known to occur in Namibia, of which 24 are natural springs and the rest are artificially tapped sources or artesian boreholes. Ten of these have been studied in some detail,[30] and range in temperature from 24.9°C for Osterode Süd to 66°C for Gross Barmen. These springs feature 28 kinds of algae. Green algae (Chlorophyceae) occur only in cooler springs but diatoms and blue-green algae (Bacillariophyceae and Cyanophyceae) occur in all, with blue-green algae dominating the hotter waters. The three hottest springs, Ai-Ais, Gross Barmen and Rehoboth, have been developed as tourist resorts. Geothermal springs in Windhoek also induced the first settlement of the capital over a century ago.

— Shirley Bethune

Fig. 2.17 Geothermal spring. Courtesy K Roberts

Fig. 2.18 *Euphorbia namibensis.* Courtesy G Williamson

2.2 Environmental change

Natural climatic variability

Rainfall is without a doubt the main limiting factor in arid environments such as ours.[31] Globally, where rainfall is very sparse, it is also very variable in both space and time, and this is also true of Namibia. This strong climate variability within and between years has spawned a high degree of natural variability in ecological communities.

In arid environments, the influence of single or 'episodic' events such as a year of exceptionally high rainfall or a severe drought can be felt for years or decades.[32] Such events can indeed drive environmental change. The effects of variation in rainfall are often concentrated in habitats such as ephemeral pans or rivers, and these habitats may provide a more obvious record of episodic events and the resultant environmental changes.

Long-term climate variation

Rainfall runoff in perennial or ephemeral rivers reflects several factors, including current and recent rainfall, vegetation cover, and overall habitat condition. The low runoff recorded at Victoria Falls on the Zambezi River during the early decades of this century was similar to that observed today.[33] Yet for about 30 years in mid-century, the runoff volume was about double. The record is not long enough for us to know if these large scale changes are part of a long term cycle or simply random variation. Significant changes in habitats and ecological communities must nonetheless have accompanied these natural variations, certainly in the headwaters of the Zambezi and possibly throughout the Zambezi Basin, including northern Namibia. Similarly, Lake Liambezi on the Kwando and Chobe Rivers has varied several times this century between a perennial lake teeming with fish and a dry depression (Box 2.3).

Namibia was apparently drier in the height of the last Glacial Maximum. This is suggested by Kalahari dunes, some now vegetated, by the *oshana* ephemeral rivercourses of northern Namibia,[34] and by linear dunes south of Okahandja. Yet other evidence suggests that rainfall was higher during the Glacial Maximum, and that the ephemeral rivers of western Namibia carried heavier flows and greater silt loads than they do today.[35,36] Whichever interpretation is correct — and both scenarios may have occurred — it is certain that climate changes were followed by habitat changes throughout Namibia.

Organisms in arid environments can often cope better with variation in available moisture than those in wetter environments. An evolutionary history of adaptive response to small scale natural habitat changes may allow at least some species to adapt to minor anthropogenic environmental changes.[31] As a result, biodiversity loss in the face of moderate environmental change may be somewhat less in variable environments than in more constant ones, at least in theory.

Changes in socioeconomic and natural environments

Humans and their changing lifestyles have influenced the natural environment in Namibia for many centuries. The first inhabitants were hunter-gathers (section 1.2), and herding and crop-growing appear to have developed less than a thousand years ago.[26] These changes in land use allowed human populations to increase significantly.[37] Such quantum shifts had major effects on natural habitats, some of which were cumulative, such as those accompanying the reduction of wildlife and the increase of livestock.[10] Reductions in species diversity of ungulates, changes in their distribution, and changes in herd behaviour and predator densities, must have affected habitat structure and composition.[99]

The shift from nomadic to sedentary lives

The establishment of agriculture in Namibia also accompanied a shift from nomadic or semi-nomadic herding practices to sedentary lifestyles. Areas which had been used occasionally for grazing or water following rain, or only as refuges during drought, were now used more continuously by people and livestock.[10] Although not well documented, such changes in land use have undoubtedly affected habitats in many ways.[38]

Another major change was the modification of shifting agriculture as human populations grew. Since the soils of northern Namibia are poor in nutrients, they can only support crops for a few years without fertilisation. With low population pressure, people could shift their fields as needed to newly cleared lands. More people practising dryland cropping probably meant that fields were located closer to one another, and more land was cleared.[38] The rapid increase in human populations has been one of the most powerful agents of environmental change.

The shift to active water management

Human lifestyle changes have provoked changes in the way water is managed. In present-day Namibia, surface water is retained mainly in artificial impoundments, which are all built on ephemeral rivers (section 2.1). As well as directly inundating habitats with water, land surrounding the new water body is affected by land use changes associated with the impoundment. By altering the frequency, duration and volume of floods in ephemeral watercourses, dams alter the habitats downstream, often dramatically. In Namibia, many dams have been built in single catchments, with cumulative effects which depend on the sensitivity of downstream habitats and the relative position of dams.

A documented example of habitat alteration is the lowering of the water table in the Otjimbingwe district, which has eliminated the potential for crop production in the bed of the Swakop River and its tributaries. This was the result of two large dams built in the upper Swakop catchment to meet Windhoek's water demands.[39] Another example is the death of hundreds of ana trees *Faidherbia albida* and some previously perennial wetlands in the Huab catchment (Fig. 2.19), downstream of several large and many small farm dams.[10] A change associated with the construction of all large state dams in Namibia, however, is the creation of small, perennial wetland habitats immediately below the dam wall.[40]

Groundwater management has also led to widespread habitat change. Boreholes have frequently been drilled in areas where water was not previously available. In principle, this allows grazing pressure to be distributed over a larger area, and contributes to better livestock and natural resource management. However, it also provides the basis for permanent occupation by people and stock, accompanied by widespread habitat change. Livestock-induced changes following the drilling of boreholes include overgrazing and selective grazing, excessive trampling in a limited area, creation of distinct paths along which erosion can occur, and bush encroachment. Human settlement-induced changes at new boreholes include overuse of wood, wildlife and resources, as well as concentration of livestock.

The permanence of these changes is not entirely clear. In some areas, changes may be rapidly reversed with several years of above average rainfall, with little or no lasting habitat degradation.[41] In others, habitats may never recover their pre-settlement features.

Fig. 2.19 The links between biodiversity loss and desertification need clarifying. Courtesy MAWRD

Fig. 2.20 Borehole pump at Khowarib. Courtesy E Marais

Fig. 2.21 Omatjette - Omaruru border fence. Courtesy E Marais

In a few cases, groundwater management has led to a loss of water resources *per se*. Most geothermal springs in Windhoek have dried up as the water table was lowered by municipal boreholes, eliminating habitats associated with these natural hot springs.

In other areas, water tables have dropped considerably, with unknown consequences.[10] Overextraction of groundwater from alluvial aquifers has caused localised habitat degradation. The lower Kuiseb River, a source of water for central Namib coastal towns, is a case in point. There the lowered water table has caused the death of natural vegetation, most notably ana trees, and a loss of production of *!nara* melons.[10]

Fencing and control of fire

Fencing and fire have a major influence on habitat and species diversity. In Namibia fencing is often used as a substitute for, rather than a tool of, good management. When livestock are confined in fenced areas for some time, they tend to use the available grazing or browse in a selective manner, leading to short term and possibly long term habitat change. Bush encroachment may be one manifestation of the incorrect use of fencing. In communal farmlands, fencing is being used as a tool by richer farmers to secure land for themselves, leaving many smaller-scale farmers crowded into less space. Landscapes associated with fenced farming are often far removed from their natural state — occasionally enhanced in some way, but more often degraded.

Fire as a management tool can have different effects in different habitats. The frequent fires set in Namibia's sub-humid northeast accelerate habitat degradation by reducing species richness, lowering nutrient availability and altering habitat structure (Box 2.4[38]). Where fires are prevented, as in the drier farming areas, the result can also be reduced biodiversity and the build-up of moribund vegetation. Mismanagement of fire in any form is a powerful force for habitat alteration.

Box 2.4 Fire and habitat change

African savannas and woodlands have evolved with fire, and fire has powerfully shaped their biological communities. Yet the frequency, scale and timing of fires have changed greatly during the recent centuries of human influence and population growth. These changes, to which some species may not easily adapt, can be a major agent of biodiversity loss.

A dramatic multiple satellite image analysis of the frequency and extent of fires in Caprivi Region[38] shows that fully 60% of Caprivi's vegetation was burnt between 18 April and 2 October 1996. This happened mainly through many localised fires, perhaps up to 3000, rather than a few widespread fires. It may be the increased frequency of fires which is most harmful to biodiversity. Annual fires have prevented seedling establishment of valuable trees such as teak Baikiaea plurijuga *and kiaat* Pterocarpus angolensis, *and mature trees are eventually killed by frequent fires. Large areas are now encroached by dense thickets of* Terminalia sericea, Combretum *spp. and* Dichrostachys cinerea, *causing valued grazing areas and timber resources to become scarce.*

— Source: Mendelsohn & Roberts 1997[38]

Other socioeconomic shifts

Environmental change has also been induced by ongoing changes such as the shift from a subsistence to a cash economy, from animal to machine ploughing, and from exclusively rural to urban living. Where people have a purely subsistence economy, for example, excessive use of natural resources is neither desirable nor encouraged. With the shift to a partial or full cash economy, based primarily on natural resources, overuse of these resources is possible and to some extent encouraged. All of these factors, of course, have been greatly exacerbated by rapid human population growth.

Environmental degradation

The term environmental degradation is often used from a human perspective, referring to loss of productivity of land or other resources. It can also refer to biodiversity loss, which itself can underpin loss of productivity, or to a reduction in largely subjective factors such as aesthetic values. Degradation is often a slow process. It may be noticed by the people causing it, but may not be regarded as a solvable, or even a serious, problem.

Environmental degradation has taken place for a long time in Namibia. The first recorded example may be the overuse of woody vegetation in the Owambo kingdoms for homestead construction and copper smelting.[26,42] Trees are today still used mainly in the northern regions for subsistence — for fuel, homestead construction, and fencing to enclose crops (Chapter 4). Rapid population growth has severely stressed the remaining resources. Degradation in the region is manifested not only by deforestation but also by the symptoms of overgrazing, reduced soil fertility, and soil erosion. The integrity of the extensive *oshana* ephemeral wetlands has been severely compromised, due mainly to loss of woody vegetation and associated habitat quality, but also to other habitat changes induced by population pressure.[26]

Deforestation takes a slightly different form further east in the Okavango and Caprivi Regions. Fire is by far the biggest cause of deforestation there, largely for clearing croplands or 'improving grazing.' The amount of land cleared for crop agriculture in four areas of Caprivi since 1943 has grown by an average of about 4% per year, similar to recent average population growth.[38]

Bush encroachment is a major form of degradation, especially on commercial farms in the central, eastern and northern areas.[43] Dramatic increases in the density of thin-stemmed woody species have reduced the overall productivity and carrying capacity of both livestock and wild mammalian herbivores. Bush encroachment is a serious economic problem, accounting for annual losses of over N$100 million on commercial farmlands alone (Box 4.9). The evidence is contradictory, but it appears that there has been major land conversion from open grasslands to dense bush in the current century.[43] Although this could be part of a natural cycle, it is likely to be accelerated by poor grazing management. Such large-scale alterations of habitat can be rapidly induced by farming practices.

Expectations of the environment

Despite humans' extraordinary environmental impact, many impacts are neither planned nor desired by people. People have expectations of the values and benefits to be provided by the environment, however. Such expectations may be based on lessons learned from less arid nations, which may be unrealistic for Namibia.

People commonly expect that the environment will provide enough water for any conceivable use. Large and small dams and boreholes have been developed irresponsibly across Namibia in response to these expectations. The use to which this water is then put contributes to both negative and positive environmental changes, and may induce change further afield by requiring development of additional supplies. The expectation that 'water is from God' and should thus be free has contributed heavily to degradation around waterpoints. A newly implemented cost recovery system may help reduce these environmental impacts.

People may also expect a stable or steadily increasing income from the environment, no matter how many others are doing the same. Yet natural resources are finite if used unsustainably, and variable in space and time. This is often forgotten as more and more people try to earn a living from livestock or dryland cropping. In arid regions like Namibia, the concept of carrying capacity is only useful if understood to be a variable, not a constant. When misused, the concept can contribute to bush encroachment, reduced productivity or other kinds of environmental degradation.

Predicted environmental change

Habitat degradation related to socioeconomic change will probably continue well into the foreseeable future. With a human population doubling every 23 years and, at the same time, depending mainly on natural resources, degradation can be expected to accelerate.

Fuelling this degradation are increasing expectations of improved livelihoods and higher incomes, which are exacerbated by politicians' promises. When combined with a lack of political will to implement sometimes unpopular measures required for sustainable resource use, accelerated environmental change is inevitable.

The rate of urbanisation in Namibia is almost double the overall rate of population growth (section 1.2). This population shift is likely to have an increasing effect on environmental change. While it may mean a smaller proportion of people attempting to subsist directly from natural resources, resource demands from the urban population, and investment in rural livestock herds by urban-based absentee owners, will all contribute to environmental change in rural areas.

Global natural resource markets

Namibia is, to a limited extent, part of the global natural resource market. The mining and export of diamonds and uranium have disturbed habitats in vast, if localised, areas of the Namib Desert. Export beef production from an arid environment not ideally suited to this form of land use, and the past focus on export of karakul sheep pelts (section 1.2), have already caused extensive habitat alteration. Should Namibia become further involved in global resource marketing, for example of hydroelectric or natural gas energy, the accompanying environmental change may be great. Small-scale natural resource transfers, such as the production of crafts for tourism or charcoal for export, contribute to localised environmental changes. So may the unsustainable exploitation for the global market of resources such as plants for the pharmaceutical industry (*e.g.* Box 4.10). However, the global ecotourism market offers enormous potential for land uses which promote biodiversity conservation in Namibia (Chapter 4).

Waste, pollution and climate change

Most forms of waste production and pollution are relatively limited in Namibia, although they may degrade key resources and habitats such as rivers. The main large-scale source of pollution is savanna burning, a major source of atmospheric greenhouse gases,[44] which is regularly practiced in much of northeastern Namibia. In addition to habitat changes caused by repeated fires (Box 2.4), the influence of these gases on the southern African atmosphere may be considerable.

The first sign of global climate change is predicted to be increased climatic variability. Due to Namibia's natural variability, changes may be very difficult to detect. Only long term data sets and careful analyses will help us differentiate natural from anthropogenic climate variability. In addition to increased variability, the overall trend is likely to be increased temperature and decreased rainfall, which would cause increasing aridity.

The Benguela upwelling system has a major impact on Namibia's climate (section 1.1), especially west of the Namib escarpment. There is little consensus on how the Benguela will change in the long term. It will almost certainly become more variable, but it is not clear exactly how, nor how this may affect the regional terrestrial environment. Extrapolating from a South African analysis,[45] bioclimatic regions are likely to become more arid in Namibia. Semi-arid parts of the country are predicted to become arid, with a temperature increase of several degrees. This means that up to about 97% of Namibia will be arid and a small portion, now sub-humid, is likely to become semi-arid. These shifts in bioclimatic regions will have dramatic implications for the natural environment and biodiversity conservation. As people with their livestock attempt to adapt to these changes, we can expect environmental change in Namibia to accelerate, especially in intensively used habitats such as wetlands.

In summary, environmental change in Namibia is an ongoing process driven by many factors, both natural and human-induced. All habitats in Namibia are affected by this ongoing change to different degrees.
— *Mary Seely*

2.3 Areas of high species endemism

Africa's arid southwest, roughly centred on Namibia, is a major zone of evolution for groups such as melons (Cucurbitaceae), some families of succulent plants, fishmoths (Lepismatidae),[46] solifuges or sun-spiders (Solifugae),[47] geckos[48] and tortoises. Namibia is obliged by its Constitution and the Convention on Biological Diversity to protect its *endemic* species, which are unique and occur nowhere else. This section summarises the major areas of Namibia which are rich in endemic species. A taxonomic overview of the numbers of endemic and other species in Namibia is given in section 2.9.

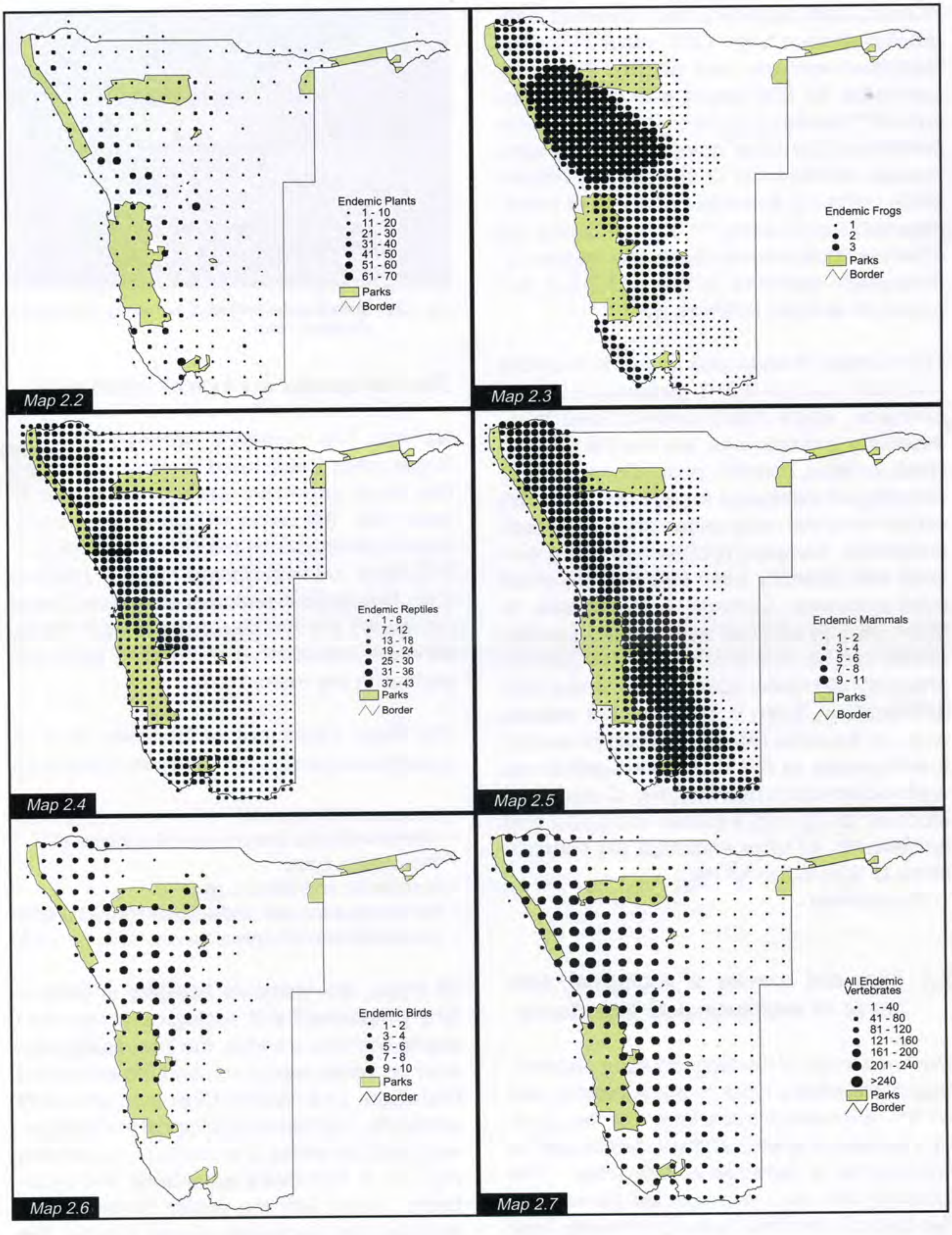
A recent analysis of endemism patterns[49] has shown that most Namibian endemic plants, invertebrates, amphibians, reptiles, mammals and birds are found in a zone running along, and to the west of, the Namib escarpment (maps 2.2-2.7). There is also an important region of endemism for succulent plants, reptiles and invertebrates in the Succulent Karoo Biome (see map 2.1). Congruence between endemism hotspots, particularly on rocky substrates, is remarkably high, implying broadly similar speciation processes.

Areas of endemism and species richness overlap poorly for endemic vertebrates, which are mainly arid-dwelling, as richness is highest in the mesic wetlands and woodlands. However, the correlation between endemism and richness for succulent plants, insects and arachnids is relatively high.[49]

Centres of endemism for plants and vertebrates fall mainly outside state protected areas, as few parks were established with biodiversity indices in mind.[50] The similarity of endemism patterns in different taxa[49] is a strong argument for developing additional protected areas, using creative non-traditional conservation approaches, to safeguard Namibia's unique biota (section 2.6).

Broad-scale analyses of endemism contend with certain problems. First, the use of the term 'endemism' is not consistent in Namibia. Vertebrate zoologists tend to class a species as endemic if 75% or more (frogs, reptiles and mammals) or 90% or more (birds) of its total range occurs within Namibian political boundaries. For insects, arachnids, flowering plants and freshwater fish, a species is endemic if 100% of its range falls within Namibia. Except for fish, most endemics in these groups are found in the Namib Desert or escarpment. This ancient desert stretches marginally into southwest Angola and northwest South Africa, so political boundaries dissect ecological ones, and Namib Desert endemics are not necessarily restricted to Namibia. Also, political instability in Angola means that the Namibian near-endemics occurring there may be essentially unprotected. For now, Namibia must assume greater responsibility for their conservation.

Fig. 2.22 Endemic *Namibia pomonae*, the *Sperrgebiet*. Courtesy G Williamson



Maps 2.2 - 2.7 Patterns of endemism in Namibian plants and terrestrial vertebrates in relation to protected areas.

Maps show the species richness distribution of endemics for: (2.2) plants; (2.3) frogs; (2.4) reptiles; (2.5) mammals; (2.6) birds and (2.7) vertebrate taxa combined. The plant map is a preliminary analysis and is thus shown at the half degree-square level to minimise sampling bias.[49]

Second, data accuracy and coverage vary greatly between taxa. Only about 24% of all Namibian spiders, and about 18% of an estimated 35 000 insect species, are described[49] (section 2.9). By contrast, the Southern African Bird Atlas[6] comprehensively summarises distributions of all southern African birds, allowing fine-scale analysis of Namibian bird distributions.[7,51,52] Data quality for other taxa falls between these two extremes. Endemism patterns in maps 2.2-2.7 are based on species richness data.[49]

The number of endemics known in Namibia (overview, section 2.9) is certainly an underestimate, since many undescribed taxa, especially invertebrates, are likely to occur in small, isolated, endemic populations. Further sampling on inselbergs in particular is almost certain to reveal more endemic invertebrates and plants. Sampling of birds, mammals, and frogs has probably been sufficient to reveal most endemics. Unevenly sampled taxa, or those such as reptiles[53] with 'cryptic' species (which can be distinguished only by genetic analysis) may reveal additional endemics with further study. Even in birds, recent genetic work on the larks (Alaudidae) has promoted a subspecies of the dune lark *Certhilauda erythroclamys* to a new species, *C. barlowi.*[54] Much of the country's terrain is rugged, arid and remote, so more endemics will certainly come to light in the future.
— *Rob Simmons*

2.4 Sites and species of ecological, economic or archaeological importance

Our knowledge of the biogeography and ecology of Namibia's biota remains patchy, and so only a minimum assessment of the country's outstanding sites and species of special importance is feasible at this time. The following are sites and species (or categories thereof) identified by the Biodiversity Task Force and other specialists. All merit urgent individual consideration for some form of conservation protection where this does not yet exist or is not yet secure. This assessment needs to be updated regularly as our knowledge base improves.

Fig. 2.23 Upland succulent Karoo, Aurusberg, *Sperrgebiet.* Courtesy J Irish

Sites of special ecological importance

Namibia has numerous localised sites and larger areas which need protection. Among the most important categories of larger areas are the *areas of high species endemism* outlined above (section 2.3, maps 2.2-2.7), and *underprotected habitats* (section 2.6). Due to their treatment elsewhere, these categories are not discussed here in detail, although individual sites needing particular protection are mentioned.

The major categories of Namibian sites of special ecological importance are (Table 2.2):

- caves and sinkholes;
- inland wetlands (perennial and ephemeral);
- the coastal zone;
- mountains and inselbergs;
- the Namib sand sea and adjacent gravel plains;
- the winter-rainfall desert zone.

Of these, the wetlands category is particularly threatened and ecologically important due to Namibia's aridity, the increasing pressure on water resources, and the ecological isolation and distinctiveness of many wetlands. Terrestrial ecological importance, especially in terms of endemism, is perhaps highest in Namibia's mountains and inselbergs, along with the winter-rainfall desert zone of the Succulent Karoo Biome, the Namib gravel plains, and the Namib sand 'sea.' In all of these categories, we have only an extremely fragmentary knowledge of the resident biota and their status. Research in these areas is a matter of national and regional priority.

Table 2.2 Sites of special ecological importance in Namibia

Category	Site	Known distinctive values
Northeast wetlands	Zambezi River frontage*	Biotic richness; red data birds, plants, etc.
	Okavango River frontage*	Biotic richness; threatened plants and insects
	Isolated pools, eastern Caprivi	Endemic Caprivi killifish (*Nothobranchius*)
	Impalila Island	Biotic richness, red data spp., unique vegetation communities on basalt
Border rivers	Lower Kunene River	Endemic fish; edible oysters and shrimps; habitat threatened by Epupa Dam
	Lower Orange River	One fish endemic to lower river; two others endemic to the river basin are threatened
Ephemeral pans	Tsumkwe Pans **	Biotic richness; endemic crustacea; red data birds; habitat/resource for people and wildlife
	Cuvelai Basin/ Etosha pans	Biotic richness; important ephemeral pan habitat; breeding red data birds; resources for people; significant basis of Namibia's tourism industry
Ephemeral rivers	particularly Ugab, Huab, Hoanib and Hoarusib Rivers	Biotic richness; large desert-dwelling mammals; high value for human subsistence and tourism
Karst caves/ sinkholes and springs	Aigamas, Arnhem and Dragon's Breath Caves; Lakes Guinas and Otjikoto; Ongongo Falls	Endangered cave catfish (*Clarias cavernicola*); endemic Otjikoto tilapia (*Tilapia guinasana*); endemic or restricted insects and crustacea; habitats threatened by water abstraction
Coastal wetlands	Kunene River mouth	Transition zone; sea turtles; migrant shorebirds
	Orange River mouth	Migrant shorebirds (Ramsar site)
	Sandwich Harbour	Biotic richness; 36 fish spp; migrant shorebirds (important Ramsar site); red data birds
	Walvis Bay lagoon	Biotic richness; migrant shorebirds (most important Ramsar site)
	Lüderitz lagoon	Migrant shorebirds; seabird breeding site
	Cape Cross	Cape fur seal and seabird breeding site
Coastline	entire coast	Biotic richness (arachnids, birds, lichens)
Offshore islands	All 18 islands	Seabird breeding sites; rich marine fauna plus artificial guano platforms
Namib escarpment and inselbergs, especially northern (Kaoko) escarpment	general:	Phylogenetic relicts; high endemicity
	Brandberg	High endemicity (plants, reptiles, insects); major rock art sites; threatened by tourism pressure
	Otjihepa Mountains and Baines Mountains	Highly restricted-range and vulnerable biota (shorthead barb; butterfly *Acraea brainei*)
	Otavi Mountains	Biotic richness (plants, birds)
	Aurus Mountains	Botanical richness and endemism, scenic value
	Karas Mountains	Botanical richness; endemic insects, lizards
	Waterberg Plateau	Biotic richness (lichens, plants, birds); Cape griffon breeding site, endemic insects and lizards

(continued)

Table 2.2 *(cont.)*

Category	Site	Known distinctive values
Escarpment, mts and inselbergs (cont.)	Erongo Mountains	Botanical richness; endemic vertebrates
	Auas Mountains	Highly-restricted range butterflies, lizard
	Hunsberge	Vertebrate richness and endemism
	Brukkaros	Endemic rodents
	Tiras Mountains	Endemic reptiles
	Campbell's Valley, near Helmeringhausen	Highly restricted-range lizard, *Cordylus campbelli*
Granite domes	Omaruru district domes	Biotic richness and endemism (vertebrates, probably other taxa). Habitats are on private and communal farmland and need protection
Namib gravel plains	Coastal fog belt	Biotic richness and endemism (lichens, arachnids, insects); habitat threatened by off-road driving
Winter rainfall zone	Aus area; *Sperrgebiet* incl. Aurusberg, Roter Kamm	Biotic richness and endemism (succulent plants, arachnids, insects); scenic grandeur
Sand dunes	Southern Namib dune 'sea'	High endemicity (arachnids, insects, lizards)
Major tourism areas	Spitzkoppe	Biotic richness and endemism; habitat somewhat threatened by tourism pressure
	entire Kaokoveld	High endemicity; habitat and cultural integrity threatened by tourism pressure
	Sesriem Canyon	Scenic grandeur; habitat threatened by tourism pressure

* *River frontage includes riparian belt, floodplains including oxbow lakes and other features, open water and river bed. Quartz outcrop biota near Andara on the Okavango River merits special attention.*
** *Tsumkwe Pans are widely known as 'Bushmanland Pans' and have wildlife tourism potential.*

Sites of special archaeological importance

Namibia's remarkable archaeological heritage is a major national treasure, and well known internationally. The country has a rich array of rock paintings and engravings, some many thousands of years old and, just as valuable, a wide array of 'archaeological landscapes' which represent a detailed record of the palaeoenvironment and early human land uses (Table 2.3). The most famous rock art sites at Brandberg, Twyfelfontein and Spitzkoppe have been jeopardised by tourism pressure, and a lack of education among the public and tour guides about the value and preservation of these sites. Training of rural rock art guides has recently been initiated through the auspices of the Southern African Rock Art Research Association.[55]

Namibia's varied 'archaeological landscapes' include about 5000 sites documented by the Archaeology Laboratory of the National Museum of Namibia. These have immense value in illuminating major environmental changes in Namibia, up to 50 000 years BP, as well as the impact of early human land use strategies, mainly over the last 1000 years.[56] These palaeoenvironmental records are found in landforms and deposits of five types: (a) spring tufas and other evaporite deposits, such as pans; (b) relict beaches on pan margins and the coast; (c) unconsolidated cave and rock shelter deposits; (d) bone breccia deposits and caves containing speleotherms; and (e) coeval site distributions showing land uses, *e.g.* precolonial nomadic pastoral, agricultural or riverine settlements and colonial farming settlements.[56]

Table 2.3 Sites of special archaeological importance in Namibia

Category	Site	Known distinctive values
Rock art sites	Brandberg (over 1000 sites)	Best-studied, varied and generally well-preserved art; threatened by tourism pressure
	Spitzkoppe	Varied and accessible art; threatened by tourism pressure
	Twyfelfontein	Varied and accessible art including engravings; tourist guide training a priority
	Apollo 11 Cave	Painted slabs dated to 27 000 y BP; also engraved slabs. Entry by permit only
	Erongo Mountains	Numerous sites on private farmland, *e.g.* Philipps Cave (Farm Amieb), Farm Anibib, Farm Omandumba, accessible by private guided tours
Palaeoenvironment record sites (see text)	c. 5000 sites registered by National Museum of Namibia Archaeology Laboratory	Only reliable source of long-term environmental change data, including prehistoric land uses

Sources: S-A Pager[55], J Kinahan[56]

Precise sites identified in Tables 2.2 and 2.3 may be the easiest for which to secure protection in terms of new draft environmental legislation (Chapter 5). This draft legislation provides for a category of "Sites of Special Scientific and Environmental Interest." Priority candidates for proclamation under this heading will be caves, sinkholes, inselbergs and granite domes with high biodiversity value, and rock art and palaeoenvironment sites. Legal clarification is needed for Brandberg, already a National Monument. The Ministry of Environment and Tourism must initiate consultative planning processes to identify precise sites in which to secure some form of feasible protection for all categories in Tables 2.2 and 2.3.

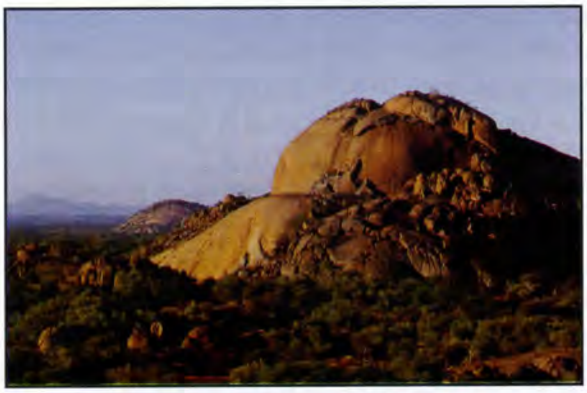


Fig. 2.24 Granite domes, Omaruru District. Courtesy R Simmons

Species of special ecological and economic importance

To an ecologist, of course, all species have ecological importance and a significant, if perhaps subtle, ecological role. However, the process of developing national biodiversity strategies requires prioritisation of a country's conservation resources. This is a difficult and ethically troublesome task for those involved.

Namibia's major categories of 'ecologically important species' are, in terms of national and international responsibility:

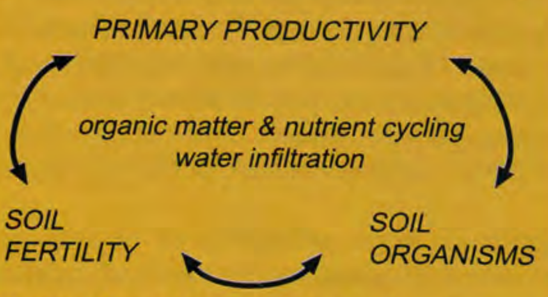
- **Endemic species**, which occur only in a specified area such as Namibia, the Namib Desert, or southern Africa;
- **Red data species** (endangered, threatened and vulnerable species, especially those imperilled globally);
- **Keystone and umbrella species**, for which conservation measures have a significant impact on other biota in the same habitat.

The summaries of conservation status for Namibian taxa (section 2.9) incorporate these major categories, particularly the first two. There is a need for identification of potential keystone and umbrella species in Namibia as a national priority, as this may in certain cases allow some rationalisation of biodiversity conservation efforts.

Some economically important species in Namibia are identified in Table 2.4. Clearly, this is a very incomplete list. For example, hundreds of palatable grass and shrub species are collectively important in rangeland agriculture. Equally, although few people could imagine assigning an economic value to termites, aside from their role as a subsistence food for some people, their value in maintaining the productivity of agricultural savannas is probably immense (Box 2.5). This helps demonstrate the interaction of ecological and economic value.

Box 2.5 Termites in agricultural savannas

Soil organisms play a significant role in maintaining soil fertility and primary productivity, by carrying out important ecological processes such as the cycling of soil organic matter, nutrients, and water. Ecosystem functioning may thus be impaired by the loss of soil biodiversity.



In arid Namibian ecosystems, termites are among the most important of these organisms, perhaps through their effects on soil structure, organic matter and water infiltration. Since healthy ecosystems support a diverse soil fauna, termite abundance and diversity may serve as a useful indicator of the status of ecosystem processes. As part of Namibia's Programme to Combat Desertification, experimental work on ecosystem functions mediated by termites will be combined with historical and current data on biogeography to assess the role of termites in maintaining the productivity of Namibian lands.[57]

Source: Juliane Zeidler[57]

There are two main categories of economic importance reflected in Table 2.4: species of importance in subsistence and commercial harvesting, which have 'positive' economic values, and agricultural pests and disease vectors, which have negative values. More information on the conservation status and uses of these and other species is given in section 2.9 and Chapter 4, and a summary of fish species of ecological importance is given in Appendix 13.

— *Barbara Curtis & Phoebe Barnard*

2.5 Threatened species: case studies

Namibian species with better known conservation management histories are red data mammals and birds, and commercially valuable marine species and their predators. Of these, black rhinos, cheetahs, wild dogs, greater and lesser flamingos, and Cape griffons are dealt with here. Marine species treated in Chapter 3 are pilchards and African penguins. The historical data are not of equal reliability, but some weaknesses are identified below.

Black rhinos: holding on against the odds

In the last three decades, black rhino *Diceros bicornis* populations in Africa have declined by 97%,[58,59] due almost entirely to the lucrative black market trade in rhino horn. Rhino species worldwide are under immense threat, and the chances of global population recovery appear slim.

Namibia has Africa's largest unfenced population of black rhinos, and about 97% of the world's population of the subspecies *bicornis*. Rhino protection has thus been a priority for the Ministry of Environment & Tourism (MET). Management activities (Box 2.1) have been generally effective at maintaining population levels in recent years.

Before the early 1800s, black rhinos were widely distributed in Namibia except for the Kalahari and western Namib, which lack surface water. Populations have since declined drastically due to hunting, human settlement, and recently poaching for the horn trade. This decline slowed dramatically in the 1980s. There are no reliable population estimates prior to 1984, when Namibia held around 450 rhinos. In 1996, the national population was about 650 rhinos. Of this total,120 occur in the arid communal land of the Kaokoveld (Kunene Region), which lacks formal conservation status. After most of Game Reserve No. 2 was deproclaimed in the 1960s (section 1.2), wildlife in this area was nearly decimated by poaching gangs, colonial officials, contractors, and local people newly armed in Namibia's war of liberation.[60]

Table 2.4 A sample of Namibian species of economic value

Species or group	Description/ source of value	Conservation threats
Gracilaria	Red marine alga, mariculture	
Terfezia pfeilii	Truffle-like fungus	Harvesting sustainability unknown
Termitomyces schimperi	Large delicious mushroom, symbiotic with termites	Harvested on small scale (subsistence and commercial)
Harpagophytum procumbens	Kalahari medicinal plant	Threatened by overexploitation
Pterocarpus angolensis	Subtropical tree used for carvings and furniture	Threatened by overexploitation
Cucurbitaceae	Melons, agricultural potential	Unknown
Sclerocarya birrea	Subtropical fruit tree with diverse subsistence values	Often protected informally
Cleome spp.	'Wild spinach,' subsistence use	Unknown
Lepidoptera	Butterflies collected and traded	Some threatened by overexploitation?
Mantica horni, Mantichora spp.	Rare collectors' insects	Threatened by overexploitation?
Imbrasia belina	Mopane caterpillars	Threatened by overexploitation?
Usta wallengreni	Mopane caterpillars	Threatened by overexploitation?
Termites	Some destroy grazing	Unknown
Locusts	Some are crop pests	
Mosquitoes	Some are disease vectors	
Alien invasive insects	Livestock pests or crop pathogens	
Macrobrachium vollenhoveni	Edible freshwater shrimp	Threatened by Epupa Dam
Mutella dubia	Edible freshwater mussel	Unknown, harvested for subsistence
Bulinus globosus	Human schistosome vector	
Bulinus tropicus	Livestock paramphistome vector	
Biomphalaria pfeifferi	Human schistosome vector	
Lymnaea natalensis	Livestock liverfluke vector	
Chaceon maritae	Deep-sea crab, harvested	
Jasus lalandii	Spiny rock lobster, harvested	
Sardinops ocellatus	Pilchard, harvested	Past bottlenecks via overharvesting
Engraulis capensis	Anchovy, harvested	
Pyxicephalus adspersus	Bullfrog, subsistence use	Threatened by overexploitation?
Tortoises, six species	Subsistence use, pet trade	Threatened by overexploitation/ trade
Python anchietae	Dwarf python, pet trade	Threatened by illegal trade
Bitis spp.	Dwarf adders, pet trade	Threatened by illegal trade
Francolins	Gamebirds, harvested	
Quelea quelea	Major pest bird on crops	
Arctocephalus pusillus	Cape fur seal, harvested	
Manis temminckii	Cape pangolin, medicinal trade	Threatened by illegal trade
Diceros bicornis	Black rhino, horn trade	Threatened by illegal trade
Loxodonta africana	African elephant, ivory trade	Secure in southern Africa

Box 2.6 Rhino management in Namibia : countering a 'total onslaught'

Namibia has invested substantial public and private funds in several pioneering rhino management strategies (see also Box 4.12). These include:

- *'community game guards,' patrol units controlled by rural communities with donor funding as part of a broader community-based conservation and tourism approach;[61]*
- *the Wildlife Protection Service (WPS), an anti-poaching patrol unit of the Ministry of Environment and Tourism;*
- *a custodianship programme, in which rhinos are 'loaned out' to well-guarded private farms meeting stringent requirements; and*
- *dehorning of rhinos as a deterrent to poachers.[62]*

Dehorning has been through an experimental and controversial period in Namibia.[62-68] Since the start of dehorning there has been less poaching, but Namibia is still evaluating the dehorning programme in light of potential side effects, poaching of hornless animals elsewhere in southern Africa, and financial costs.

The community game guard programme, which provides incentives for local people to manage rhinos and other wildlife for longterm benefit, has been highly successful.

From 1967 to 1977, 68 rhinos were moved from the Kaokoveld to augment a small population of about 150 inside the Etosha National Park, now totalling 480 rhinos. A group of 27 rhinos was moved in 1989 to the Waterberg Plateau Park from Etosha and the former Damaraland (Erongo and southern Kunene Regions). After about seven initial translocation mortalities, this growing population currently numbers 28. Forty-two Etosha rhinos have also been translocated onto private farmland since 1993 as part of a custodianship programme (Box 2.6); these have increased to 48 animals. Finally, 11 rhinos have been moved to smaller parks and sanctuaries since 1989, and losses to disease and other natural causes have been balanced by calving rates (Fig. 2.25).

The serious threats faced by rhinos in Africa leave management authorities little room for error. While current management tactics such as anti-poaching patrols, translocation, and custodianship (Box 2.6) are designed largely to counter the immediate threats, they are only the first phase of a conservation strategy involving close monitoring, intensive management and husbandry which is necessary to ensure the long term viability of rhino populations under changed circumstances. The Namibian Government has three long term goals: 1) to increase the national black rhino population to 2000 animals, 2) to develop and institute a national rhino conservation plan, and 3) to introduce a sustainable use scheme. New and innovative conservation measures, possibly including the legal trade of horn, need to be investigated to enable the recovery of rhinos in Namibia and elsewhere.

-- H-O Reuter & Phoebe Barnard

Fig. 2.25 Female rhino and calf. Courtesy H-O Reuter

Fig. 2.26 Courtesy P Tarr

Cheetahs: a Namibian stronghold

Cheetahs, *Acinonyx jubatus*, have declined or become extinct due to habitat degradation and human pressure in much of their former range, including north Africa and southwest Asia. The Cat Specialist Group of the IUCN Species Survival Commission (IUCN/SSC) ranks cheetahs among the more vulnerable felids in sub-Saharan Africa.[69] Yet large populations remain in east and southern Africa. Namibia holds a substantial number of cheetahs, perhaps the largest population of any single country. The IUCN/SSC and MET have just produced the only national cheetah conservation plan in the species' range.[70] The relatively high cheetah population is reflected in an annual non-commercial export quota of 150 live cheetahs or trophies. This contrasts with five in Botswana and 50 in Zimbabwe, the only other countries in which cheetahs are legally exported.[71]

Cheetahs have fared surprisingly well on ranches and pastoral lands in east and southern Africa[70,72] (Fig. 2.26). In Namibia the vast majority are thought to live on commercial farmland, mainly in the north-central areas.[70,73] Most other large predators, such as lions *Panthera leo*, leopards *P. pardus*, and hyaenas *Crocuta crocuta* and *Hyaena brunnea*, have been extirpated from farms. Commercial farmers are allowed to kill cheetahs which threaten their livestock, and this is the greatest limiting factor to cheetah populations. Livestock farmers have traditionally regarded cheetahs as pests and frequently trapped and shot them. This perception remains today, but is changing in some areas due to the public relations efforts of two Namibian-based NGOs, the Cheetah Conservation Fund (CCF) and AfriCat.

Before the colonial era, Namibia was a much more transitory place for wildlife, with vast seasonal migrations of springbok *Antidorcas marsupialis* which were a major prey item of cheetahs. Conversion of land to commercial agriculture brought boreholes, fences, large herds of cattle, sheep and goats, and guns.[70] This land conversion decimated the springbok populations through fragmentation, restriction from their habitual range, and culling by farmers: springbok were not only eaten, but killed as perceived competitors of sheep. It also may have reduced cheetah numbers directly from persecution and habitat alteration via overgrazing, fire control, and bush encroachment.[70]

Seventy years ago, an indirect survey of large predators (Table 2.5) estimated that 3010 cheetahs occurred in Namibia.[74] This was based on magistrates' discussions with farmers and policemen, and is probably very unreliable. However, it does suggest that cheetahs have been more widespread than lions and hyaenas throughout this century.

More recent cheetah population estimates vary widely, with little agreement about the direction of longterm trends. Joubert and Mostert[75] reported two estimates: 6252 cheetahs on commercial farmland from replies to a questionnaire, and 5000 cheetahs nationwide in a second estimate by the Directorate of Nature Conservation, precursor of the MET. These data suggested a cheetah density of roughly one per 100 km^2 over about two thirds of the country.[70] Joubert & Mostert[75] and Gaerdes[76] felt cheetah numbers to be on the increase, as lions and hyaenas disappeared and kudus *Tragelaphus strepsiceros*, an alternative prey species, grew common. At the same time, however, a pan-African survey[77] put the population at only around 1500 - 3000. This report proposed that Namibian cheetahs were in decline due to the live animal trade, and predicted their extinction on Namibian farms by 1980.

A decade later, Morsbach[73] used field data, based on radio telemetry, to estimate 2000 - 3000 cheetahs nationwide, or one resident adult per 50 km² in optimal habitat in the north-central farmlands. While Joubert *et al.*[78] had reported 'healthy, and probably increasing, populations on farms,' Morsbach felt that record levels of persecution by farmers and the decimation of kudus by a rabies epidemic were harming cheetah populations. He noted the folly of trying to estimate numbers without basic data on population structure.

The most recent (1992) MET farm survey estimates about 2350 adult cheetahs, an apparent decline of 25% from 1972.[70] If judged by the percentage of farmers reporting cheetah presence, rather than estimates of numbers, there has been about a 10% decline since 1982.

Less is known of cheetah densities in protected areas. For Etosha National Park, a report in preparation has analysed preliminary data gathered as part of the predator-prey study of Gasaway *et al.*[79] to yield a density estimate of one cheetah per 80 km² on the short-grass plains south and east of Etosha Pan.[70] In the broadleaved woodland of Khaudum Game Reserve, Stander *et al.*[80] used transect spoor counts to estimate an extremely low density of one cheetah per 1666 km² (0.05-0.07 per 100 km²). Outside the reserve, density was twice this estimate (one per 833 km²). Khaudum contains similar small antelope densities to Etosha or just outside Khaudum, but also numerous lions (1.2 - 1.7 per 100 km²), hyaenas (1.6 - 2.3 per 100 km²) and leopards which may discourage cheetahs from setting up territories.[70]

Overall, habitat changes in Namibia may have favoured cheetahs, despite their persecution by commercial farmers.[70] Two popular beliefs about cheetahs are that they have benefited during the 20th century by the eradication of direct competitors such as lions and hyaenas, and that bush encroachment has hampered their hunting ability. Both of these are countered by a wide review of game surveys and ecological studies.[70] Rather, lions and hyaenas have probably always been fairly rare in Namibia due to the lack of surface water. Bush encroachment has favoured kudus, and probably aids rather than hinders the cheetah's hunting success. Nowell[70] models the past dynamics of the cheetah population based on past removal rates by farmers, and concludes that the current population in Namibia is between 2000 and 3000 adults and sub-adults. This population fluctuates with changes in its ungulate prey base caused by drought and disease. When fewer game are available, cheetahs probably take more livestock, leading to increased retaliation by farmers until game species recover. Due to their large litter size and the lack of competing large predators which might otherwise kill cubs, Namibian cheetahs can potentially recover quickly from a decline.[70,81] They are increasingly trapped for live export for reintroduction to reserves elsewhere in southern Africa, as a result of efforts by the Cheetah Conservation Fund and AfriCat to reduce conflict with farmers. This could bring significant revenue directly to Namibian farmers, and not just to game dealers.[70]

— Phoebe Barnard

Fig. 2.27 Bush encroachment in Namibia has probably favoured kudus, a prey species of cheetahs. Courtesy P Tarr

Wild dogs: everywhere on the run

Wild dogs or African hunting dogs, *Lycaon pictus* (Fig. 2.27), are under pressure everywhere on the African continent and have been eliminated from large areas of their former range.[82,83] Outside southern Africa, small and probably non-viable relict populations occur still in the wooded savanna zones of sub-Saharan Africa. In the Serengeti, which should have been one of the best protected areas for wild dogs, they have been drastically reduced in the past 100 years by a combination of human encroachment and diseases carried by domestic dogs.[83]

In Namibia, large parts of the country are widely thought to be too arid for wild dogs. However, since their range in the 17th and 18th centuries included southwestern and northern parts of the Cape Province in the Nama-Karoo biome,[82] this was probably not always the case. A canid jaw recovered in 1995 from a recently-exposed peat bank at Sandwich Harbour, south of Walvis Bay, is almost certainly of a wild dog,[84] suggesting that they may have ranged opportunistically and widely along the riparian and coastal zones of the hyper-arid Namib Desert.

The 1926 magisterial survey of large predators (Table 2.5) generated estimates for wild dog populations by district. These are highly unreliable, and probably reflect public loathing and fear of wild dogs, especially in the farming communities. In the district of Outjo, for example, an estimate of 8000 dogs was reported, which is surely exaggerated by at least an order of magnitude. However, even inaccurate figures suggest that wild dogs seventy years ago were much more widespread than today.

Today, wild dogs are endangered in Namibia, as in other areas, but their numbers appear stable in a 61 100 km^2 area in northern Namibia, of which 3842 km^2 is protected.[80] There are somewhere between 242 and 1235 individuals in Khaudum Game Reserve, eastern Otjozondjupa and eastern Omaheke Regions,[80] with minimum home ranges of three packs estimated at 1756, 1342 and 789 km^2 and an overall density of 0.61 - 3.1 animals per 100 km^2.[80] In addition to these areas, wild dogs range infrequently across Okavango, former Owambo[85] and Caprivi. As packs cross routinely into adjacent Botswana, and possibly Zambia and Angola, protection is difficult without regional committment. In Namibia, the much reduced present range of wild dogs unfortunately corresponds closely with land earmarked for resettlement by Herero cattle farmers, many of whom hunt wild dogs with their domestic dogs at heel.[86]

Table 2.5 Estimated numbers of cheetahs and wild dogs in Namibia, 1926[74]

District	Cheetahs	Wild dogs
Aroab	60	0
Bethanie	50	300
Gibeon	200	500
Gobabis	500	1500
Grootfontein	no data	no data
Karibib	no data	100
Keetmanshoop	100	32
Lüderitz	no data	0
Maltahöhe	no data	50
Okahandja	200	400
Omaruru	20	400
Otjiwarongo	800	520
Outjo	no data	8000
Ovamboland	80	200
Swakopmund	no data	0
Warmbad	no data	0
Windhoek	100	50
Namutoni/Etosha	900	2000
Total	3010	14 052

Due to their susceptibility to canine distemper, adenovirus and parainfluenza virus,[87,88] all of which are present in sympatric domestic dogs, wild dogs are unlikely to persist in Namibia in any form of multiple-use protected area that allows contact with humans, their vehicles, or domestic dogs. Once introduced into a pack, these viruses can attack all individuals rapidly through the elaborate greeting rituals which involve mutual licking and grooming.[87] Establishment of some form of large core wilderness area for wild dogs and other sensitive species is an urgent conservation priority.

— Phoebe Barnard & Flip Stander

Flamingos: declining in southern Africa

Flamingos are among the most specialised and conspicuous of birds. Greater and lesser flamingos, *Phoenicopterus ruber* and *Phoeniconaias minor*, are long-lived waders which breed sporadically at only two main sites in southern Africa: Botswana's Makgadikgadi Pans and Namibia's Etosha National Park. There are occasional minor breeding attempts by lesser flamingos at sites such as South Africa's Lake St Lucia. On Etosha Pan, flamingos have experienced only four major breeding events in 40 years. Non-breeding or breeding failure often occurs because high evaporation rates rapidly dry the pan, and up to 100 000 flightless chicks may starve at such times. Flamingo pairs breeding in Etosha thus have extraordinarily low recruitment (0.040 young per pair per year), which by extrapolation suggests that if they bred solely at Etosha, they could replace themselves only by breeding for between 38 and 50 years with 100% offspring survival.[89] Actual chick survival from fledging to adulthood is about 46%, so Etosha flamingos would have to breed for an unrealistic 83 years[89] for Etosha to be a viable breeding site on its own. There are insufficient data for population viability assessment of any other flamingo breeding site in Africa.

Like many other wetland birds of arid regions, however, flamingos do not necessarily breed solely in one site, but shift opportunistically to alternative sites as these receive rainfall. Therefore, the non-viability of Etosha as a flamingo breeding site might not pose a problem if flamingos could breed successfully at other sites in the region. Unfortunately, alternative sites in Africa are increasingly under threat from soda ash mining (Lake Magadi, Lake Elementeita, Sua Pan) or potential damming (Lake Natron). Other than Etosha, only the small Lake Nakuru in Kenya falls within a protected area.

Estimates from both southern Africa and the continent as a whole suggest population declines of 20% - 40% in both species over the past 20 years (Table 2.6). The Namibian coast and inland pans regularly support 84% (40 000 of 47 000) of the southern African population of greater flamingos, and 85% (34 000 of 40 000) of southern African lesser flamingos.[90] Conservation efforts are thus best focused in Namibia.

To reverse poor breeding success, breeding islands with a moat deep enough to retain water for the three-month breeding season have been suggested as the only feasible solution.[89] The rearing of chicks abandoned in seasons of widespread breeding failure has again recently proven unsuccessful in terms of recruitment to future generations.[91] By contrast, schemes using artificial islands with moats to enhance breeding have been successful for over 15 years in the Camargue, southern France, a site which remains the only consistently active colony in Europe and north Africa. These methods should be tried in Namibia, either on minor pans of the Etosha system or in the already altered habitats of the coast.

Flamingos are partly victims of their own specialisation. Their population decline has, however, been exacerbated by long periods of low rainfall and habitat degradation at many of their breeding sites. Some form of active conservation management is necessary to reverse this decline.

— Rob Simmons

Table 2.6 Flamingo population declines in Africa

	1975	1995	% decline
Southern Africa			
lesser flamingo	55 000	40 000	27
greater flamingo	75 000	50 000	33
All Africa			
lesser flamingo	5 057 000	4 029 000	20
greater flamingo	165 000	85 000	48

Sources: Cooper & Hockey,[96] Kahl,[97] Dodman & Taylor[90]

Fig. 2.28 Flamingos at Sandwich Harbour. Courtesy P Tarr

Cape griffons: life on the edge

The Cape griffon (or Cape vulture) *Gyps coprotheres* is endemic to southern Africa. Once found soaring around Table Mountain, the species today has undergone a major range contraction and now has the smallest diistribution of any Old World vulture.[92] It nests on cliffs and travels long distances in search of carcasses. World population numbers are presently put at 4400 breeding pairs, up from a 1976 estimate of 2500 pairs and 10 000 individuals.

In Namibia, Cape griffons were seen commonly in the early 1970s in the Namib-Naukluft Park,[93] but are rarely seen there today. At least eight extinct colonies are known, mainly from the edge of the Namib Desert.[94] In their Namibian stronghold on the sandstone cliffs of the Waterberg Plateau Park, there were estimated to be 300 birds in 1969. In the next 16 years their numbers plummeted 95% to about 15 individuals and 3 nests.[94] In an effort to save this tiny colony a vulture restaurant was set up in the 1980s, providing at least one ungulate carcass per week.[95] This scheme slowed and began to reverse the rapid decline, but records and observations in 1995-97 show only five non-breeding adults.

Other, more subtle, factors seem to have contributed to the demise of the Cape griffon in Namibia. One of these is bush encroachment in the Waterberg area since the turn of the century. This appears to have greatly reduced the ability of vultures to find and use animal carcasses. Decimation of browsing ungulates through epidemics, such as the severe rinderpest outbreaks of 1897-1905,[98] can lead to the establishment of *Acacia* seedlings over vast grassland areas, slowly changing an open landscape to a bush encroached one.[99]

The decline of this vulture, a process perhaps started by landscape changes, has been rapidly hastened by indiscriminate poisoning. Persecution of vultures even within protected areas has continued[100] and the bird's survival into the next milennium, with less than 5% of its 1969 population, is thus more a matter of chance than certainty.

— *Rob Simmons*

2.6 Underprotected habitats

Namibia has a state-controlled protected area network of 21 proclaimed parks and reserves (Box 1.9, map 2.8), which make up about 13.8% of Namibia's land area. At first glance this is an impressive figure, which comfortably exceeds the 10% recommended by IUCN to be set aside for conservation. In addition to 10% of overall land area, it is Namibian government policy[101] that 10% of vegetation types, or 'all ecological regions and their major variations,' be explicitly represented in the protected area network.

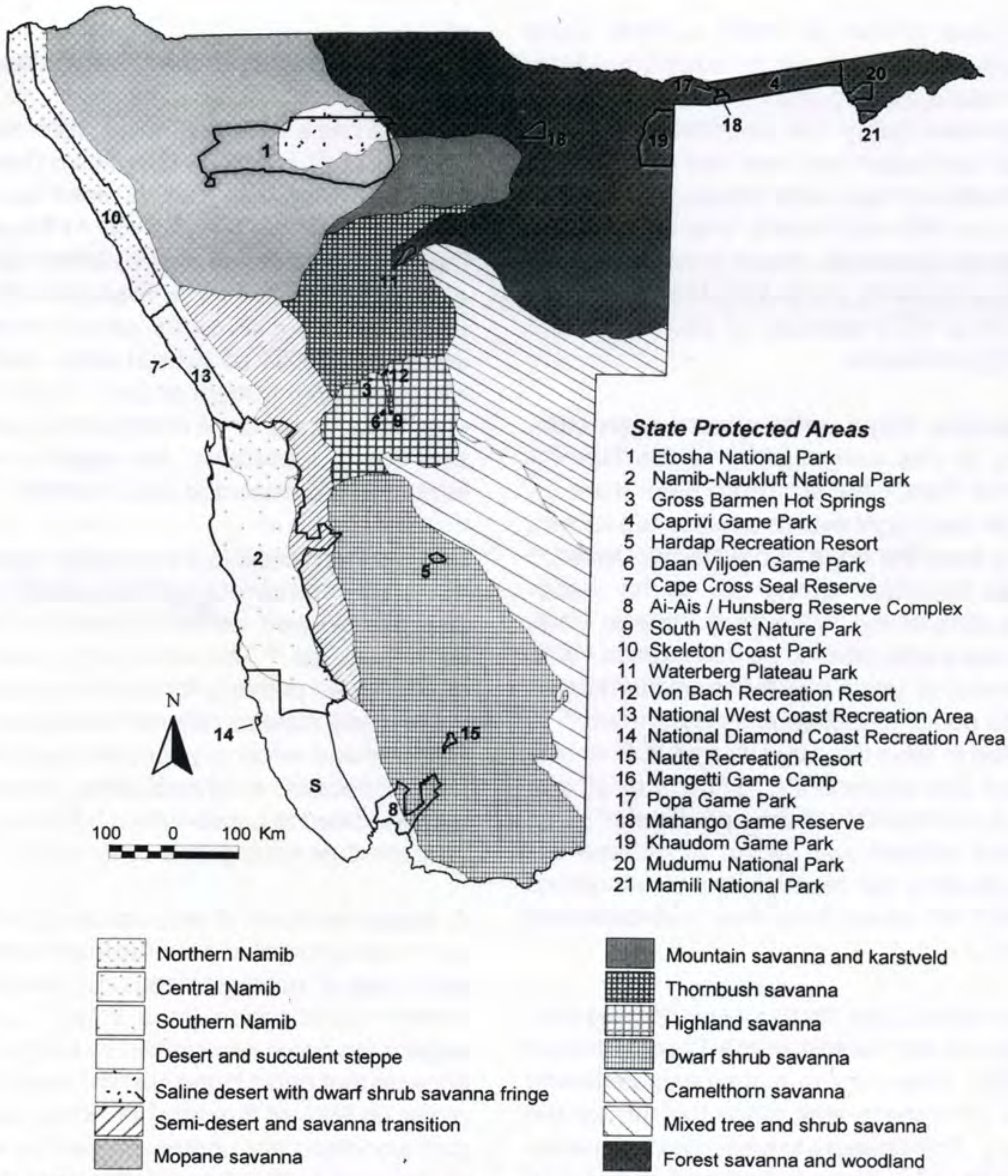
Despite this, Namibia's ecological diversity is not evenly represented in this network, which is highly skewed towards desert and saline desert habitats.[50] The early parks system was not designed primarily for biodiversity conservation, and instead reflects ideological, recreational and veterinary considerations of past administrations. In several cases, desert land was allocated to conservation because it was perceived as having little other value.

A recent analysis of ecological representation in the protected area network[50] relied on two levels of 'ecological regions:' the SABAP biome classification (map 2.1b)[6,7] and the vegetation types recognised by Giess.[5] This showed that parks in the Namib Desert biome make up 69% of the network, while savanna and woodland are underrepresented slightly (7.5% and 8.4% of respective land areas). The Karoo biome is badly underrepresented relative to the 10% target (1.6%)(Table 2.7).[50]

Table 2.7 Distribution of state protected areas in the four major biomes of Namibia[a]

Biome	Proportion of land area (%)	Total protected area (km^2)	Proportion of biome (%)	No. of protected areas per size category (km^2 x 100): < 1	1-10	10-200	>200
Woodland	17	11 766	8.4	1	3	3	0
Savanna	37	22 704	7.5	4	1	0	1
Namib	32	77 728	29.7	1	1	3	1
Karoo	14	1 882	1.6	0	2	0	0
Total/ mean	100	114 080	13.8	6	7	6	2

[a]*Major biomes as in Fig. 2.1b*[6,7]



Map 2.8 The Namibian state protected area network and the 14 major vegetation zones.[5] S = Sperrgebiet diamond mining concession, currently not part of the state network.[50]

At the finer scale of vegetation types, 4 of 14 desert vegetation types are comprehensively protected, with 67% to 94% representation in the protected area network, but six savanna types are virtually unrepresented (Fig. 2.30). Mountain Savanna, a unique vegetation type (Fig. 2.29), is wholly unprotected.[50] Thornbush Savanna, Highland Savanna, Dwarf Shrub Savanna, Camelthorn Savanna, and Mixed Tree and Shrub Savanna are all badly underrepresented, with 0-2% coverage in the protected area network (Fig. 2.30).

These vegetation types are purely terrestrial. Turning to wetlands, virtually all types summarised in Table 2.1 are underprotected. For example, our species-rich perennial rivers are restricted to our borders, where they are shared with neighbouring countries and in heavy demand for water abstraction.[33] They are thus in need of special conservation measures including stringent legal protection (Box 2.7), but are poorly protected in Namibian reserves (Table 2.8).[102] Ephemeral pans other than those in the Etosha system are underprotected, and ephemeral rivers need conservation attention in their upper and middle catchments, where human densities and resource demands are greatest.[10]

To what extent is the ecological skew in the state protected area network mitigated by other conservation approaches, such as conservancies, private nature reserves and game farms (section 1.2)? So far, these approaches appear to balance the state PAN reasonably well in terms of vegetation types.

The nine commercial conservancies established by late 1997 include those in the Highland Savanna (three conservancies), Thornbush Savanna (two), Forest Savanna and Woodland (one), Mountain Savanna and Karstveld (one), Mopane Savanna (one) and Camelthorn Savanna (one), with several conservancies overlapping adjacent vegetation types slightly[50] (map 1.8). These land units collectively account for more than 10 000 km^2 of farmland, and range in size from about 600 km^2 to 2 300 km^2. They will be mapped in the near future, allowing more precise analysis of ecological coverage.

Communal land conservancies also show excellent potential for balancing the state network. Of the five communal conservancies now at advanced stages of development, the 9 023 km^2 Nyae Nyae Conservancy (Tsumkwe District) in the Forest Savanna and Woodland vegetation type should be a valuable model of community management.[103] Other conservancies include a roughly 910 km^2 area joining Mudumu and Mamili National Parks in Caprivi.[50] Caprivi has extremely high overall species richness, and offers significant potential for a transboundary multiple-use protected area with parks in Angola, Botswana, Zambia and Zimbabwe.[38]

Several very large conservancies are forming in the former western (Kaoko) corridor of the old Game Reserve No. 2, now Kunene and Erongo Regions. These will stretch along the eastern border of the Skeleton Coast Park, covering Northern Namib, Central Namib and escarpment (Mopane Savanna) vegetation types.[50] Ultimately, about 50% of the land formerly occupied by Game Reserve No. 2 could again be protected in this way.[103] Not only will this provide communities with incentives to safeguard land with high conservation value, but it will also create a mosaic of formal and informal protected areas stretching to Angola's Iona National Park.

Box 2.7 Protection of riparian corridors

Not only are wetlands poorly represented in the state protected area network, legal provisions for safeguarding wetlands are weak and piecemeal. The only current legislation explicitly protecting riparian corridors in Namibia is a paragraph (14) in the Forestry Act of 1954 which makes it an offence to damage or remove any plant or part of a plant from a river or within 100 yards of a rivercourse without a permit from the landowner. This and related legislation is often disregarded and unenforced, and fines are not punitive. The MET's Wetland Policy promises protection of riparian zones in the future. Environmental legislation is currently under review (Chapter 5) and it is essential that protection of riparian corridors be included and enforced in both commercial and communal areas.

— Shirley Bethune

Fig. 2.29 Mountain Savanna is currently wholly unprotected by the Namibian parks system. Courtesy E Marais

Table 2.8 Lengths of Namibian perennial rivers and approximate lengths protected in reserves[102]

River	Length in Namibia (km)	Protected %
Kunene	340	12
Okavango	470	3
Kwando-Chobe	484	18
Zambezi	152	0
Total	2076	Mean 10.6

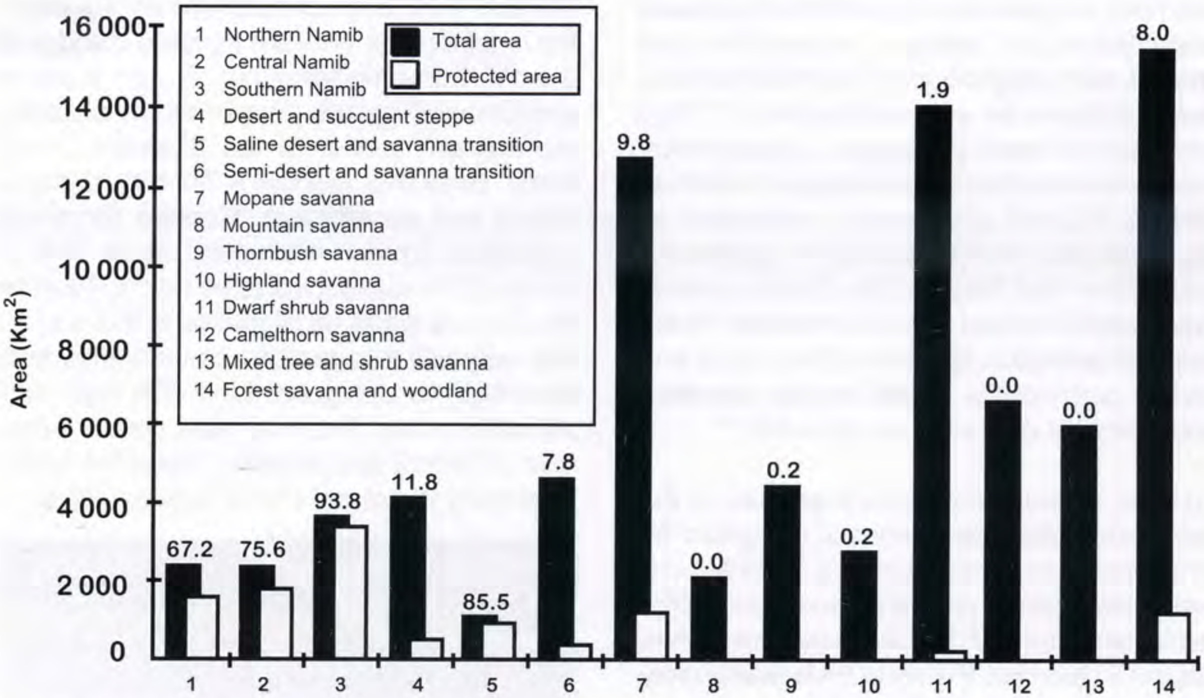


Fig. 2.30 Percent representation of the 14 major vegetation types[5] in Namibia as a whole (dark bars) and in state protected areas (white bars).[50] Numbers atop the bars are percentage representation in the protected area network.

Probably the most significant gaps in habitat protection are Namibia's two priority areas for endemism: the northern Namib (Kaoko) escarpment, along with the nearby inselbergs and granite domes of the Kunene and Erongo Regions, and the *Sperrgebiet* winter-rainfall region in the Desert and Succulent Steppe vegetation type.[49] The Kaoko escarpment forms an important regional centre of endemism. This escarpment, including the Brandberg massif and nearby inselbergs and granite domes, is the most important endemism hotspot for vertebrate taxa in both Namibia and Angola (maps 2.2-2.7).[49] For example, among the highest avian endemism in Namibia occurs locally within the Kaoko escarpment zone at the intersection of vegetation types containing rocky terrain, especially granite domes, and major river courses.[49,52] These habitats fall largely on private farmland, and deserve urgent action in cooperation with landowners to ensure longterm protection (Table 2.9).

The *Sperrgebiet* is part of the Southern Namib centre of endemism, abutting South Africa's floristically rich Richtersveld succulent steppe.[155] The 26 000 km^2 *Sperrgebiet* diamond mining area has been managed by multinational interests for most of this century (section 1.2). The concession agreement for this biotically valuable and endemics-rich area expires in about 2020, at which time the *Sperrgebiet* may be included in some form of biosphere reserve adjoining the Richtersveld National Park in South Africa.[50] Sections of this area have been abandoned by the concessionaire, but will remain under its protection until a land use plan is developed.

Optimal protection of the Kaoko and Southern Namib centres of endemism requires transboundary conservation, and indeed this has been discussed by all three countries for some years. If the Kaoko and *Sperrgebiet* regions can both be incorporated into some form of multiple-use park by Namibia (see Box 5.3), this would create an unparalleled multi-zoned conservation area stretching from Iona National Park in southern Angola to the Richtersveld National Park in South Africa. The ecological uniqueness and endemism of this landscape is extraordinary by regional and international standards (Fig. 2.31).

More localised centres of endemism which have been recently identified[49,102] include the extinct volcanic crater of Brukkaros and the karst caves and sinkholes of the Mountain Savanna vegetation type. Ephemeral pools and mineral springs, and 'islands' of dune, gravel plain, mountains and rocky hillsides in the Namib Desert habitat mosaic, are intrinsically valuable for endemics.[47,49]

Major regional river systems, such as the Okavango and Zambezi, contain numerous 'catchment endemics'[102] which need regional protection via established international committees.

Nearly 85% of Namibia's land is zoned for potential or actual agricultural use, so effective biodiversity protection also means working outside the formal protected area network to improve the sustainability and diversity of farming practices. Agricultural biodiversity planning is at a fairly early stage in Namibia, but a working group is now being established of specialists from the Biodiversity Task Force, others within the Ministry of Agriculture, Water and Rural Development, and NGOs to develop strategy and practical forms of implementation at the landscape, habitat, species and genetic diversity levels. Two important existing programmes in this context, the Sustainable Animal and Range Development Programme (SARDEP) and the Northern Regions Livestock Development Project (NOLIDEP), do not have an explicit biodiversity focus but work with farmers to improve the overall sustainability of rangeland management. A key institute at the genetic diversity level is the National Plant Genetic Resources Centre (below), housed in the agriculture ministry.
— *Phoebe Barnard*

Fig. 2.31 The northern, Kaoko section of the Namib escarpment is one of Namibia's top priorities for conservation protection. Courtesy R Simmons

Fig. 2.32 The Caprivi Region offers valuable opportunities for regional consolidation of transboundary multiple-use or 'people's parks'. Courtesy LC Weaver

Table 2.9 Summary of top priorities for additional terrestrial and freshwater conservation protection in Namibia[50]

Region or locality	Vegetation zones	Suggested approach/ comments*
Kaoko escarpment, Brandberg and nearby inselbergs and domes	Mopane Savanna, Semi-Desert and Savanna Transition	Transboundary multiple use park with conservancy zones linking Skeleton Coast, Etosha and Iona (Angola) National Parks. Would protect important ephemeral river and inselberg habitats. Top endemism zone; also region of appropriate traditional land management.
Sperrgebiet	Desert and Succulent Steppe	Transboundary national park linking Namib-Naukluft Park and Richtersveld (South Africa) National Park. Top richness and endemism zone.
Caprivi woodlands, river floodplains and riparian vegetation	Forest Savanna and Woodland	Transboundary 'people's park' or multiple use park Mahango Game Reserve, Caprivi Game Park, Chobe National Park (Botswana) and Okavango Delta (Botswana) with conservancies in Caprivi. High richness zone, many red data species, some endemics.
Otavi Mountains	Mountain Savanna and Karstveld	Multiple sites of interest or strictly protected area to supplement existing conservancy, protecting karst sinkhole and cave endemics and sites of botanical importance. High richness and endemism zone.
Brukkaros Crater	Dwarf Shrub Savanna	Communal conservancy / site of interest for endemic species and geological history.
To be identified	Thornbush Savanna Highland Savanna Camelthorn Savanna Mixed Tree and Shrub Savanna	Commercial and communal conservancies, sites of interest or private parks (*e.g.* Arnhem Cave) or multiple use parks. Savanna types important for supporting agriculture and other land uses, currently virtually unprotected

** Comments on protection strategy refer to protected area categories in draft legislation (Chapter 5, Box 5.3) as well as to conservancies. Reference should also be made to Tables 2.2 and 2.3 for additional categories and sites of ecological and archaeological importance.*

2.7 *Ex situ* conservation facilities

Botanical facilities

Ex situ conservation of plants and their genetic material is relatively new to Namibia. After Independence in 1990, the country joined the Southern African Development Community (SADC), and a National Plant Genetic Resources Programme was initiated as part of the regional SADC Plant Genetic Resources Centre (SPGRC) Project. The value and development of indigenous plant genetic material had received little attention in Namibia before then. National capacity is developing slowly, since most infrastructure and expertise must be newly developed.

The National Plant Genetic Resources Centre

The SPGRC project aims to conserve all plant genetic resources in the region and promote their use. The project was started because the threat of genetic erosion in the region was believed to be growing.[104]

Under this project a National Plant Genetic Resources Centre (NPGRC) was established in the Ministry of Agriculture, Water and Rural Development (MAWRD) as a section of the National Botanical Research Institute (NBRI) in Windhoek. The Namibian Government built a new complex, completed in 1992, to house the NPGRC. Its facilities comprise an office, documentation room, seed threshing room, laboratory, deep-freezer room, and walk-in cold room, with other facilities shared with the rest of the NBRI. Essential equipment is linked to a stand-by power supply.

Important equipment was provided to the NPGRC through an agreement between SPGRC and the Swedish International Development Authority (SIDA), but running costs are met by the MAWRD. Specific projects may be funded through the SPGRC project, which in turn is funded by the five Nordic countries. Since 1994, SPGRC is also supported by contributions from SADC member states, which must assume full financial responsibility for the project in 2005.

A curator was trained under the SPGRC project to MSc level and began work in 1993. Overall, five staff positions (two researchers, two technicians and one assistant) have been allocated by MAWRD to the NPGRC. By 1997, only one researcher, a technician and an assistant had been employed.

At present, the NPGRC's storage capacity is almost filled. Storage space for the project will double, however, and the remaining 50% of capacity should take an estimated three years to fill. Currently all germplasm is accepted for storage. Once a basic collection of important germplasm has been stored, the NPGRC will be more selective. In future, only local germplasm accompanied by sufficient passport information will be stored.

The collection so far contains only Namibian material, both wild species and crops. There are over 1900 accessions, of which over half (53%) are of pearl millet, the main crop in Namibia, mostly collected by ICRISAT in 1991. Most accessions of wild species are of indigenous Cucurbitaceae. The majority of accessions are duplicated at the SPGRC regional centre in Lusaka, Zambia. As the collection is still very young, it does not yet represent the country's diversity. The millet collection is relatively representative, but by no means complete. Many accessions also need to be multiplied or regenerated, and most other species are poorly or not at all represented. Managing the collection is a problem due to staff shortages, but this situation should improve with the help of staff in other sections of the MAWRD.

Namibian material is collected according to a priority list identified by the NPGR Committee (Appendix 3). This lists wild and cultivated species considered to be of great value or in danger of genetic erosion. Collection is done by the NPGRC or the National Herbarium of the NBRI. Collecting missions of foreign institutes in Namibia are obliged to deposit a subsample of each collection at the NPGRC; in the past five years six such collections have been received. Collecting missions for specific crops are carried out according to the needs of agronomists, who meet once a month to advise the NPGRC.

Random sampling is used wherever possible for both crops and wild species. General collecting of wild species is mainly opportunistic according to rainfall, and planning has recently been aided by the use of Vegetation Index Maps generated with NOAA satellite data.[105]

Almost all material from wild species in the collection is collected at the request of foreign taxonomists. The NPGRC receives very few requests for wild material to be used in breeding projects or evaluation of agricultural potential. Locally, germplasm is used by MAWRD scientists for the Sorghum and Pearl Millet Improvement Programme and research on the potential of indigenous cucurbits.

Fig. 2.33 *Citrillus lanatus* seed diversity in Namibia. Courtesy C Mannheimer

The NPGRC collection database is entered into DBase IV, which is used by all NPGRCs in SADC to facilitate data exchange, and backups are sent annually to the regional SPGRC facility. The PRECIS Specimen Database, developed by the South African National Botanical Institute in Pretoria, was implemented at the National Herbarium in 1996, and will facilitate both *in situ* and *ex situ* conservation activities considerably.

The NPGRC tries to use crop experts to carry out seed characterization and evaluations, due to staff shortages. When supplying seed, the NPGRC has a contractual requirement that information obtained using the seed must be fed back to the NPGRC. As there is so far no legislation backing up this request, one-time users of the NPGRC can get away with not responding. Users requesting seed again receive it only if feedback on previous requests was obtained. Legislation to back up these agreements is in preparation.

The NPGRC intends to regenerate material once the viability of the seed falls below 85% for crop species or 65% for wild species. Once crop accessions have been tested for viability, multiplication and regeneration will be done in collaboration with SPGRC or the MAWRD Subdivision of Agronomy.

Other botanical facilities

At present no arboreta, field genebanks or botanic gardens are involved in *ex situ* conservation in Namibia. Land for a small (11 ha) botanical garden in Windhoek is being developed by the NBRI and Ministry of Environment & Tourism as personnel and financial circumstances allow. This will complement conservation activities, mainly by raising public awareness. The MAWRD's Namibia Root Crops Research Project plans to establish field genebanks for cassava *Manihot esculenta* and sweet potato *Ipomoea batatas* at Bagani. Both locally available germplasm and material from the SADC region will be held there.

Genetic resources of indigenous trees are being developed by the Tree Seed Centre Network, a joint project of the MET's Directorate of Forestry, the Southern African Development Community (SADC) and the Canadian International Development Agency. This project collects, tests, stores and regenerates seed from economically valuable indigenous tree species in Namibia, as part of a regional programme.[106]

Finally, international herbaria with holdings of Namibian plant specimens have been summarised in Appendix 4.

— *Herta Kolberg*

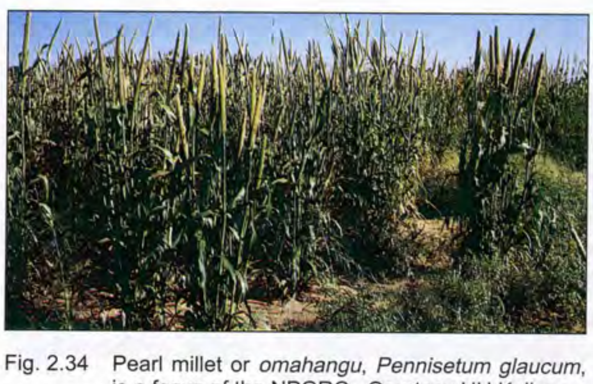


Fig. 2.34 Pearl millet or *omahangu, Pennisetum glaucum*, is a focus of the NPGRC. Courtesy HH Kolberg

Animal facilities

Genetic material and traditionally preserved specimens are held at the National Museum of Namibia, which maintains significant collections of many animal groups in addition to cultural, archaeological and historical material. Some of the major collections, breeding facilities and other *ex situ* conservation facilities are outlined below. Namibia has no substantial facilities for the *ex situ* conservation of any live animal species for captive breeding purposes.

Invertebrates

The most comprehensive *ex situ* facility for any invertebrate group is the Namibian National Insect Collection (NNIC) at the National Museum of Namibia. The NNIC maintains a core collection of *ca.* 500 000 specimens, and 250 000 - 500 000 additional specimens. This includes representatives of all orders and most families recorded from Namibia, though ectoparasitic fauna are poorly represented. About 50% of the collection is identified to genus, and 20-40% to species. Species identifications are usually identified by an acknowledged systematist working on the taxon. Most identified specimens are beetles (Coleoptera), which also make up about 60% of the collections.

The NNIC is actively promoted abroad, and *ca.* 40 000 specimens from ten orders are presently on loan to researchers worldwide. A core library of entomological information is maintained, and an on-line information service on Namibian insect diversity, taxon holdings, and geographical coverage is being developed. An active, goal-oriented programme to extend the scope and coverage of entomological diversity is pursued, and where possible other expertise and institutions are involved in programmes. Researchers are encouraged to deposit voucher material from Namibia in the NNIC, particularly taxa new to science, to promote local reference and information sources.

Important *ex situ* sources of Namibian insect material are listed in Table 2.10. Most comprehensive and specialized collections contain some representative material from Namibia. "Important" is a value judgement based on criteria, such as geographical and taxon coverage of Namibia, historical importance, information accessibility, number of specimens and number of type specimens.

At present there is no known live *ex situ* facility for indigenous insects, though small, temporary facilities are sometimes kept for research or public education at the Desert Ecological Research Unit (DERU) at Gobabeb in the central Namib Desert. One captive breeding facility exists for an alien insect used in biological control of an aquatic weed (Box 2.8).

Other than insects, the National Museum of Namibia holds substantial collections of other invertebrates, especially arachnids, some myriapods (Table 2.11), and aquatic invertebrates. There are *ca.* 23 000 aquatic specimens representing 12 phyla, 39 orders, 497 families and 992 species. All these collections, plus those of three vertebrate classes, have been managed by a single curator. Many groups are well known, but it is difficult even to estimate how fully some collections reflect Namibian diversity.

— Eugéne Marais & Eryn Griffin

Box 2.8 A facility for biological control

A biological control agent breeding facility in Katima Mulilo was set up by the Department of Water Affairs (DWA) of the MAWRD. The DWA took responsibility in 1980 for controlling infestations of Kariba weed Salvinia molesta *in the eastern Caprivi wetlands. After two years of research, DWA decided to use a host-specific alien weevil,* Cyrtobagous salviniae, *for biological control, given the ecological sensitivity and inaccessibility of many wetlands. The first 500 weevils were imported from CSIRO in Australia in 1983, and a second batch was imported when the first was unsuccessful. Since then, insects have been successfully bred for regular release at all infestation sites, and are regularly monitored. Kariba weed is now under control, and healthy populations of weevils exist which remain dependent on the host plant for breeding and larval development.*

— Shirley Bethune

Table 2.10 Important museums holding Namibian insect specimens

Institution	City	Namibian specimens	Notes
National Museum of Namibia	Windhoek	*ca.* 500 000	Comprehensive in-country repository
Transvaal Museum	Pretoria	*ca.* 250 000	Coleoptera, Lepidoptera
Museum für Naturkunde	Berlin	*ca.* 180 000	Comprehensive historical (1900's) & recent
National Collection of Insects	Pretoria	*ca.* 120 000	Isoptera, Orthoptera, Neuroptera, Hymenoptera
Lund University	Lund	*ca.* 20 000	Important comprehensive historical (1950's)
South African Museum	Cape Town	*ca.* 30 000	Important historical (1920-40)
Nasionale Museum	Bloemfontein	*ca.* 40 000	Important comparative collection
Natal Museum	Pietermaritzburg	*ca.* 15 000	Diptera
Medical Research Institute	Johannesburg	*ca.* 10 000	Ectoparasites & medical problem groups
Albany Museum	Grahamstown	*ca.* 15 000	Aquatic fauna
Riksmuseet	Stockholm	*ca.* 5 000	Important historical (1850-1880)
Veterinary Research Institute	Pretoria	*ca.* 5 000	Veterinary problem groups
California Academy Sciences*	San Francisco	*ca.* 40 000	Embiidina, Hymenoptera
Alexander König	Bonn	*ca.* 60 000	Reference collection in Germany
British Museum (Nat. Hist.)	London	*ca.* 60 000	Reference collection in U.K.
Los Angeles County Museum	Los Angeles	*ca.* 60 000	Value status unclear

Note: Ex situ Namibian material in the large USA collections is presently not clear. Listed institutions are known to have collected extensively in Namibia, holdings are approximated. Source: Eugéne Marais

Table 2.11 Arachnid and myriapod specimens in the National Museum of Namibia

Arachnid order	No. of specimens	Myriapod order[a]	No. of specimens
Spiders	80 000	Earth centipedes	100
Solifuges	20 000	Large centipedes	370
Scorpions	4 500	Stone centipedes	120
Pseudoscorpions	1 200	Shield centipedes	—
Opiliones	40	Pill millipedes	—
Amblypygi	40	Pincushion millipedes	110
Mites and ticks	8 000	Worm-like millipedes	—
		Keeled millipedes	—

[a]*Common names of taxa following Lawrence.*[107] *Source: Eryn Griffin*

Fig. 2.35 Mathilda Awases at the Namibian National Insect Collection. Courtesy E Marais

Vertebrates

The National Museum of Namibia houses the largest and most extensive collections of Namibian vertebrates, including *ca.* 17 000 mammal, *ca.* 10 500 bird, *ca.* 7500 reptile, 6000 fish and 900 amphibian specimens (Table 2.12). During colonial times, foreign museums gathered and exported extensive specimen collections. Chief among these are the British Museum (Natural History), Transvaal Museum, Los Angeles County Museum, Field Museum of Natural History, Carnegie

Museum, United States National Museum, Museum of Vertebrate Zoology, California Academy of Sciences, Berlin Natural History Museum of Humboldt University, Vienna Natural History Museum, and the Alexander König Museum, Bonn. Altogether about 45 foreign museums have Namibian material, and we estimate that roughly 40 000 mammal, 30 000 reptile, 2500 amphibian and 24 700 bird specimens are available worldwide for study. Table 2.14 indicates the approximate holdings of bird collections from Namibia.

Animal genetic material, chiefly blood and skin tissue, has been collected from Namibia only rather recently. Most of these fairly small collections, which are mainly from vertebrates, are listed in Table 2.13.

Table 2.12 Vertebrate specimens in the National Museum of Namibia

Order	Approx. no. of specimens
Reptiles	
Turtles	50
Snakes	1410
Lizards	6010
Crocodiles	—
Amphibians	
Amphisbaen	79
Frogs	900
Fish	
Bony fish	6000
Sharks	22
Birds	
All birds	10 500

Sources: Eryn Griffin, Chris Brown

The MET occasionally supplies red data species to adjacent countries for restocking purposes. For example, black rhinos of the subspecies *bicornis* have been supplied to South African parks elsewhere in their former range. When political stability returns to Angola, Namibia is likely to be involved in restocking animals there, as the original Angolan populations were genetically closest to Namibian stock.

Local and international NGOs can potentially play a major role in *ex situ* conservation in Namibia. As an example, the Cheetah Conservation Fund, based near Otjiwarongo, maintains a cheetah tissue sample database and keeps the international cheetah studbook (a register of zoo animals and their reproduction). It also facilitates the introduction to zoo gene pools of new genetic stock from the wild, usually in the form of 'problem animals' from Namibian commercial farms, in addition to its *in situ* conservation efforts (section 2.5).[108]

Table 2.13 Animal tissue collections from Namibia[1]

Institution	Type of material
Namibia	
National Museum	B,M,H, I
Central Veterinary Laboratory	M, Micro
MET	M, H
MAWRD	M, Invert
MFMR	F, Invert
MHSS	M (human)
Regional	
South African Museum	B, M, H
Transvaal Museum	B, M, H
University of Cape Town	B, M
University of Stellenbosch	B, M, H
University of Witwatersrand	B, M, H
University of Pretoria	M
Europe and North America	
University of Copenhagen	B, M, H, I
Université de Paris	B, M
Edinburgh University	B
Stirling University	B
Yale University	B, M
British Museum (Nat. Hist.)	B, M, I
Alexander König Museum	M, H

[1] B = birds; M = mammals; H = herpetiles (reptiles, amphibians); I = insects; Invert = other invertebrates; Micro = microorganisms. Includes only tissue collected explicitly for genetic use. Source: Joris Komen

Finally, the captive breeding of Namibian dwarf pythons *Python anchietae* (Fig. 2.36) at the Transvaal Snake Park, South Africa, is part of a cooperative programme with the MET. Its aims are to gather breeding data for this threatened species, as well as to produce progeny for reintroduction to the wild and for educational and scientific uses.

— Mike Griffin

Fig. 2.36 Dwarf python. Courtesy M Griffin

Table 2.14 Important museums holding Namibian bird specimens

Institution	City	Namibian specimens
National Museum of Namibia	Windhoek	10 500
Transvaal Museum	Pretoria	3 766
Durban Natural Science Museum	Durban	2 060
British Museum (Natural History)	Tring	1 832
South African Museum	Cape Town	1 295
Zoologisches Forschnungsinstitut und Museum Alexander König	Bonn	1 275
Los Angeles County Natural History Museum	Los Angeles	875
Älvsborgs Länsmuseum	Vänersborg	751
Cornell University Vertebrate Collection	Ithaca	748
Museum für Naturkunde der Humboldt-Universität	Berlin	571
Peabody Museum, Yale University	New Haven	498
Zoology Museum, University of Michigan	Ann Arbor	402
National Museum of Natural History, Smithsonian Institution	Washington	104
Albany Museum	Grahamstown	35
Koninklijk Museum voor Midden-Afrika	Tervuren	3
Florida Museum of Natural History	Gainesville	3
Total		24 718

Source: Chris Brown

Domesticated animals

The MAWRD conducts research related to the conservation of genetic material of both small and large livestock.[109] Three projects involve small stock, specifically indigenous goats, Damara sheep, and Karakul sheep.

The first two projects aim to conserve and characterise the gene pool of indigenous small stock. In the goat project, about 110 animals are kept at Uitkomst Research Station for blood typing to determine their relationships and origin. If necessary, this stock could be improved and distributed to farmers for upgrading of their herds. A Damara sheep herd has been at Omatjenne Research Station since 1951, and presently numbers about 700 animals. Research on this herd has been completed and the herd will be maintained to conserve its gene pool. The herd has been improved through selective breeding. At Gellap-Ost Research Station, about 1200 Karakul sheep are kept for the conservation of genotypes for the three different pelt colours. This is purely a conservation of genetic material to serve as 'base stud' for the Karakul industry.

Regarding large stock, the MAWRD has an ongoing genetic project on indigenous Sanga cattle (see also section 2.8). Herds are kept at four research stations: Omatjenne (about 200 head), Sandveld (about 200 head), Sonop (about 350 head) and Sachinga (about 120 head). This project aims to conserve, characterise and evaluate the available gene pool, and to supply superior genetic material to farmers for upgrading of their herds. The Northern Regions Livestock Development Project (NOLIDEP) provides a link between the scientific and farming communities. NOLIDEP has selected five villages in which to implement this project.

Gaps and problems

Ex situ conservation needs and problems in Namibia can be summarised as four points:

- a shortage of Namibian graduates interested in careers in the conservation of genetic resources, biosystematics, or curation;
- an inadequate level of collaboration between relevant persons and institutions;
- an inadequate institutional capacity to determine the genetic display of indigenous species;
- a lack of adequate legislation to protect genetic resources from exploitation.

-- *Herta Kolberg*

2.8 Genetic diversity knowledge and research needs in Namibia

Many people cannot really fathom the reasons for conserving genetic diversity. Even within the framework of the Convention on Biological Diversity, many national programmes operate almost exclusively at the species level. If they appear at all, safeguards for genetic variability are tacked on almost as an afterthought.

Why is genetic diversity important? Such variation can be thought of as the building blocks on which the all-important mechanism of evolution proceeds. It is the grist to the mill of natural selection. Any loss of this variation may be cause for concern, since genetic variation allows a species evolutionary options for coping with environmental change (section 2.2). Evolution is, after all, the main process by which species will survive the environmental changes and challenges that we humans throw at them.

To understand the role of genetic variation, consider the cheetah (below), a mammal with extremely low genetic variation and a high susceptibility to disease. In theory, at least, all cheetahs could be wiped out by a single epidemic, because their immune systems (designed on the 'instructions' of nearly-identical genetic codes) might all fail equally. A more variable species would probably contain individuals with some resistance to the disease, and these might survive.[70]

Of more direct concern to our own survival and livelihood is the low genetic diversity of species on which we depend for food (below). We rely on only 30 major crops, of which three (wheat, rice and maize) provide 60% of the world's food.[110] In a risky attempt to improve agricultural production, indigenous crops are being replaced with genetically uniform cultivars.[111] We are, often obliviously, engaged in a dangerous evolutionary race--a race against the rapidly evolving crop pests and diseases which can decimate these genetically similar strains of wheat or maize over wide areas, inducing famine. A key part of the Biodiversity Convention, therefore, is to safeguard the genetic diversity of domesticated species and their disease-resistant wild relatives, as critical weapons in this evolutionary 'arms race'.

Finally, in addition to these very direct benefits of genetic diversity *per se*, there is a great value in the genetic uniqueness of taxa in Namibia. Spanning much of the South West Arid Zone, Namibia holds many taxa which are genetically very different from their nearest relatives. *Welwitschia*, *Kaokochloa*, and the Herero chat *Namibornis* are a few of the

specialties of our area. These are not just of academic intrest. Often strikingly well adapted to arid environments, Namibian plants and insects may be of potential use in land reclamation and agriculture (see below). They are emblems of Namibia, with which we can identify proudly. And as representatives of unusual taxa, they contain a large chunk of unique genetic material. So genetically, not all species are 'created equally,' but some have more unique information than others. These genetic 'outliers' must be rated highly when setting conservation priorities.
— Phoebe Barnard

Genetic diversity of microorganisms

Microorganisms such as algae, bacteria, fungi, protozoa, viroids and viruses form a large proportion of the world's biomass, and the major portion of global genetic diversity. Until recently, their diversity was largely ignored, and no realistic inventory of microbial diversity exists. A recent estimate suggests that less than 5% of species are known.[112]

The genetic diversity of Namibian microbes is completely unstudied. Since microorganisms underpin the maintenance of land productivity and other critical processes, Namibia should take explicit steps to survey them. Extreme environments are considered valuable sources of microbial genetic material.[113] Microorganisms in hot, dry or saline habitats are often highly adapted to environmental extremes that other, more complex organisms cannot tolerate, and may thus be of immense ecological and economic importance.

Ex situ collections are the mechanism by which microbial diversity is conserved for study and possible exploitation.[112] Namibia has neither the manpower nor the facilities to undertake microbial genetic inventories and *ex situ* storage, which elsewhere are done by regional microbial genetic resource centres, but could benefit by inviting these and other institutes to sample in Namibia and maintain collections at their own facilities. Legislation to protect Namibia's intelllectual property rights with respect to such material needs to be developed, so that our country can potentially benefit from its own unique microbes.
— Coleen Mannheimer

Genetic diversity of wild plants

Botany in Namibia has so far focused mainly on taxonomy, ecology and to a lesser extent ethnobotany. Little is known of plant physiology, biochemistry or genetics, particularly molecular genetics. Genetic diversity studies in Namibia are not given a higher priority than research on taxonomy, phytogeography, ecology, conservation or resource utilisation. If the Namibian flora is poorly known on a higher level, genetic data may also be of little use.

In recent years the International Plant Genetic Resources Institute and Kew Gardens have collected genetic resources from numerous plant taxa in Namibia.[114-117] Extensive collecting for the pharmaceutical industry, or bioprospecting, has not taken place legally in Namibia, although there are local suspicions that material collected for academic research or without permit has served other purposes. However, there is little published literature describing Namibian genetic resources diversity.[115,117,118-120] A national workshop on plant genetic resources[111] served mainly to build awareness and plan future activities.

In situ genetic conservation of wild plants, mainly in the protected area network, is included in the mandate of the NPGRC, but has not yet been addressed. The present reserves of the country may not adequately conserve plant genetic diversity, as they were not established with genetic criteria in mind.[121] Genetic variation studies could indicate ideal sites for reserves, and should be considered before the establishment of any future parks.

Namibian plants are likely to be important in the development of traits for arid-zone agriculture and land reclamation, such as drought and salinity tolerance. Wild relatives of existing crops, and new crops developed from wild plants such as cucurbits (Box 2.9), could have immense value in arid lands.

Box 2.9 Namibian cucurbits: potential dryland crops

Southern Africa is an important centre of diversity for the family Cucurbitaceae (melons), of which 43 species in 14 genera occur in Namibia. Several endemics and near-endemics are found here, including the *!nara* melon *Acanthosicyos horridus*, which is endemic to the Namib.

Lucrative cultivated crops such as sweet melon *Cucumis melo* and watermelon *Citrullus lanatus* originated in southern Africa. Other cucurbits are traditionally used in local agriculture and subsistence gathering. Many, especially *Citrullus*, can produce large fruits in dry seasons, yielding nutritious pulp and seeds with a high oil and protein content. They therefore have excellent potential for development to supplement or replace cereal production in arid regions. Even so, the Cucurbitaceae are poorly known. The taxonomy of the group is still in doubt; basic data on many species are lacking, and the ancestral forms of cultivated species have been largely ignored in crop improvement programmes.

The National Botanical Research Institute is investigating and documenting the agricultural potential of indigenous cucurbits in a project co-funded by the MAWRD and the Danish Government. This aims to improve the yield and quality of selected species and promote agricultural use. Crop diversification will also permit the productive use of marginal lands by farmers with limited resources. Because the cucurbits already occupy a niche in traditional agroecosystems, cuisine, culture and economy in Namibia, they are in many ways preadapted for a new level of exploitation.
— *Gillian Maggs*

Gaps in our knowledge of the genetic diversity of wild plants are extensive, because more pressing issues take priority for the limited human and financial resources in Namibia. So much basic information remains to be collected, and it would be unrealistic to expect massive reallocation of government resources to this area. However, opportunities abound for studies funded through private, corporate or international funds to be done in association with the NPGRC. The potential for scientific and economic benefit is considerable.

Recommendations

- Prioritise species and habitats for study, including genetic diversity analysis.
- Include genetic diversity as a criterion for selecting new conservation areas.

— *Herta Kolberg*

Genetic diversity of indigenous food crops

Crop genetic diversity is often overlooked as it is difficult to measure at a large scale.[122] However, judging from the rest of Africa, it is safe to assume that substantial crop genetic variation exists both within and between areas in the Namibian subsistence farming sector.[123-128] This variation is likely to contain highly valuable genes for resistence to drought and salinity, especially in pearl millet.

Until recently, neither government nor private institutions gave much research or development attention to crop production. Crops in Namibia are cultivated mainly by subsistence farmers in northern regions. Since Independence, new research and development work has begun, mainly in the form of collaborative projects between Namibian and international organisations. Regionally, concern over the conservation of genetic resources was addressed in 1989 with the establishment of the SADC Plant Genetic Resources Centre Project (section 2.7) to conserve and utilise the region's resources by *ex situ* and *in situ* methods.[104]

Other than watermelon *Citrullus lanatus* (Box 2.9), none of the world's major crops have centres of diversity within Namibia or southern Africa.[129,130] Watermelons originated in Namibia and Botswana and are considered the region's most important crop genetic resource. However, unusual regional genetic variation has also been found in other taxa, such as millet.[131]

Aside from an unpublished paper[132] and short notices in various annual reports, there is no published literature on Namibian crop genetic diversity. The genetic diversity represented in the National Plant Genetic Resources Centre (NPGRC) has not yet been described, although the characterisation of this material started in 1995. From international principles and preliminary results, however, the following inferences can be cautiously made.

A great deal of genetic variability must exist in Namibian crops that have been cultivated in the country for many years.[132,133] These are mainly the traditional crops of northern Namibian subsistence farmers (Box 4.7): pearl millet *Pennisetum glaucum*, sorghum *Sorghum bicolor* var. *bicolor*, groundnut *Arachis hypogaea*, Bambara groundnut *Vigna subterranea*, cowpea *V. unguiculata*, watermelon and others. This diversity is likely for three reasons. First, these crops have been grown in Namibia long enough to have developed distinct traits. Second, a degree of cultural isolation of crop farmers in the past, both from other countries and other areas of Namibia, could have enhanced the development of distinct local landraces. Third, a lack of 'improved' cultivars and the low priority given to agronomic research and development in the recent past must have allowed any distinct local landraces to be maintained. Indeed, modern agriculture in Namibia, as elsewhere, could be a major threat to this genetic diversity if there is insufficient appreciation of its value.

Differences in ecological conditions and cultivation practices within crop growing areas in Namibia seem to have produced different ecotypes. In controlled experiments,[132-135] performance and morphological differences in Namibian landraces of pearl millet and sorghum could be linked to their areas of origin and cultivation. In general, genetic variation in crop plants is associated with their use and adaptation to habitat.[126,136] Harlan[123] suggests that on a global scale, the more marginal areas for cultivation contain less genetic variability, but study of more material from these regions is needed. For example, the cowpea is less variable in its centre of origin, southeast Africa, than in areas of more recent cultivation.[137]

Inbreeding and outbreeding also have an effect on the genetic diversity of crops. Outbreeders are usually more heterozygous and polymorphic than are inbreeders.[138] It can probably thus be assumed that pearl millet, an outbreeder, is genetically diverse because of its breeding system.

Crops grown in Namibia by commercial farmers are 'improved' varieties or cultivars.[139] These must be genetically uniform to be registered. The genetic diversity of such crops within an area is thus assumed to be very low. There may be some genetic differences between areas due to the use of different cultivars.

Wild relatives of domesticated plants are numerous and diverse in Namibia. The genetic proximity of these species to the crop has not been well studied, and their agricultural value is mostly unknown. Several wild relatives, such as *Citrullus lanatus* and *Vigna unguiculata*, are regional endemics.

Fig. 2.37 Sorghum is expected to show significant genetic variation in Namibia. Courtesy HH Kolberg

The *ex situ* conservation of domesticated plants in Namibia has been started with the establishment of the National Plant Genetic Resources Centre in 1993 (section 2.7). The pearl millet collection is fairly representative, but other crops require extensive collection (Table 2.15). It will take several more years to make the collection fairly representative. *In situ* or on-farm conservation of crop diversity has not yet been attempted in Namibia. This falls within the mandate of the NPGRC, but is so far prevented by lack of expertise and manpower.

Genetic diversity is the basis for all advancement in agronomy.[136,140,141] The adaptation of landraces of pearl millet to marginal and variable cultivation conditions has preserved genes enhancing drought tolerance. This is important nationally, regionally and globally, with droughts becoming a common occurrence. For increased food security, high yielding, locally adapted cultivars will be of vital importance. This potential is being used in the Sorghum and Millet Improvement Programme of SADC/ICRISAT. A Namibian Drought Tolerant Composite (NDTC) was formed from 400 collections in Namibia, and yielded some grain during the drought of 1991-92.[133]

Table 2.15 Namibian crop accessions in the National Plant Genetic Resources Centre

Crop	No. of accessions
Pearl millet	
Pennisetum glaucum	1010
Sorghum	
Sorghum bicolor	126
Groundnut	
Arachis hypogaea	22
Bambara groundnut	
Vigna subterranea	44
Cowpea	
Vigna unguiculata	10
Watermelon	
Citrullus lanatus	63

Gaps and problems

The few small studies of genetic diversity in Namibian crops have been done on a morphological or performance basis.[132-135] No molecular methods,[122,142] which directly compare genetic diversity and eliminate environmental effects on gene expression, have been used. The NPGRC will over the next few years characterise germplasm morphologically, and has plans to use molecular methods. The current lack of competent staff is a severe constraint on these activities.

Recommendations

The following steps must be taken to obtain a clear understanding of crop genetic diversity in Namibia and its potential uses for the advantage of all Namibians:

- Ensure conservation of existing diversity through both *ex situ* and *in situ* methods to prevent any further loss of diversity;
- Characterise and evaluate local crops with morphological and molecular methods to establish genetic diversity patterns within Namibia, and later between Namibia and other regions;
- Develop the human resources capacity to achieve these aims.

— *Herta Kolberg*

Fig. 2.38 Millet genetic diversity is a focus of the NPGRC. Courtesy Ministry of Information and Broadcasting (N Akukothela)

Genetic diversity of wild animals

Little information exists on the genetic diversity of any wild animal in Namibia, with several important exceptions. Most genetic work concerns red data mammals, and is already generating valuable information. Box 2.10, for example, describes current work on carnivores in Etosha National Park which will yield genetic, ecological and behavioural data on lions, *Panthera leo*. All of these forms of data can be essential for making informed management decisions, especially when conservation spending must be prioritised.

Box 2.10 Genetic variation in Etosha lions

The genetics of lions in Etosha National Park is one of the subjects of a joint carnivore research project of the Etosha Ecological Institute (EEI) and Chicago Zoological Society. This project is generating data on the genetic distance of Etosha lions from other populations in the region, levels of heterozygosity, pride lineages, paternity, and other aspects of behavioural ecology. These data will allow staff to estimate the genetic impact, if any, of management actions such as translocations. It will also help in judging the population effects of the large numbers of lions, mainly subadult males, which are shot every year just outside the park.

Early results? Etosha lions cannot be distinguished genetically from those in the Tsumkwe District, and share 99.4% of their genes (using 509 bases) with lions in South Africa's Umfolozi Reserve. Many cat species have very little genetic variation within populations, but this seems to confirm that Etosha lions are not a distinct subspecies, as is sometimes suggested.

— *Source: Venzke & Forge*[143]

Genetic diversity can be threatened by several processes, including hybridisation. Box 2.11 outlines some threats to the genetic integrity of the black-faced impala *Aepyceros melampus petersi*, an endangered antelope which is endemic to northwest Namibia and southwest Angola. This case study highlights the need for circumspect management to safeguard distinct populations. Since high species richness is valued by game farmers and tour operators, especially those catering for trophy hunters, land users may be tempted to maximise species richness at the expense of genetic integrity.[144]

Cheetahs are genetically better known than many large mammals, due to research on problems experienced in captive breeding. Southern and east African cheetahs have such low levels of **heterozygosity**, or multiple forms of a gene (see Box 2.12), that their genetic variation is no more than that of deliberately inbred lab mice.[70,146,147] Southern African populations have an average heterozygosity of 0.0004,[146] less than that for east Africa and one or two orders of magnitude less than in other cat species.

The reasons for this have been hotly debated. Low genetic diversity could reflect **population bottlenecks** (Box 2.12) since the Pleistocene era, when mammalian extinctions in Asia and the Americas were widespread.[148] It may be related to the cheetah's hunting or breeding strategy,[149,150] or may be fairly typical of carnivores.[151] So far, there is no consensus on the reasons.

Whatever its causes, what might be the effects of this extremely low genetic diversity on cheetah conservation? As the nation with probably the largest cheetah population (section 2.5), Namibia has a particular responsibility for their conservation. A national cheetah management strategy,[70] the first for any country in the cheetah's range, has been drawn up to help preserve genetically viable populations in Namibia. Low heterozygosity has been blamed for reduced evolutionary fitness in captive cheetahs, as shown by susceptibility to disease, asymmetric body development, and breeding abnormalities, but it is not clear to what extent wild populations suffer from these problems. It has been argued[152] that cheetahs suffer from **inbreeding depression** (Box 2.12), but until recently there has been no evidence that susceptibility to disease in captivity is matched in the wild. An important exception may be the vulnerability of cheetahs to anthrax *Bacillus anthracis* in Etosha National Park, where all six radio-collared cheetahs have succumbed to the disease after eating infected prey.[153] Although the authors did not link this mortality to low heterozygosity, further work is desirable to establish why cheetahs would not develop immunity to anthrax when this disease commonly afflicts their prey.[154] Finally, cheetahs in capivity suffer from breeding abnormalities linked to low heterozygosity, such as defective sperm and high cub mortality. However, wild cheetahs do not seem to suffer. The Namibian cheetah population can double every five to seven years, in the absence of limiting factors.[70,81]

More should soon be known about the genetic diversity of other Namibian mammals, as there is an increasing focus on tissue sampling for genetic study (section 2.7).

Box 2.11 Trading one threat for another: genetic pollution in the black-faced impala

The black-faced impala *Aepyceros melampus petersi* is an endangered subspecies, endemic to southwest Angola and northwest Namibia.[145] It is of conservation concern due to the risk of hybridization with, or 'genetic pollution' by, the common impala *A. melampus melampus*. Historically, its distribution was separate from that of the common impala, but the two have recently been extensively introduced onto game farms, in some cases onto the same farm. The Etosha National Park population is also at risk, as common impala, which are adept at moving through game fences, have been introduced onto numerous adjacent farms. The risk of interbreeding has been increased by economic and bio-political incentives for farmers to have both types of impala on their land. These incentives include:

- a much higher current price for black-faced (up to N$6500) than common impala (N$250), which encourages most game farm owners to stock common impala;
- the wish of many game farm owners to offer tourists and hunters a variety of mammal species, especially regional 'specialties'; and
- trophy import restrictions on black-faced impala for U.S. hunters, who are perceived as paying more than other nationalities. This removes an important economic incentive for game farmers to stock black-faced impala: U.S. hunters will not hunt for a trophy they cannot bring home.

Due to the threat of extinction in its natural range, the black-faced impala was introduced into the Etosha National Park from the former Kaokoland (now Kunene Region) in 1968-71, with a founder population of 180 impala. Introductions into the national park have been highly successful: the Etosha populations have since increased to more than 1500. Meanwhile, Kaoko populations have increased little if at all; they are fragmented, and seriously threatened by poaching and competition with livestock, despite support among ovaHimba leaders in the region for their presence and reintroduction.

Ironically, the management strategy adopted to rescue this Kaoko endemic by translocating it into public (and then private) protected areas has inadvertently jeopardised its genetic integrity. The threat of future interbreeding can be addressed through concerted management action with game farmers, the Namibian Professional Hunters' Association, and rural communities.
Source: Green & Rothstein[144]

Box 2.12 Conservation genetics terms in (fairly) plain English

Heterozygosity
A measure of the genetic diversity in a population, based on the average proportion of an individual's genes which exist in two different 'versions' (*alleles*). Populations with high heterozygosity can usually adapt better to environmental change.

Population bottleneck
A dramatic crash in number of a population. During this process, genetic diversity is often lost, and the future genetic profile of the population is shaped by those individuals which survive.

Inbreeding depression
A state of lowered survival, vigour and breeding success of individuals, due to negative genetic changes (increased *homozygosity*) caused by repeated breeding among relatives.

Fig. 2.39 Black-faced impala are at genetic risk through hybridisation. Courtesy P Tarr

Genetic diversity of domesticated animals

Almost as diverse as its people and wild biota are Namibia's livestock. Livestock production in Namibia varies from small scale, extensive subsistence farming to large scale, extensive commercial farming. Table 2.16 gives background data on livestock numbers in the different regions. The former 'Owambo' (now Oshikoto, Ohangwena, Omusati, and Oshana Regions), western Kunene, Okavango and Caprivi Regions are communal farmland.

Most well known imported cattle breeds, plus indigenous Nguni or Sanga cattle, are found in Namibia (Table 2.17). Most imported breeds entered Namibia from South Africa, but two, the Simmentaler and Brahman, were imported directly to Namibia from Germany in 1894 and the USA in 1958 respectively. Namibia has few dairies, and there are no data on the number of breeders or animals per breed. Dairy breeds in Namibia are Frieslands and Jerseys.

Conservation of indigenous livestock has a high priority in the MAWRD's National Research Policy. 'Sanga' is a collective term for all the indigenous cattle breeds of southern Africa (Afrikaner, Tuli, Shangaan, Drakensberger, Pedi, Venda, and Namibian ecotypes), but due to the lack of a suitable distinct name, indigenous Namibian breeds are also referred to as Sangas by government agriculture staff.

North of Namibia's Veterinary Cordon Fence, the 'Red Line,' most cattle are Sangas, with very small numbers of other breeds introduced over the years. Of the roughly 2.04 million head of cattle in Namibia, approximately 700 000 are Sanga cattle held by northern communal farmers. Sangas are the most numerous of all breeds.

Sanga cattle have been undervalued by government agriculture staff for many years. They are a 'low maintenance' breed, naturally selected over centuries, with an inherent parasite resistance, high fertility and excellent maternal care. Communal farmers need to have animals that can thrive under harsh conditions, as their access to production supplements (e.g. salt licks and medicine) is often less than that of commercial farmers.

Sanga cattle are used for meat and milk production as well as draught purposes. They excel in standard indices of production: they are particularly fertile, have a low intercalving period, the highest weaning mass per unit of maternal body mass of any breed in Namibia, a high growth rate and a high feed conversion ratio.[157-159] These features plus their small size, low maintenance needs and tolerance of dry environments mean that they crossbreed excellently with large bulls of introduced breeds to produce heavy offspring. There is thus now a considerable demand for Sanga cows by commercial cattle farmers. Purebred Sangas are only surpassed in terms of biomass production by crossbreeds of pure Sanga cows with large European type beef bulls. This latter fact, however, creates a strong incentive among farmers to crossbreed the indigenous and imported cattle, which may jeopardise the integrity of the Sanga genepools.

Due to the presence of stock diseases in some areas, Sanga are the only large stock found there. Recent studies in Namibia and South Africa have found that Sanga cattle generally have a high resistance to ticks and other parasites, and the Caprivi Sanga has a strong resistance to trypanosomiasis. Sanga can also tolerate conditions from the humid Caprivi to the arid Kunene Region, and can survive under conditions where exotic breeds have died from starvation and thirst.

Fig. 2.40 The indigenous Sanga cattle breed. Courtesy P Hugo

Table 2.16 Number of different livestock per region[156]

Area	Cattle	Sheep	Goats	Pigs	Poultry	Ostriches
Caprivi	95 136	44	4 302	35	16 852	0
Okavango	106 209	137	34 799	2 491	37 562	0
Otjozondjupa	308 913	90 262	131 984	2 173	76 884	518
Owambo*	339 725	18 769	172 318	2 145	50 291	0
Kunene	272 611	128 854	389 521	1 882	28 739	116
Erongo	67 911	54 072	178 912	1 576	57 670	112
Omaheke	418 786	325 664	173 498	3 170	44 065	2 513
Khomas	175 390	159 161	32 198	1 952	64 000	2 811
Hardap	92 428	942 469	228 789	1 159	79 837	14 205
Karas	32 685	900 093	292 891	1 260	17 410	2 945
Total	1 909 794	2 619 525	1 639 212	17 843	473 310	23 220

** 'Owambo' is made up of the Omusati, Oshana, Oshikoto and Ohangwena Regions.*

Table 2.17 Cattle breeds, stud breeders, registered animals and participants in the Performance Testing Scheme, PTS

Breed	No. of breeders	No. of cattle	Participants in PTS
Afrikaner	20	2 150	5
Bonsmara	31	4 615	31
Brahman	103	6 158	31
Charolais	18	692	0
Drakensberger	-	-	1
Gelbvieh	8	121	2
Hereford	-	-	0
Limousin	6	151	0
Nguni/ Sanga	11	721	7
Santa Gertrudis	-	-	6
Shorthorn	1	-	0
Simbra	10	1 350	7
Angus	4	71	0
Sussex	-	-	0
Beefmaster	2	100	2
Brown Swiss	20	991	4
Pinzgauer	2	312	2
South Devon	2	70	1
Simmentaler	40	4 000	13

Source: Namibian Stud Breeders' Association[159]; Simbra and Simmentaler Breeders' Association.[160]
- = no data available

The Afrikaner is a breed indigenous to South Africa and Namibia, with a relatively small distribution and a limited gene pool. Genetic material is available only in these two nations, and is periodically imported to Namibia from South Africa. Afrikaner pure- and crossbred cows are used in rangelands for meat production in the commercial farming sector. They have good maternal care and are adapted to the harsh conditions.

Sheep are more numerous in Namibia than cattle, and play an important role in livestock production in the southern commercial and communal farming systems, as well as in the northwest of the country. Eight breeds of sheep occur in Namibia: Dorper, Karakul, Damara, Black-headed Persian, Afrikaner, Dohne Merino, South African Wool Merino, and Letelle.

The Dorper, developed in South Africa, is the most numerous breed. It is bred for mutton production and is highly fertile. It grew in popularity after economic hardship in the Karakul industry.

The Karakul, originally imported at the turn of the past century, has undergone such development since then that it could almost be called an indigenous breed. From the old traditional 'pipe-curl' pelts to the modern 'water silk' types, new variants have been selectively bred. Before the slump in this industry, Namibia produced 5 million pelts per year. The MAWRD also selectively bred the brown, grey and white Karakul sheep. At present, small nucleus herds of these different types are kept at Gellap-Ost Research Station, and are the only pure herds still in the country.[157]

The Damara sheep is the only true indigenous breed in Namibia, originating from the former Kaokoland and Damaraland (now Kunene and Erongo Regions). This is a hardy, fat-tailed breed with high fertility and excellent maternal care. Multiple births are not common. Damara sheep are adapted to the arid western areas, and all have predominantly red and black wool. The MAWRD has a herd, recently acquired in Kunene for comparison trials with a herd which has been selected for fertility and growth over the past forty years. This will determine the amount of progress made in terms of growth and fertility, but also the extent to which disease resistance may have been lost. The Damara sheep is more of a browser than other breeds.[157]

Goats are very important in Namibia's livestock industry. In the commercial sector, goat farming is practised as a primary industry in the south and as a secondary industry in the central and northern regions in conjunction with cattle. Most goats on commercial farms are Improved Boer goats, a breed developed from indigenous goats in South Africa and Namibia. This breed is very fertile and long-lived, with good maternal care, milk production and meat production. There is a high incidence of multiple births.

Fig. 2.41 Damara sheep are the only truly indigenous Namibian sheep breed. Courtesy P Hugo

Fig. 2.42 Improved Boer goat. Courtesy MAWRD

In the southern communal farmlands of Karas Region, a local type of goat is often cross-bred with Improved Boer goats for increased mass. Little is known about this breed. Two and possibly three indigenous goats are found in the northern communal areas: a long legged type in the Kunene Region, a small type in northern 'Owambo' similar to one in eastern South Africa, and a possible third type in the Okavango Region. Goats from Okavango and southern 'Owambo' have often been crossed with Boer goats, and may not be genetically distinct. A mission to collect genetic material from these breeds has just taken place, and the MAWRD has recently acquired goat herds from northern 'Owambo' and Kunene. The production and reproduction of these herds will be compared with those of the Improved Boer goat at Uitkomst Research Station.[157] In the Okavango Region, a project will determine resistance to internal parasites.

Most pigs kept on farms are for domestic use, and the most numerous commercial breeds are Large Whites, Landraces, and Durocs. There are currently about ten commercial pork producers with 1500 breeding sows. Roughly 7000 indigenous pigs are found in the northern communal areas. These pigs differ from known commercial breeds by having short snouts with a pronounced dish in the forehead, short, potbellied bodies, and variable skin colours. They are much smaller and lighter than commercial pig breeds, and accumulate fat much more quickly. Very little is known of their production potential, disease resistance, or cultural role. A current joint project of the MAWRD and the Irene Animal Production Institute of South Africa aims to characterise these pigs genetically and estimate their genetic distance from a similar South African indigenous pig, the Colbrook.

Most chickens in Namibia are of commercial breeds and crosses between these breeds. In the northern communal areas, people keep chickens which appear to represent different ecotypes. Their production potential will be evaluated, and high quality chickens will then be selected and multiplied for local use.

There are no true wild horses in Africa, but a unique group of feral horses exists in the southwestern Namib Desert (Fig. 2.43). This group is probably descended from the herd of a German captain who kept about 350 horses at Duwisib Castle, 200 km distant, until World War I. Thoroughbred stallions were bred to English Warmblood mares there, and the crossbreeds were renowned as military and police horses.

The horses came to public attention in 1987 when ten were sent to a South African veterinary institute. They show unique traits fixed by years of isolation, adaptation and inbreeding, and are related to the American and Shagya strains of Arabian horses, which were present in Namibia in early German colonial times.[161] A 1994 study revealed about 124 animals, of which 54% were stallions, 46% mares, 38% immature and 62% adults, and foal survival was 60%. They had no immunity to horse diseases, and their progeny will be used to test vaccines for horse sickness and equine flu. The horses are strongly inbred, with extremely low genetic variation. Indeed this is the second lowest level of heterozygosity of any horse.[161]
— *J.F. Els*

Fig. 2.43 Feral horses of the southern Namib Desert. Courtesy P Tarr

2.9 Species richness and conservation summary

Fig. 2.44 The tenebrionid *Onymacris langi* in Hartmann's Valley. Courtesy E Marais

This section of the Biodiversity Country Study gives what might be regarded as the 'meat' of Namibia's information on the biodiversity of terrestrial and inland wetland habitats. Major species groups in these habitats are treated in taxonomic order, as this was the only feasible way of systematically addressing the issue in the necessary detail. Unfortunately, the 'patchiness' of information alluded to elsewhere in the book is nowhere more apparent than here. For some taxa we can say only that next to nothing is known; while for groups such as birds, the comparative breadth and sophistication of the database have allowed a much fuller treatment, and serve as a model for other taxa.

The essential components of this section are summaries of *species richness* (or *species diversity* where this can be assessed), *endemism*, and *conservation status*. Taxonomic summaries are preceded below by a brief numeric overview of richness and endemism. A summary of the *areas* of high species endemism was given in section 2.3 .

Overview of richness and endemism

A numerical summary of known species richness in any nation — even one with ample funding and a large, well-organised coterie of scientists — is never set in stone. Table 2.18 lists, very tentatively, the known richness and endemism of Namibian species. Still, many groups can only be labelled 'unknown.' We hope this book will prompt research into these taxa, some of them decidedly unglamorous, which keep Namibia, its environment and economy running: bacteria, soil arthropods, algae, mycorrhizal fungi, and so on.

As part of Africa's Southwest Arid Zone, Namibia is a centre of endemism for diverse groups from melons to tortoises. A summary of its endemism is complicated by gaps in taxonomic knowledge, as well as historical differences in the use of the term *endemism* by different specialists (see section 2.3). To most vertebrate zoologists, a species is 'endemic' if 75% or more (frogs, reptiles and mammals) or 90% or more (birds) of its range falls within Namibia, but for insects, arachnids, flowering plants and freshwater fish, an endemic species has strictly 100% of its range in Namibia. These awkward and, to the analyst, annoying inconsistencies reflect the past isolation and iconoclastic views of Namibia's biodiversity specialists, a situation which is belatedly but rapidly changing.

The degree of endemism in Namibian plants, invertebrates, reptiles and frogs is relatively high (Table 2.18), whereas mammals, birds and fish, many of which are highly mobile, have levels of endemism below 10%. The figures for fish need careful interpretation. Since major fish habitats are the perennial rivers bordering Angola and South Africa, even species endemic to these rivers are by definition not Namibian endemics. This is exemplified by the Orange River, where 42% of the 15 species are endemic to the river but not to Namibia alone.[162]

Figures for many taxa in Table 2.18 are very tentative, but the greatest uncertainty lies in the data for lower kingdoms and invertebrate animals. Given that invertebrates form the vast majority of species and biomass,[163] it is not surprising that less than a quarter of Namibia's insect and arachnid species are described, despite biosystematic research at the National Museum of Namibia since 1968. Preliminary analyses of endemism[47,49,102] show that Namibian invertebrates are highly species-rich. Taking insects as an example, about 35% of the roughly 100 000 southern African insect species are believed to occur within Namibia. Fully 24% of a subsample of 6331 recorded insect species are wholly endemic (below). Many of these endemic insects have been isolated for millennia following climate change,[164] and indicate the biotic uniqueness of Namibia, the Namib Desert, and the Namib escarpment. This theme of the uniqueness and endemism of Namibian biota will feature in many of the taxonomic accounts below.

Table 2.18 Endemism and species richness of known indigenous Namibian taxa in terrestrial and freshwater habitats[a]

	Endemics	All species	% endemism[b]
Viruses	unknown	unknown	—
Monerans	unknown	unknown	—
Protists	unknown	unknown	—
Fungi	unknown[c]	189	—
Lichens	unknown[d]	140	—
Plants	687	4138	17
Rotifers	unknown	unknown, c. 200	—
Poriferans	unknown	unknown	—
Cnidarians	unknown	unknown	—
Platyhelminths	unknown	unknown	—
Ectoproctans	unknown	unknown	—
Nematodes	1	unknown	—
Annelids	4 aquatic	unknown, >27	—
Molluscs	9	104	9
Arachnids	164	1411[e]	12
Crustaceans	39 aquatic	142 aquatic	27
Myriapods	13	45	29
Insects	1541 (incl. 38 aquatic)	6331[f] (incl. 558 aquatic)	24 (14% aquatic)
Frogs	6	50	13
Fish	5	115	4
Reptiles	59	250	24
Birds	14	658	2
Mammals	14	200	7
Total known	2556	13 773	

a *Figures are based on studied taxa, which in some case represent less than 20% of the expected total. Data are therefore absolute minimum estimates. Source: Updated from Simmons et al.*[49] *and Curtis et al.*[102] *based on contributions to this book.*

b *Endemism is defined as 100% of global range occurring in Namibia for all taxa except birds (90%), amphibians, reptiles and mammals (all 75%).*

c *As fungi are often specific to endemic host species, numerous endemic fungi are expected.*

d *Lichens have been studied only on the Skeleton Coast, Sperrgebiet and Waterberg Plateau Park; at least one genus and numerous species are endemic, some with extremely restricted ranges.*

e *This figure represents about 24% of the expected 5650 non-acarine arachnids (scorpions, spiders and allies) in Namibia. Mites are little known and endemism will increase with further study.*

f *This figure represents about 18% of the expected 35 000 insect species in Namibia.*

Viral, moneran, and protist diversity

With the unaided eye we cannot easily see viruses, monerans (bacteria), and protists (amoebae, flagellates, slime moulds, diatoms, single-celled algae). Yet they dominate the biosphere in numbers: more bacteria are present in a handful of soil than the total number of people who have ever lived.[165] They are exceptionally diverse and abundant, especially in soils, in water, and as disease-causing organisms associated with other species. They can also have a negative effect on biodiversity when ecosystems are under some form of environmental stress.[166,167]

Only species of disease importance to humans, crops, livestock and wild animals are at all known in Namibia. Appendix 5 lists known viral, bacterial and other pathogens in southern Africa for which Namibia observes an agricultural quarantine alert,[168] although these may not have been recorded from Namibia. Appendix 6 lists viral and microbial pathogens of Namibian domestic and wild animals.[98,170,171]

Apart from their significance in human and animal medicine and crop pathology, many of these organisms play fundamental ecological roles in nutrient cycling. They thus merit basic and applied research in Namibia.
—Phoebe Barnard & Herta Kolberg

Fungal diversity in Namibia

Economic and ecological roles

Fungi are typically seen as inhabitants of moist environments, and have received scant attention in the drylands of the world. They include mushrooms and truffles; moulds and mildews which decompose organic matter; rusts and smuts which cause costly plant diseases; and human pathogens such as ringworm. All of these are found in Namibia. Fungi depend on other organisms for their nutrition, and grow as parasites, saprophytes or mutualists. Their role in arid ecosystems has been greatly underestimated.[172]

Fig. 2.45 *Battarrea sp.*, Kuiseb River. Courtesy P & K Jacobson

The economic importance of fungi is immense, with a global annual economic contribution of billions of US dollars[173] in the spheres of foods and food additives, alcoholic beverages, amino acids, enzymes, antibiotics, vitamins, herbicides and pesticides, biocontrol and biodegradation agents, and pharmaceutical and medical uses. Innovative uses of fungi have led to a three-fold increase in the number of patented strains deposited annually.[174] Fungal pathogens also cause considerable economic losses worldwide, although there are few Namibian data. Many are important plant pathogens,[175] and can cause severe crop failure. As fungi can cause disease in virtually all types of organism, however, they hold potential for biocontrol of pests such as plant pathogens, locusts, and nematodes,[176-177] and merit research in Namibia for these purposes.

However, the greatest significance of fungal diversity is found in ecosystem functioning. Fungi have diverse and essential roles in sustaining ecological processes, especially nutrient cycles and soil-plant relationships.[174] In addition, we now know that most vascular plants have obligate or opportunistic mycorrhizal relationships.[178,179] Mycorrhizal associations are essential for plant survival and growth in environments where water and phosphorus availability are limited, and they are increasingly appreciated in forestry. Mycorrhizal fungal diversity has been used to monitor ecosystem integrity under the threat of global climate change in Europe,[180] and to distinguish human-induced degradation from natural climate stress in Namibia.[181]

Fig. 2.46 *Terfezia pfeilii*, the *n'abba* or Kalahari truffle. Courtesy P & K Jacobson

Fig. 2.47 *Termitomyces schimperi* growing on *Macrotermes michaelseni* mound. Courtesy P & K Jacobson

Regional and national status

There are no estimates of fungal diversity in southern Africa. Studies have focused on fungal associates of imported plants, but there has been no work on the indigenous fungi of any of southern Africa's unique biomes. Research is hampered by a regional shortage of qualified personnel. Taxonomic work is done at institutes in South Africa and Zimbabwe, principally the Plant Protection Research Institute (PPRI) of the Agricultural Research Council in Pretoria.

Appendix 7 summarises 189 species in 47 different families recorded so far for Namibia, based on a literature survey by the National Botanical Research Institute and a list of Namibian specimens held at the PPRI. A national assessment of fungal diversity was started by the NBRI in 1995. However, very little was known of Namibian fungi prior to 1990, when Jacobson[172,181-185] began studies of arid-zone fungal ecology. This ongoing work documents the presence and function of diverse decomposer and mycorrhizal fungi in the hyper-arid Namib 'sand sea,' arid grasslands, and ephemeral rivers. A preliminary list of macrofungi compiled from 1990 to 1995 documents at least 80 species in these habitats, many of them undescribed. Actual macrofungal diversity in these regions is estimated to be five-fold greater, given the diversity of habitats not yet sampled and the difficulties of collecting (below).

Important parasitic fungi in Namibia include agricultural pathogens (Appendices 5 and 6). Namibian saprophytic fungi include dung- and wood-decomposing mushrooms[173] which are especially prevalent in ephemeral rivers, rangelands and forests following rain. Plants with documented mycorrhizal associations in Namibia include *Colophospermum mopane*, annual and perennial grasses, *Welwitschia mirabilis* and *Faidherbia albida*.[182-184] Lichens (below) are mutualisms of blue-green bacteria and fungi well adapted to using fog moisture. The high lichen diversity of Namibia thus reflects a high fungal diversity.

Distribution patterns

Distributions of two edible species are fairly well known. *Terfezia pfeilii*, the *n'abba* or Kalahari truffle, occurs in the Kalahari sands of south- and central-eastern Namibia (Fig. 2.46). It is also reported from sandy areas in Kunene Region, and a similar fungus is eaten in the Okavango Region. *Terfezia* is the most economically important edible indigenous fungus, but its ecological role is unknown. Based on taxonomic affiliations, it is thought to be a mycorrhizal associate of woody savanna plants. However, host plants have not been identified, hampering efforts to commercialise production or determine whether current harvesting is sustainable.

Namibia's best-known fungal mutualist is *Termitomyces schimperi* (Fig. 2.47), a large edible mushroom found on *Macrotermes michaelseni* termite mounds after rains.[182,186] This fungus, eaten by humans and other mammals, provides enzymes needed for decomposition of wood by termites; in return, termites provide a sterile, moist environment for fungal growth. The distribution of *Termitomyces* is thought to be limited to that of the termite, which extends from the Swakop River north to eastern Kunene Region, east towards Botswana, and north to Caprivi.[187] The termites are found in virtually all soils other than deep, unconsolidated sands, so the fungus probably extends likewise.

A 1992 ICRISAT mission found two important plant pathogens throughout the crop growing regions of northern Namibia: long smut *Tolyposporium ehrenbergii* on sorghum, and smut *T. penicillariae* on pearl millet. Downy mildew *Sclerospora graminicola* was found in the north-central and northeast regions, and ergot *Claviceps fusiformis* in Caprivi.[188]

To document fungal diversity and distribution in Namibia, systematic collecting must focus on the rainy season. Special efforts should be made to collect repeatedly in areas after rains or river flow. The production of fruiting bodies required for positive identification is highly seasonal. Ongoing surveys in the western ephemeral rivers have shown a successional pattern of fruiting body production in response to drying of the substrate after a flood.[185] Large woody gasteromycetes, which decompose grass detritus and dung in sandy soils of the Namib Desert, also show successional fruiting as soils dry after rains.[172]

Endemism

No endemic Namibian fungi are yet known. However, this reflects our very patchy knowledge. As fungi are heterotrophs, the endemic plants and animals of Namibia are likely to be associated with endemic fungi. Documenting the degree of endemism will require much more comprehensive data on regional fungal diversity. *Broomeia*, an unusual gasteromycete genus, is currently the only Namibian fungus thought to be endemic to the southern African arid zone.[189] A number of rust and smut species were originally described from Namibia,[190] but their global distributions are not known.

Conservation status

The conservation status of specific fungi cannot be determined without better ecological and biogeographic data. Seasonal harvesting of *Terfezia pfeilii* and *Termitomyces schimperi* is apparently extensive, but the sustainability of harvesting is unknown.

Given the importance of fungi to ecosystem integrity and function, plus their potential economic value as resources, the loss of fungal diversity would be a substantial cost of habitat degradation.[10] Current threats of greatest importance include deforestation, hydrological alterations such as damming of ephemeral rivers, draining of seasonal wetlands, and excessive water abstraction in areas such as the Mountain Savanna and Karstveld (map 1.8). On an international scale, the changes in rainfall distribution anticipated from global climate change will certainly affect the Namibian mycoflora.

Box 2.13 Fungi of economic importance

The only Namibian fungus harvested for export and sale in the formal sector is the truffle *Terfezia pfeilii*. The economic value of this species could probably be increased, although it has not yet been cultivated successfully. Currently only very few individuals benefit appreciably from its harvest. Efforts are underway to determine the value of truffle sales to harvesters, landowners and exporters. *Terfezia pfeilii* and *Termitomyces schimperi* are important and popular seasonal foods for rural people. They are also a cash crop, and are sold seasonally next to main roads.

Fungal plant pathogens often cause pre- and post-harvest crop losses in Namibia. Both commercial and subsistence farmers are affected, although to what degree is unclear. The production of carcinogenic toxins by some grain-borne pathogens[176,191,192] is also of concern and should be monitored. A fungus may have a negative impact on the near-endemic plant *Welwitschia mirabilis*, an important tourist attraction. *Aspergillus niger* infects *Welwitschia* inflorescences and may render a large proportion of the seeds infertile.[192] However, this has not been confirmed in the field, where abiotic conditions may more strongly limit *Welwitschia's* distribution.

Box 2.14 Constraints in the study of fungi

- *A lack of baseline data on the diversity and ecology of Namibian fungi*
- *A lack of basic mycological research facilities and qualified Namibian staff, especially in the field of fungal pathology*
- *A lack of adequate quarantine facilities for plants and plant products entering Namibia*
- *A lack of effective legislation on indigenous knowledge and genetic property rights, to allow for more collaborative research and development of fungal resources*

Recommendations

The global dearth of data on fungal diversity and ecology can be addressed in Namibia by addressing the gaps in Box 2.14:

a including fungal biodiversity in national surveys, including environmental monitoring programmes;

b training several Namibian students in fungal systematics and ecology;

c developing international contacts with mycological systematists;

d drafting effective legislation (Chapter 5).

As there are few staff and facilities in Namibia, effective fungal research needs collaboration between research and training institutions, government agencies and foreign researchers. A local specialist should coordinate this to prioritise research and ensure that Namibia benefits from any research leading to financial gain. Several priority projects should also be addressed as part of Namibia's Programme to Combat Desertification (NAPCOD), the National Biodiversity Programme, relevant ministries and other agencies (Box 2.15).

The diversity, importance and function of fungi has been greatly neglected in Namibia. They have immense ecological and economic potential and merit far greater attention.
—Coleen Mannheimer & Kathryn Jacobson

Box 2.15 Three priority projects on fungi

♦ **Conservation and utilisation: fungi as integral components of healthy ecosystems**

This project would aim to establish the role of fungi in maintaining ecosystem integrity, and to establish their use as indicators of ecosystem health.[180] Special attention should be paid to the indigenous mycorrhizal associates of woody plants, crops and critical rangeland grasses:

- Initiate long-term fungal surveys in key habitats, e.g. forests, rangelands, wetlands and rivers.
- Encourage public participation in surveys.
- Initiate studies of indigenous knowledge.

♦ ***Fungal pathogens of plants and humans***

A collaborative project would assess the medical, agricultural and economic importance of Namibian fungal pathogens, and means of biological control:

- Participate in international efforts to develop fungal biocontrol agents for insect pest species.
- Develop mechanisms to regulate and assess the impacts of mycotoxins in imported grain.
- Construct simple fungal identification keys for phytosanitary officers and farmers.
- Monitor contamination of imported maize by fuminosin, a potential carcinogen,[191] and sorghum storage in northern Namibia.
- Assess *in situ* the threat of *Aspergillus niger* to *Welwitschia mirabilis* (to commence in 1998).
- Train additional phytosanitary officers and establish adequate quarantine facilities.

♦ ***Species of economic potential***

This project would assess the ecology, market value, harvesting sustainability and cultivation potential of *Terfezia pfeili* and *Termitomyces schimperi.* Value-adding by bottling merits study, as bottled truffles are sold for high prices overseas.

Fig. 2.48 Stored or imported grain can be infected by carcinogenic fungal pathogens. Courtesy HH Kolberg

Lichen diversity in Namibia

Lichens are very little known, but have a host of important roles. They decrease wind erosion and stabilise desert sands,[193,194] can increase soil nitrogen content by two to sevenfold,[195] may act as pioneer species in desert communities,[196] provide habitat for microfauna, with up to 17 mite species recorded on *Teloschistes capensis* in the Namib,[195] provide food for beetles[197] and ungulates,[194,198] and provide shelter for nests of the vulnerable breeding endemic Damara tern.[199] In practical terms, they can be used to age substrates, including rock art, which are otherwise difficult to date, and are used to monitor air pollution. They add to the aesthetic and tourism value of the desert[200] and rock features of Namibia,[201] and are used medicinally to treat rheumatism, arthritis and other complaints.[202,203]

World-wide, over 13 000 lichen species have been identified. Although Namibia's lichen flora is patchily known, making comparisons unreliable, it is internationally agreed that Namibia's lichens are unique with regard to their species richness, community diversity, fog dependence in coastal areas, and the presence of unusual restricted range species.

Several early publications described Namibia's coastal lichen fields or gave preliminary species lists.[190,204-206] Wessels[207-208] has greatly furthered our lichen knowledge. But , no systematic study or survey has been carried out by a lichenologist, and the taxonomy is in a state of confusion. Due to the uniqueness of the lichens, overseas specialists find identification difficult and time consuming, and the majority of species can still not even be identified to genus level.

Work has focused on specific lichens,[209-213] ecology,[195,214] chemistry,[198] geobotany,[215] or tools for mapping lichen fields.[196] Areas studied include the northern Namib coast, Waterberg[201] and *Sperrgebiet*.[208,216] Little is known of the less conspicuous species in other areas of Namibia.

Estimates of lichen species richness are not possible at a national scale, and are available only for the Namib Desert and Waterberg Plateau. Wessels[193] put the number of lichen species in the Namib Desert at over 100, but the true number may be far greater as many remote areas have been undercollected, and the *Sperrgebiet* in the southern Namib alone holds over 90 species.[217] Namib lichens have been grouped into four categories:

- genera and species characteristic of arid areas which are fairly cosmopolitan;
- species mainly found in the southern hemisphere;
- species limited to the west coast of southern Africa, including some endemics;
- species endemic to the Namib Desert.

Lichens may have been the first organisms to colonise the Waterberg sandstone, and over 140 species are estimated to occur there.[201]

Areas of high richness

The coastal mist zone is the region of greatest richness and abundance, and features vast lichen fields. These fields differ considerably from each other in species composition in four areas of the Namib: Skeleton Coast Park, rocky outcrops in the sand desert, National West Coast Recreation Area, and southern Namib.[195] A 400 km^2 area northeast of Wlotzka's Baken has one of the most extraordinary lichen communities in the world. Less obvious, but numerous are the endolithic lichens which occur in both the mist zone and interior. These grow inside porous rocks and in cracks, and occur together with epilithic (rock-covering) lichens in the Namib.[201] Other areas of high diversity include the rock faces of the Waterberg Plateau. Lichens have been noted at rock art sites such as Twyfelfontein, but have not been studied.

Fig. 2.49 Namib lichen fields are highly diverse, with many restricted range species. Courtesy P Tarr

Endemicity

So little is known about species richness that no endemism statistics are available. Although many lichens have cosmopolitan distributions, various authors have confirmed that Namibia's lichen flora is characterised by its unusual endemicity. Speciation and specialisation are also considered well advanced.[195] One lichen genus and numerous species are endemic to the Namib Desert. *Santessonia namibensis*, from the Skeleton Coast Park, is probably one of the world's most restricted lichen species. Endemics also occur inland at the Waterberg Plateau on both rock and bark.[201]

Conservation status

Lichens in parts of the Namib have been greatly damaged by off-road driving, which scars the landscape for many decades. However, many major lichen communities are protected within the Skeleton Coast Park, Namib Naukluft Park and Waterberg Plateau Park, and in the restricted-access *Sperrgebiet*. MET staff have diligently enforced rules restricting vehicles to established roads inside the state parks, but outside parks this is nearly impossible. Lichen research also needs to be consolidated and put on a more systematic footing (Box 2.16). At present, no-one in Namibia is responsible for lichen research, monitoring or control of species outside parks, and the MET does not employ a lichen specialist. Research by foreign specialists is often lost to Namibia, as no effort is made to obtain this information or coordinate research.

Box 2.16 Constraints on lichen research and conservation

- *A **lack of coordination and responsibility** for lichen research and conservation*
- *Lichens are highly specialised, long-lived and slow-growing, and many do not reproduce sexually, so they lack genetic recombination. This renders them extremely **sensitive to ecosystem disturbance and direct damage.***
- *Lichens cannot be grown in botanical gardens or kept as spores, so **threatened species cannot be protected** ex situ.*
- ***Public awareness** of the sensitivity and value of lichens is still low.*

Recommendations

The following recommendations are based on those made by Hale:[218]

Unique lichen communities should be recognised as important and potentially threatened botanical treasures.

- Areas occupied by these lichens should be identified and inventoried.
- The most important areas should be officially designated as floral reserves and posted to increase public awareness.
- Access to these areas by vehicles must be severely restricted to prevent damage.
- A specialist must be appointed to conduct and coordinate research, educate various sectors, and ensure that recommendations are carried out.
- Any development in lichen-field areas must be preceded by an environmental assessment, and entry to parks by all persons must be carefully controlled.

— Patricia Craven

Plant diversity in Namibia

Plants are a resource of fundamental importance, as humans and at least four million other different kinds of organisms depend on about 250 000 plant species for their survival.[219] Some 20 plants provide over 85% of our food, and only a few hundred species are widely cultivated. Most species have not been assessed for useful properties, and thousands have not yet been scientifically described and named.

Namibia is floristically diverse and complex, with a variety of unusual taxa reflecting its long millennia as an island of aridity in a sea of dynamic, less arid habitats.[220,221] Ongoing studies by the National Botanical Research Institute indicate that plant species richness in Namibia far exceeds previous estimates, and this does not take accurate account of formerly neglected groups such as algae, mosses and ferns.

Phytogeographically, Namibia contains part of three floristic regions: the Zambezian regional centre of endemism, Kalahari-Highveld transition zone, and Karoo-Namib regional centre of endemism.[222] The latter includes two recognised centres of plant diversity: the Kaokoveld (Kaoko escarpment) and the Succulent Karoo.[223] There appears to be a strong correlation between species richness and endemicity,[224] and there appear to be at least five clear foci of plant species diversity and endemism in Namibia.[155]

Excessive and increasing demands are placed on Namibia's plant resources, seriously limiting options for sustainable development. Concerted efforts must be made not only to document plant diversity, but develop action plans to protect plant resources, especially where threats are most acute.

Global and regional perspective

In general, the diversity of plants increases from the poles to the equator, but can also vary markedly on smaller scales.[225] Roughly two-thirds of the world's plant species grow in the tropics, half in Latin America and half shared between Africa and Asia.[219]

Fig. 2.50 Endemic *Adenia pechuelii*. Courtesy HH Kolberg

The remarkable diversity and high level of endemism in the southern African flora has been discussed in detail[226] and inventoried fully on an ongoing basis.[227-228] Southern Africa contains almost 10% of the world's flora, with an estimated 24 500 plant species.[228] The region has the largest number of vegetation types of all the floras in Africa, and is being studied primarily by locally-based botanists.[229] This diversity is concentrated in eight distinct hotspots, including two in Namibia (below).[230]

While southern Africa is famed for its diversity of higher plants, we do not know whether lower plants are as diverse. The regional and global status of bryophytes and pteridophytes is vague, as is the regional status of freshwater algae. The stoneworts occurring in Namibia are a small percentage of a cosmopolitan family.

National situation

The National Herbarium of Namibia (WIND), in existence since 1953, houses over 65 000 vascular plant specimens. In 1992 the National Botanical Research Institute was formed to include the National Herbarium, the National Plant Genetic Resources Centre (section 2.7), the Vegetation Survey Unit and the National Botanic Garden. A review of the inventory of Namibian taxa, based on herbarium holdings and literature,[231] is being updated as part of the *Flora of Namibia* project. Future publications will include neglected groups like the cryptogams, aided by the final computerisation of herbarium specimen data.

Fig. 2.51 The NBRI complex. Courtesy HH Kolberg

The following assessment of Namibian plant richness relies primarily on the floristic reference work *Prodromus einer Flora von Südwestafrika*,[232] published following collecting missions by the University of Munich in the 1960s and 1970s. Namibia is also included in the *Flora of southern Africa (FSA)* and partially in the *Flora Zambesiaca (FZ)* projects. Taxonomic revisions and monographs in the region contribute continuously to local records. However, plant distribution data in these publications are often based on inadequate collections, not uniformly gathered throughout Namibia. There are still large gaps where collecting activity has been low.[233] Lower plants are more poorly collected than other flora,[234-236] and have been subjected only to taxonomic and a few physiological studies due to a lack of in-country expertise.

A synopsis of the Namibian flora is given in Table 2.19, based on the NBRI's ongoing *Flora of Namibia* project. There are now 4344 higher plant species and infraspecific taxa recorded from Namibia, including naturalised taxa, as opposed to 3210 in *Prodromus*.[232] A recent global overview,[219] although based on outdated figures, credits Namibia with double the number of species of Botswana, four-fifths that of Angola and slightly less than those of Zambia and Zimbabwe. The Namibian flora resembles the Sudanese flora in number of species and infraspecific taxa, even though Sudan has nearly twice the land area of Namibia and more than twice the number of vegetation types.[229] Judgments by many taxonomists over many years, however, may make these direct comparisons misleading.

Namibia's dominant plant families are those for southern Africa as a whole. Most speciose are the Poaceae (grasses, approximately 422 species); Asteraceae (composites, 385 species); Fabaceae (legumes, 377 species) and Mesembryanthemaceae (vygies, 177 species). Orchids, the world's second largest plant family, are hardly represented in arid Namibia. The Scrophulariaceae is unusually dominant here, perhaps due to the occurrence of both tropical and arid environments.[229] The monotypic Welwitschiaceae, represented by *Welwitschia mirabilis,* is the only gymnosperm in Namibia. As a general rule, Africa has a very poor gymnosperm flora. Total species richness for Namibia will vary with further taxonomic revision and intensified collection. Certain dominant groups, such as the Mesembryanthemaceae, may be reduced in number when they are critically revised.

Data for freshwater algae are unavailable, as this group has received little attention despite its importance in freshwater ecosystems. Another poorly known hydrophytic group is the Charophyta (stoneworts). The cosmopolitan family Characeae is represented in Namibia by two genera and seven species, all important as food for waterfowl, but confusion still reigns in the taxonomy of this group.[237] A recent review by the NBRI[235] indicates that bryophytes are surprisingly widely distributed and successful in Namibia's arid environment. Altogether 91 bryophyte species (32 liverworts, 59 mosses) in 21 families are known to occur.

Twelve families of ferns occur in a great variety of habitats in Namibia, ranging from fully aquatic to xerophytic.[236] Currently, 61 species in 19 genera are recorded from this country. Two families, Adiantaceae and Marsileaceae, are highly diverse, with more than half of the southern African Adiantaceae and 13 of 16 Marsileaceae occurring here.

Distribution and areas of high richness

The southern Namib falls within the floristically rich, semi-arid Succulent Karoo, which holds about a third of all Namibian vascular plants.[155] This high richness may be due to the area's microclimatic variability. The southern Namib, like the adjacent Richtersveld region of South Africa, receives both winter and summer rainfall, with local aridity due to rain shadow effects. Coastal mists and fog from the west increase local climatic variability.[220] Recent speciation of succulent groups has also enhanced the area's richness, although the taxonomy of many groups needs revision, and the area's relative richness may partly reflect intensive sampling.

The Kaokoveld is known to have high floristic individuality,[223] but also shows relationships with other floristic regions. There are many endemic elements (defined as 100% of global distribution within Namibian political borders), as well as taxa related to the rest of the Karoo-Namib and to southern Angola. A number of species belong to taxa with disjunct distributions in arid regions on either side of the equator, indicating a former connection between southwest and northeast Africa.[238] A range of habitats is encountered in this district, due in part to its tremendous geological complexity.

The Otavi highland/ Karstveld area, in the Mountain Savanna and Karstveld (map 1.8) is a species-rich 'island' of higher altitude and rainfall within the broadly defined Kalahari Basin. This area supports relic populations of southern vascular plant elements with an earlier widespread distribution. The higher altitudes, cooler temperatures and sheltered sites also offer refuge from harsh conditions to mosses and ferns.[235,236]

High species richness in the Okavango region probably stems largely from the incursion of tropical species down the Okavango River. The river also supports elements of the Zambezian Domain, which is characterised by many widely distributed species. The high rainfall and habitat diversity of this region underlie its plant species richness. These habitats include wetlands, dry deciduous woodlands on sand, microphyllous woodlands on clay, riverine forests, and specialised habitats on quartzites in the Andara area.

High species richness in the Windhoek district partly reflects sampling effort, but the district has high altitude habitats such as the Auas Mountains (2479 m) which may support specialised taxa. Little is known of the flora of these mountains, the second highest in Namibia, despite their proximity to Windhoek.

Cryptogam distribution in Namibia must be described with caution due to scanty records. These groups appear to have the same general distribution patterns as the higher plants,[220] but this must be clarified by intensified collecting and taxonomic work.

Fig. 2.52 Cryptogams need biogeographic study in Namibia. Courtesy C Mannheimer

Table 2.19 Synopsis of Namibian plant taxa, including recognised infraspecific taxa

Taxon	Families	Genera	Species	Naturalised species	Total incl. naturalised
Algae (freshwater)	?	?	?	?	?
Stoneworts	1	2	7	-	7
Mosses/ liverworts	21	46	91	-	91
Ferns	12	19	61	1	62
Gymnosperms	1	1	1	-	1
Monocots	33	129	968	26	994
Dicots	124	730	3010	179	3189
Total	192	927	4138	206	4344

Table 2.20 A first estimation of endemic plant taxa in Namibia

Taxon	Endemic genera	Endemic species*
Algae (freshwater)	?	?
Stoneworts	-	1
Mosses/ liverworts	-	3
Ferns	-	1
Gymnosperms	-	-
Monocots	2	103
Dicots	14	579
Total	16	687

* *includes recognised infraspecific taxa*

Endemicity

A provisional listing of endemic plants in Namibia shows 687 taxa confined within the country's political boundaries (Table 2.20). This table is based on recent taxonomic studies which have vastly escalated previous estimates.[155] Near-endemics are not considered here, as there is uncertainty about the extent of their distribution in neighbouring countries, especially Angola.

We estimate that about 17% of the Namibian vascular flora is wholly endemic, a figure far exceeding estimates from most of our neighbouring countries. Except for Angola (24.3%) and South Africa (70%), Namibia surpasses Botswana (0.8%), Zambia (4.4%) and Zimbabwe (2.1%) with a surprisingly high degree of endemism for an arid region.[223, 239-241] Two regional centres of endemism fall partly within Namibia, as identified by Namibian botanists[155] and the Centres of Plant Diversity Project:[223] the Kaokoveld, in the Kunene and Erongo Regions, and the Succulent Karoo.

Kaokoveld endemics (23 taxa) are well-defined and often taxonomically isolated, such as the monotypic genus *Kaokochloa* (Poaceae). Many are endemic relics with connections to north-east Africa.[226,242] Intense recent speciation is occurring within certain groups, such as *Petalidium.*[243] In addition to 136 Namibian endemic taxa found in this region, 75 near-endemics are shared between the Kaokoveld and Angola.

An area unusually rich in endemic species is the Brandberg massif in the Erongo Region.[243] The Brandberg has eight of its own endemic plants, plus 80-91 Namibian endemics.[244] The altitude (2579 m) of this isolated relic inselberg, and the cool, moist conditions at its summit, could explain this high endemism. Although the Brandberg flora appears unique, further study of the surrounding inselbergs is needed to confirm this.

The Succulent Karoo of the southern Namib Desert is extraordinarily rich in endemics, with 180 Namibian endemic and nearly 200 near-endemic taxa. Recent speciation in succulent groups could contribute to this. The genus *Lithops*, for example, has 92% endemism, although the figure is inflated by infraspecific taxa. Most hot deserts have high endemism, despite their low plant cover, and mountains occurring in hot deserts considerably increase total endemicity.[245]

At present, rather few lower plant species wholly endemic to Namibia are known: one fern,[236] three mosses[235] and one stonewort (Table 2.20). However, numerous southern African endemics occur here. It has been suggested that Namibia partially represents a major centre of diversity and endemism for the xerophytic liverwort genus *Riccia.*[246] Too little is known of freshwater algae to estimate their degree of endemicity.

Conservation and harvesting

Plant species are disappearing at an alarming rate throughout the world, with 10% of recorded species classified as rare or endangered.[247] The survival of rare species is also jeopardised by unscrupulous specialist collectors. No reliable Namibian data exist, but legal and illegal trade in 'spectacular succulent' species such as the halfmens *Pachypodium namaquanum* is thought to be considerable. Efforts should focus not only on *in situ* protection of rare species, but also on controlling their commercialisation and export. Hilton-Taylor[248] cites red data status for 266 Namibian plants, compared to 56 in previous studies.[249] As elsewhere, the conservation status of plants in Namibia is dynamic, and will change with greater research effort and with environmental and social influences. A list of 478 plant taxa (Table 2.21) is proposed for protection under new draft environmental legislation (Chapter 5), excluding species protected under forestry law. Of the 365 taxa, 190 (28%) are endemic to Namibia, 24 (3.5%) of which appear on the CITES list. Most endemic taxa have not yet been assigned a conservation status.

Plant harvesting for export, local sale, or subsistence use is mainly poorly monitored in Namibia, but this is changing. Unsustainable harvesting can quickly pose a serious risk of local extinction for many species. Plant protection efforts need to include urban and peri-urban areas, which are often overlooked. Yet Namibia's national economy could only benefit by the non-destructive, sustainable harvesting of plant resources. The sale of succulent plants, for example, can generate substantial revenues if responsibly produced and marketed (Box 4.10). Overharvesting of species like devil's claw *Harpagophytum procumbens* would reduce exports and lose foreign exchange for Namibia as steadier markets are sought elsewhere. Degradation of plant communities through loss of diversity also has economic implications for land uses such as tourism (Chapter 4).

So far, Namibia is lucky not to have the degree of degradation and extinction experienced in many developing countries. Yet certain habitats face increasing threats which jeopardise plant species. Increases in human population, burgeoning exploitation of plant resources, large development projects, monoculture cash-cropping, and overgrazing are serious threats to the floristically rich areas such as the Okavango Basin, Kaokoveld and southern Namib.[155] The extent of these threats is not well documented, but the level of current protection is inadequate. Poorly documented plants are of special concern. For example, 21 of the 61 Namibian ferns are considered rare or very rare,[236] but have not received conservation attention to date. As for higher plants, conservation status assessment of many of these groups is impossible without better systematic and ecological data.

The role of protected areas

As elsewhere in southern Africa,[224] Namibia's protected area network is not well located with regard to hotspots of plant diversity and endemism(section 2.6). Only eight of the 13 vegetation types identified by Giess[5] contain protected areas, some of which represent less than 5% of that vegetation type[121] (Fig. 2.30).

Table 2.21 Plant taxa affected by old and new Namibian legislation*

Taxon	Forestry Ordinance		Nature Conservation Ordinance		IUCN listed	Alien, proposed
	Old	Proposed	Old	Proposed		
Algae (freshwater)	-	-	-	-	-	-
Stoneworts	-	-	-	-	-	-
Mosses/ liverworts	-	-	-	10	-	-
Ferns	-	-	-	20	-	-
Gymnosperms	-		1	1	1	-
Monocots	-		52	82	1	2
Dicots	49		334	365	31	33
Total	49		387	478	33	35

* *Chapter 5 gives details of Namibian environmental legislation*

Fig. 2.53 *Pachypodium namaquanum* may be threatened by unscrupulous collectors in Namibia. Courtesy P Tarr

Namibia must make earnest attempts to afford protection to neglected vegetation types. For example, the savannas occupied by commercial farmers for the last century or so have no formal conservation status, and have undergone significant ecological changes (section 2.2). Many farmers are sensitive to conservation needs, so the savanna receives some measure of *in situ* protection. However, the biodiversity of many commercial farms has undoubtedly been eroded through poor management.[250,251]

Namibian diversity or endemism hotspots, which should be a fundamental criterion for selecting conservation areas, fall outside such areas at present. For example, while the Succulent Karoo hotspot receives *de facto* protection as a restricted mining area, this is only a temporary concession (section1.2). Mining there causes some disturbance to the natural environment,[217] while recreational off-road driving and plant poaching pose a more serious threat. In the Kaokoveld hotspot, former protection within the originally vast 'Game Reserve No. 2' was lost through deproclamation in the 1960s.[50] Ironically, areas of high richness and endemicity are heavily used, support high human densities, or are targeted for major development projects. Rural people depend heavily on plants for their subsistence and livelihoods, and their involvement in decision-making and conservation monitoring is essential for the long-term success of plant conservation.[252]

Institutional linkages

The NBRI is responsible for undertaking and coordinating botanical research in Namibia. It needs to strengthen existing linkages and establish new agreements with international institutes. A regional project (Southern African Botanical Diversity Network) to coordinate botanical activities in southern Africa has recently been initiated, and will help ensure effective communication and data-sharing. Namibia could play a vital role in research and conservation regarding plant resources that are shared across borders. For example, strong floristic affinities exist between Namibia and Angola. Given Angola's ongoing political instability, Namibia could help promote and protect a threatened regional heritage.

The bioprospecting potential of Namibian plants appears good. More extensive surveys to document plant use in the field, and develop promising plant extracts in the laboratory, can be done through collaboration with internationally reputed institutes. Intellectual property rights and patenting issues need further legislative attention, however, so that Namibia benefits directly from product development (section 2.7; Chapter 5).

Box 2.17 Constraints on the improvement of botanical diversity knowledge

Namibia faces basic constraints of institutional capacity in countering threats to botanical diversity.

- *A lack of trained manpower, due to a lack of post-BSc training at the University of Namibia.*
- *Government budget shortages, which severely limit funding for research and staff. Donor agencies usually do not finance essential biosystematic work.*
- *Poor coordination and planning of botanical research in the past resulted in duplication, major gaps, and little systematic sampling.*
- *Baseline botanical data left the country with colonial civil servants and foreign scientists, adding to the duplication and lack of direction.*

The areas of greatest botanical importance are most at risk of land transformation due to inadequate conservation protection. Environmental assessments (EAs) are carried out for large development projects, as directed by the Namibian Cabinet.[253] Unfortunately, EAs are often carried out on corporate timetables, and can be ineffective if fieldwork is inappropriately timed, if studies are poorly coordinated, often using inexperienced foreign consultants, and if recommendations of EA reports are disregarded by developers.

Revised legislation for the protection of indigenous plants urgently needs completion, and measures for stricter enforcement are badly needed. Prosecution for plant poaching is currently difficult,partly because customs and conservation officials are untrained in the identification of rare and threatened species sought by collectors. Finally, mechanisms to recognise intellectual property rights and accrue benefits have not yet been designed, and there is so far no national mechanism to compensate local people for the use of genetic resources or local knowledge. In this vacuum, Namibia, like other nations, is being exploited by institutions in the industrial world.

To counter these threats, Namibia needs to:

- improve its botanical capacity through coordination and collaboration;
- prioritise its research activities;
- promote biosystematic research related to management needs;
- improve data access;
- intensify fieldwork in priority areas;
- update legislation and enforcement measures;
- promote the sustainable use of plant resources, especially for agricultural and pharmaceutical purposes; and
- develop mechanisms for the equitable sharing of benefits derived from this use.

Conclusions

Although much valuable floristic work has been undertaken in Namibia in the past, improved data and analysis are imperative for future conservation management. The NBRI, with affiliated institutions and individuals, is committed to this improved knowledge base.

Box 2.18 Major threats to botanical diversity in Namibia

Plant diversity is primarily threatened by rapidly increasing land transformation:

- *Conversion of land to agriculture* ***without incentives for good management*** *has led to overstocking, overgrazing, deforestation, bush encroachment, and the spread of invasive aliens.*
- ***Poorly considered development*** *includes unplanned urbanisation, dam building, water extraction, mining development and the improvement of road networks.*

Namibia has a high level of plant endemicity, as its taxa have adapted to its unique and harsh environments over evolutionary time. This endemicity is perhaps more impressive than the country's overall species richness. However, our plant resources, endemic or not, show tremendous potential for research and development. In particular, plants of possible use in agriculture and land reclamation could be extremely important, both here and in other arid countries experiencing land degradation.

Plants are fundamental to the maintenance of our ecosystems, and are the backbone of rural people's subsistence economies. The need for their effective conservation cannot be overstated in an arid country such as Namibia, where many people live on the edge of poverty. The sustainable use of plant resources must be advocated and controlled in energetic and creative ways, to ensure that plant resources will continue to sustain future generations.

— *Gillian L Maggs*

Fig. 2.54 Species richness and endemism is pronounced in groups such as the fishmoths (Thysanura). Courtesy E Marais

Rotifer diversity

Rotifers are a phylum of acoelomate worms, lacking a cavity between the intestinal canal and body wall. Most of us do not notice these tiny (40 micron - 2 mm) aquatic animals, distantly related to flatworms, gastrotrichs and nematodes. The small, degenerate males appear only briefly in the life cycle. In one class, the leech-like bdelloid rotifers, reproduction is parthenogenetic and males have not been recorded at all.

There are about 1800 rotifer species in 120 genera worldwide: a large number for a group so easily overlooked. Yet they are common and widely distributed on every continent; many species have worldwide distributions. Systematic study of Namibian rotifers has just begun. About 266 southern African species are known, many of which must occur in Namibia.

Rotifer species richness is higher in fresh than in very saline or alkaline waters. Yet a new rotifer was recently described from a saline Namib Desert spring, tolerating almost three times the salinity of seawater. As rotifers often live in ephemeral habitats, they must cope with periodic desiccation. Bdelloid rotifers simply retract themselves into bundles and dry out, resuming activity when they rehydrate. The monogonont rotifers lay fertilised eggs which can survive many years of drought. Due to their abundance, rotifers form an important link in aquatic food chains. They are eaten by larval fish and crustaceans, and are the basis of elaborate aquaculture enterprises in Japan and Israel.

— *C K Brain*

Poriferan diversity

Very little is known about freshwater sponges (phylum Porifera) in Namibia.[254] Two families are represented in Africa, and only three species have been collected from Namibia (Appendix 8). Sponges require clear, fairly permanent water, and are therefore not widespread here. Two unidentified species of *Potamolepis*, a tropical genus, occur in the northern perennial rivers: one in the Kwando and Chobe River systems, and one at Popa Falls on the Okavango. *Ephydatia fluviatilis*, a cosmopolitan species, is found at Nama Pan in Otjozondjupa, and its resistant 'gemmules' can be dispersed by wind, insects and birds. Unidentified sponges must occur in the Kunene and Cuvelai Basins, as *Sisyra producta*, a neuropteran larva parasitic on freshwater sponges, has been found in both places. Seven species are known from the Zambezi and three from south of the Limpopo River, all of which may occur in Namibia.[296] Sponges are rare and would be seriously threatened by any changes to the northern wetlands.

— *Barbara Curtis*

Cnidarian diversity

Freshwater species in the phylum Cnidaria (Class Hydrozoa) are also uncommon and little studied, with limited distributions.[254] Two groups occur in Namibia, hydras and freshwater jellyfish. *Hydra* species have been collected from rainwater pools in the Kuiseb River, from the Omatako Dam, and from streams in the Naukluft (Appendix 8). As they are very small, they are easily overlooked and may be more numerous than records suggest. The widespread jellyfish *Limnocnida tanganyicae* was collected in Lake Liambezi, Lake Lisikili, and the Kwando and Chobe Rivers. Hydras and freshwater jellyfish develop only in lakes and pools, and would be severely affected by the draining of wetlands.

— *Barbara Curtis*

Platyhelminth diversity

In the phylum Platyhelminthes, freshwater flatworms (Turbellaria) are not abundant, and little Namibian work has been done on them.[254] Only one species, *Mesostoma brincki*, has been positively identified from Namibia. Unidentified specimens have been collected from running water in the Naukluft mountains, pools in the Namib and eastern Caprivi, pools and pans in Otjozondjupa, and farm dams.

The parasitic flukes (Trematoda) are very important medically in Namibia, and most have molluscs as intermediate hosts.[254] Four *Schistosoma* species, which cause bilharzia, occur in the Okavango and eastern Caprivi rivers. *Calicophoron microbothrium,* the conical fluke parasite of livestock, has been found in scattered localities, although few dissected snails have contained parasites. Veterinary records are confined to northern and northeastern Namibia. *Fasciola gigantica*, a livestock liver fluke, occurs in the northeast, with scattered clinical records from the south. Other parasites presumably occur in large numbers but are poorly recorded. The tapeworms (Cestoda) are a group of parasites of medical importance for which very little information is available.
— *Barbara Curtis*

Bryozoan (ectoproctan) diversity

Bryozoans are sessile, aquatic colonial animals, which superficially resemble moss or algae. They are found in temporary and permanent waters, are rarely collected and are often overlooked. They have been split into two phyla: the Entoprocta, not known from southern Africa, and the Ectoprocta. Five species in two families are known from Namibia. The three *Plumatella* species are cosmopolitan, and *Lophopodella capensis* and *L. thomasi* occur elsewhere in southern Africa.
— *Barbara Curtis*

Nematode diversity

In the phylum Nematoda, free-living freshwater roundworms have been poorly collected in Namibia.[254] As very small substrate dwellers, they are easily overlooked. Of the ten positively identified species in Namibia, five were described from this country and could possibly be endemic (Appendix 8). Unidentified specimens have been collected from small pans in the Etosha National Park and eastern Otjozondjupa. Work is needed to establish the group's conservation status.

Nematodes are generally abundant in any kind of water body, where they form an important group of decomposers. In South Africa, freshwater nematodes are much less diverse than terrestrial nematodes.[256] Although many terrestrial nematodes are of agricultural significance in southern Africa (Appendix 5), little is known of their occurrence in Namibia. The same is true of parasitic nematodes.
— *Barbara Curtis*

Annelid diversity

In the phylum Annelida, the earthworms (Oligochaeta) have been poorly studied in southern Africa, and no Namibian freshwater oligochaetes have been recently identified.[254] Ten species in five families were noted in 1914, but some of the identifications are doubtful. In recent years unidentified specimens have been found in a variety of habitats including caves, pans, pools, rivers and broad floodplains throughout the country, and two unidentified species from different genera have been found in Lake Liambezi.

Fig. 2.55 *Lymnaea* sp. is a host of *Fasciola* liver flukes. Courtesy National Museum of Namibia

Terrestrial earthworms are little known, despite their agricultural importance. Werger[220] listed 132 South African species in nine genera, and noted two genera from Namibia. An unknown number of alien earthworm species have been inadvertently or intentionally imported, mainly from South Africa, in potted plants for the nursery trade and as bait for anglers.[257] These may pose problems for indigenous species, but the extent of any problem is unknown.

The leeches (Hirudinea) are far better known in the region and have been well collected in Namibia.[258] This mainly freshwater group is represented in Namibia by two families and 15 species (Appendix 8). Many species are fairly widespread in natural waterbodies and farm dams in the country, and all described species have a wider distribution in southern Africa. In Namibia *Placobdelloides jaegerskioeldi* and *Asiaticobdella fenestrata* have been found only in eastern Caprivi, while *Aliolimnatus obscura* has been found only in its type locality in the Naukluft Mountains. Two others have type localities in Namibia. Species which are probably endangered in Namibia are those known only from single localities, such as *A. obscura* and *P. jaegerskioeldi*, which depend on hippopotami as hosts. All play an important ecological role as predators and scavengers.
— Barbara Curtis

Mollusc diversity

By far the greatest richness of freshwater species in the phylum Mollusca occurs in the Okavango and eastern Caprivi rivers, with 20 species of gastropods[259] and nine bivalves. This is the southernmost range limit for many species. The Kunene River appears to have a far less diverse mollusc fauna, with seven species of gastropods and six bivalves. This may be due partly to less intensive collecting, as the Kunene is far less accessible than the eastern rivers, and partly to the Kunene's ecological isolation from other major rivers.[254]

The snails and limpets (Gastropoda) are represented by 24 snail and two limpet species in nine families. Most are restricted to the northern perennial rivers, but a number occur throughout Namibia, notably *Bulinus tropicus*. Most freshwater gastropods have a wide African distribution.[260] *Bellamya monardi* is endemic to the Okavango and Kunene River basins and would be threatened by any interference with these rivers. *Pila occidentalis* is endemic to Angola, Namibia and Botswana, and *Melanoides victororiae* is a southern African endemic. Many species have very restricted ranges in southern Africa, but more collecting is needed to establish their distributions. Some unidentified specimens may be new species. *Bulinus angolensis* occurs in Angola and possibly Namibia. It was recorded in 1970 from streams draining into Etosha Pan,[259] but has not been collected since, and may have been misidentified.

Species of medical importance as hosts to human bilharzia parasites (schistosomes) are *Bulinus globosus*, which is confined to the rivers of the north, and *Biomphalaria pfeifferi*, which occurs in the northern rivers and the Karstveld springs. *Bulinus tropicus*, which is host to livestock and game schistosomes as well as to *Calicophoron microbothrium*, is widespread and common in Namibia except in the arid west. *Bulinus forskalii*, a potential host, is also widespread but less common. Other recorded species may have been misidentified.[259] Host snails for the livestock liver fluke *Fasciola* are *Lymnaea natalensis* and *L. columella*. The former is abundant in the northern rivers and intermittent throughout the rest of the country. The latter, an introduced North American species which is rapidly spreading through Africa,[260] has been found in Namibia, but not yet in the northern rivers. Both occur in the Orange River.[261]

Two other introduced species occur in Namibia. So far the planorbid *Helisoma duryi* is confined to fish ponds, but could spread if allowed to escape. *Physa acuta* has been collected in the Fish and Orange Rivers. Both are attractive species used by aquarists to keep fish tanks clean.

Clams and mussels (Bivalvia) are represented by 13 freshwater species, most confined to the perennial rivers. At least eight bivalve species are endemic to southern Africa.

Namibia's major wetlands in the Okavango and Caprivi Regions are less species-rich than more tropical areas to the north. However, Namibia has a fairly high species richness given its overall aridity. More work on the Kunene River is needed, and there are likely to be unrecorded species among very small species, such as limpets. The bivalves of ephemeral waters also merit further study. Species of importance as a food source to rural people in the north are the snails *Pila occidentalis* and *Lanistes ovum*, and the mussel *Mutella dubia*.[254]

There is far greater endemicity among terrestrial than freshwater molluscs, due to the unique adaptations fostered by our arid habitats. All terrestrial species are gastropods. Of approximately 65 species known from Namibia, 40 are endemic to the South West Arid zone, and nine endemic to Namibia. There are four genera and one family endemic to the South West Arid zone, comprising 60% of the terrestrial snails of Namibia. In addition, there is one indigenous slug. The genus *Afriboysidia*, with three species, is wholly endemic to Namibia, while 90% of the ranges of the genera *Dorcasia* and *Sculptaria* are in Namibia. Very little is known of their biology, and the group as a whole merits further study and conservation due to its high species richness and endemicity.[220]
— *Barbara Curtis*

Arachnid diversity

The class Arachnida in Namibia consists of the spiders, scorpions, opiliones, amblypygi, pseudoscorpions, solifuges, ticks, and mites. Ticks and mites (Acari) are very poorly known and are not discussed here; the remainder are known collectively as non-acarine arachnids.

Several traits of non-acarine arachnids make them good biodiversity indicators. They are abundant, speciose and relatively easy to collect. Most orders have small ranges, and species found in an area are likely to be resident there, with many species endemic to restricted areas. They are predators, preying mainly on other arthropods, and are thus sensitive to pollution and habitat destruction.

Data sources

Data on occurrence and distribution were obtained from collections of the British Museum (Natural History), Natal Museum, National Museum of Namibia, Plant Protection Research Institute, South African Museum, and Transvaal Museum, as well as published literature. Occurrence localities for species of spiders, scorpions and solifuges were mapped and classified according to the 14 major vegetation types in map 1.8.[5] Endemic species, defined as those whose distribution occurs 100% within Namibia's borders, and areas of high species richness and endemism were determined from these maps. Spiders, scorpions, and solifuges were deemed to have suitably reliable information for the determination of distribution and endemism. In the case of spiders, however, only 68 recently revised species were mapped.

Species richness

A total of 821 species, 296 genera, and 69 families of non-acarine arachnids in the groups Araneae, Solifugae, Scorpiones, Pseudoscorpiones, Opiliones and Amblypygi are known from Namibia (Table 2.22). A recent checklist of Namibian spiders[262] and later species descriptions[263-267] indicate that 587 described species of spiders are known from Namibia and immediately adjacent areas (Table 2.22). However, based on estimates made for world spider faunas, eighty percent of our spiders may still be unknown.[268,269] An estimated 124 solifuge species occur or are expected to occur in Namibia,[270] and recent fieldwork suggests that this figure will increase by ≥ 25% as their taxonomy is clarified.

Fig. 2.56 Namibia has a rich fauna of large sand dwelling spiders. Courtesy E Griffin

Fig. 2.57 With 124 species, Namibia may have the richest solifuge fauna in the world. Courtesy E Griffin

Apart from the 56 scorpion species established for Namibia,[271,272] there are at least another six species awaiting description. Von Beier[273-278] lists 40 species of pseudoscorpions from Namibia. Due to a lack of recent work and good taxonomic keys for the southern African pseudoscorpions, it is difficult to estimate the percentage of unknown Namibian species. Eleven species of opiliones are listed as occurring in Namibia,[279-281] five of them probably introduced from South Africa, possibly with pot plants. Three species of amblypygi are known from Namibia,[282,283] and this figure may be easily doubled.

Species richness and vegetation type

Table 2.23 outlines known spider, scorpion and solifuge species richness by vegetation type. To some extent, these figures reflect the collection history and the size of the zone. The high species richness in the Forest Savanna, Mopane Savanna and Central Namib Desert vegetation zones, for example, partly reflects intensive study over nearly 50 years by Lawrence.[282-286] The Succulent Steppe and Desert zone is also relatively well known due to early collecting. Such biases can be highly misleading when assessing distribution data. Although conclusions about endemism and richness are drawn conservatively in this paper, they should be treated as strictly preliminary.

Table 2.22 Arachnid taxon richness in Namibia and immediately adjacent areas

Order	Families	Genera	Species	Est.% known
Spiders	50	238	587	20
Solifuges	6	25	124	70
Scorpions	4	7	56	85-90
Pseudoscorpions	5	18	40	70
Opiliones	3	5	11	80-90
Amblypygi	1	3	3	70
Mites and ticks	142	292	590	20
Total	211	588	1411	

High species richness of spiders in moist areas such as the Forest Savanna and Woodland (map 1.8), with annual rainfall of 300 - 700+ mm (map 1.1), is probably related to the greater density and diversity of trees and large bushes which are important habitat. Comparative work on ground-living spiders in Forest Woodland of adjacent northwestern Botswana[287] showed that wolf spiders, mouse spiders and jumping spiders were dominant. Namibia displays the same taxon diversity and species richness of ground-living spiders in its Forest Savanna and Woodland.[47]

Namibia's arid areas give a different picture. The numerically dominant families in desert areas are known for their adaptations to arid conditions. Spider communities are generally most speciose in areas with rainfall of over 300 mm/yr; solifuges are mainly found in dry sandy areas with rainfall of under 200 mm/yr, especially the sand seas of the southern Namib, and scorpions are most species rich in low rainfall areas of both rocky (Namib escarpment), and sandy substrates.[47]

Table 2.23 Spider, solifuge, scorpion species in Namibian vegetation types[47]

Vegetation type*	Spiders	Solifuges	Scorpions	% veg. type/ Namibian total	Species/km²
Forest Savanna & Woodland	153	5	7	20	0.0110
Mountain Savanna & Karstveld	22	3	6	3	0.0015
Thornbush Savanna	36	14	13	5	0.0014
Mopane Savanna	115	22	21	16	0.0012
Saline Desert with Dwarf Shrub Savanna fringe	25	13	7	1	0.0041
Highland Savanna	33	21	16	3	0.0027
Camelthorn Savanna	41	7	8	8	0.0008
Mixed Tree & Shrub Savanna	9	14	14	7	0.0006
Semi-Desert & Savanna Transition	33	14	19	6	0.0014
Dwarf Shrub Savanna	63	30	22	16	0.0008
Succulent Steppe & Desert	95	27	20	5	0.0034
Central Namib Desert	45	27	19	3	0.0038
Southern Namib Desert	8	10	6	4	0.0007
Northern Namib Desert	9	4	13	3	0.0011

** Vegetation types after Giess.[5]*

Endemism

Based on the mapped distributions of 68 better-known spider species, 26 (38%) appear to be endemic to Namibia. Thirteen endemics are found only in the Namib Desert, of which seven are confined to sand dunes.[47] The genera *Leucorchestris* and *Carparachne* occur only in the Namib Desert. Three of the seven *Leucorchestris* species have northern Namib Desert distributions extending slightly into Angola. Both genera have highly specialised behaviour which enables them to survive in the Namib Desertsand dunes.[288,289] Another endemic, the monotypic genus *Arandisa*, is found only on rocky hillsides bordering the northern Namib Desert dunes. *Paradonea*, a monotypic genus, appears to be endemic to northeastern Namibia, yet it is likely that future collectors will find this genus in Botswana. The genus *Loxosceles* is commonly found in caves, and several species (some undescribed) are known only from caves in northern Namibia. There appears to be a high incidence of endemics in the family Lycosidae, but this probably reflects a need for taxonomic revision.

Of the 127 mapped solifuge species, 47 (37%) appear to be endemic, with nine genera occurring only in Namibia. Namibia probably has the highest solifuge richness in the world. Twenty-eight solifuge species are endemic to the Namib Desert. Three of these, in the monotypic genera *Eberlanzia*, *Unguiblossia*, and *Prosolpuga*, are found only in sand dunes. The endemic *Ceroma inerme* has adapted the normal solifuge xerophilic behaviour to become virtually a marine species, living just outside the high tide zone and foraging in the intertidal area at low tide. Five species and a monotypic genus are known only from the cool Highland Savanna. Most solifuges appear to have very restricted ranges, and may be habitat dependent.

Of the 56 known scorpion species, 14 (25%) are endemic to Namibia. One endemic genus includes a species found only in caves of the Mountain Savanna and Karstveld. Seven species are found only in the Namib Desert, of which three are confined to sand dunes. One species of rock scorpion, *Hadogenes lawrencei*, is only found on an inselberg in the Namib Desert sand sea.[47]

Fig. 2.58 *Opisthethalmus haackei*, one of at least 56 scorpion species in Namibia. Courtesy E Griffin

Fig. 2.59 Orb-dwelling savanna spider. Courtesy E Griffin

Conservation status

Based on species distribution maps, it appears that five endemic spiders have no protection in publicly owned conservation areas. The Von Bach Recreation Resort and Daan Viljoen Game Park (Box 1.9) are felt to be too small to provide adequate species protection. Six endemic solifuges and five endemic scorpions are totally unprotected. There is no formal red data book or similar analysis of Namibian arachnids, due to the incomplete basic data on their ecology, taxonomy and distribution.

The Namibian arachnid fauna is essentially arid-adapted, yet it is reasonably species-rich. There is pronounced endemism, particularly in desert-dwelling groups. Unfortunately, there are insufficient data on arachnids in adjacent areas, such as Namibe Province in Angola. Taxonomic and distribution data on national, regional and continental arachnid faunas are lacking everywhere, making it difficult to compare faunas. Platnick's[290] postulation that the moist equatorial tropics are not inordinately rich, relative to the semi-arid subtropics, is likely to be borne out as arachnological research in arid regions progresses.
— *Eryn Griffin*

Box 2.19 Gaps in arachnid diversity conservation

- ***Taxonomic support*** *is needed to improve the reliability and accuracy of almost all biological databases in Namibia, including that on arachnids.*
- ***National field surveys*** *need to increase the evenness of sampling effort. Priority areas for sampling are the central and southern Kalahari Desert, Aus, and the Otavi highlands.*
- ***Important areas needing protection*** *for arachnids are the Otavi highlands, central Erongo Region, caves in Kunene Region, and the areas around Windhoek, Okahandja, Keetmanshoop, Karasburg, Aus and Rosh Pinah.*

Crustacean diversity

Freshwater species in the class Crustacea are best represented in ephemeral waters in Namibia. The two key groups are Ostracoda and Branchiopoda, most of which occur in temporary pools. Curtis[254] gives a preliminary species list, which is summarised, including additional species recorded since the list was published, in Table 2.24.

The Ostracoda are the most diverse group, with 52 species recorded. At least 18 species have been collected only in this country, and are likely to be endemic. *Ovambocythere, Apatelecypris, Eundacypris* and *Afrocypris* are all endemic genera. Another five species are confined to the arid regions of Namibia and Botswana, and ten species are widespread in Africa. There may be up to 70 Namibian species.[254] Only three species have been found in saline pools, by contrast to other countries with numerous saline lakes, such as Australia which has higher species richness.[291] No ostracods have been identified from large rivers, and none of the genera associated only with permanent rivers occur in Namibia.

Table 2.24 Crustacean taxon richness in Namibia*

Subclass	Order	Families	Genera	Species
Ostracoda	Podocopida	3	24	52
Copepoda	Calanoida	1	5	10
	Cyclopoida	1	8	9
Branchiopoda	Anostraca	3	3	19
	Cladocera	5	9	19
	Notostraca	1	1	2
	Conchostraca	6	8	15
Malacostraca	Amphipoda	2	3	6
	Isopoda	1	3	4
	Decapoda	3	3	6
Total		26	67	142

* *Source: Curtis et al.*[102]

Namibia has many unknown and unusual ostracods. *Sarscypridopsis ochracea*, also found in South Africa and Tanzania,[292] has only been found in pools associated with Rössing Uranium Mine — in tailings dams, natural springs, and seepage water below tailings dams. New species, genera and perhaps even a tribe have been found in a spring at Sesfontein and a farm dam in the Gobabis District. Many species appear to have highly restricted ranges. A high degree of endemism is expected, since ostracods cannot actively disperse from one water body to another and rely on agents such as wind and waterbirds. They survive long dry periods in the form of resistant eggs buried in the mud, and may thus remain isolated in their pools for many generations. Due to their endemicity, the ostracods should be regarded as an important group, worthy of conservation protection.

Many species of Branchiopoda are typical of ephemeral pools and are thus plentiful in Namibia, but less diverse than the ostracods. Namibia has at least 19 species of fairy shrimps (Anostraca) in three families. Most are widespread in southern Africa, but six may be endemic. The tadpole shrimps (Notostraca) comprise one family with two species found throughout southern Africa. The clam shrimps (Conchostraca) comprise 15 species which are widespread in southern Africa, although three described from Namibia may be endemic. Water fleas (Cladocera) are a widespread planktonic group containing between 19 and 24 species in five families from Namibia. In the Copepoda, 19 species are recognised, some confined to the drier areas of southern Africa and some found as far northeast as Ethiopia.

Freshwater sand fleas (Amphipoda) and sowbugs and pillbugs (Isopoda) have only been found in karst caves. Six amphipod and four isopod species have been recorded, of which eight were described from Namibia and are probably endemic. *Trogloleleupia dracospiritus* is endemic to Dragon's Breath Cave in the Karstveld area, and *T. gobabis* is endemic to Arnhem Cave.[293,294] With their unique habitat and restricted range, these are threatened by any interference with groundwater.

Fig. 2.60 *Trogloleleupia dracospiritus.* Courtesy E Marais

The Decapoda contains six species in three genera found in perennial southern African rivers. One of these, the edible shrimp *Macrobrachium vollenhoveni*, reaches its southern limit at the Kunene River and may be imperilled if dams built on the river reduce water supply to the lower part of the river.[254]

Because of the high apparent endemism of the freshwater Crustacea (Table 2.18), their unusual adaptations to ephemeral habitats, and their importance in the food chain, this group warrants conservation attention. Much taxonomic work remains to be done, and the only quantitative ecological data are for various water storage dams.[295,296]

—Kevin Roberts, Nicholas Clarke & Barbara Curtis

Fig. 2.61 *Scolopendra morsitans.* Courtesy M Griffin

Fig. 2.62 A fatal duel in Omaheke. Courtesy E Marais

Myriapod diversity

The class Myriapoda includes centipedes and millipedes. Approximately 2780 species of centipedes are known worldwide, and 29 occur in Namibia (Table 2.25). Of these, six species are thought to be endemic to Namibia. Neighbouring South Africa has 130 known species. Bearing in mind that most centipedes are from tropical and subtropical ecosystems, the relatively few species known from Namibia indicate that this class is one of the poorest known invertebrate taxa in this country.[107,297-299] The majority of Namibian centipede species occur along the escarpment. Of the five known endemics, three occur in the escarpment, one in Lüderitz and Possession Island, and one in the Highland and Thornbush Savannas.

There are approximately 8375 species of millipedes known worldwide, of which 16 species in four orders are known from Namibia (Table 2.25). South Africa has over 400 species in seven orders. Millipedes require humid conditions, and so most are found in the tropics. In Namibia, millipedes survive by living in protected humid habitats such as in soil, or under logs or stones. Most Namibian species live in areas with a mean annual rainfall of over 500 mm, but the eight endemics are found in areas with under 200 mm of annual rainfall.

— Eryn Griffin

Table 2.25 Myriapod richness and endemism in Namibia

Order	Family	Species	Endemics
Centipedes			
Scutigerida	Scutigeridae	1	
Lithobiida	Henicopidae	2	
Scolopendrida	Scolopendridae	18	5
	Cryptopidae	1	
Geophilida	Oryidae	2	
	Chilenophilidae	4	1
	Schendylidae	1	
Millipedes			
Polyxenida	Polyxenidae	1	
Spirobolida	Spirobolidae	1	1
Spirostreptida	Harpagophoridae	4	1
	Ondontopygidae	6	4
	Spirostreptidae	3	1
Polydesmida	Polydesmidae	1	1

Insect diversity

Aquatic insects

Insects dominate most freshwater ecosystems, although relatively few insect taxa have colonised aquatic environments. These include orders in which the larvae depend on water for their development but the adults are terrestrial; orders which have some members with aquatic larvae; and those in which both adults and larvae live in water.[254] A fourth group includes essentially terrestrial groups, such as staphylinid beetles and some mole crickets, which live at the water's edge or in wetland vegetation. An overall provisional inventory of insect taxa, both aquatic and terrestrial, is given in Table 2.26 below.

Mayfly (Ephemeroptera) nymphs occur in most wetland habitats in Namibia, but prefer cool, clear, running water. Southern Africa has eleven families,[300] of which five occur in Namibia. All species identified so far occur more widely in southern Africa, and some beyond. None is known to be endemic, but much more study is needed. Two small families of stoneflies (Plecoptera) occur in southern Africa, and are limited to running water habitats. The two Namibian species were recorded from the Kunene River and are more widely distributed in Africa, but have a very restricted range in Namibia. Caddisflies (Trichoptera) are also associated with permanent running water and clean, well oxygenated lakes or dams. They are thus not abundant in Namibia, but occur in the Kunene, Fish, and Okavango Rivers and elsewhere. At least 100 more species could be added to the list with further collecting and identification.

The last order with entirely aquatic nymphs is the Odonata, or dragonflies and damselflies. Nymphs are common in virtually all aquatic habitats, but most species in Namibia inhabit permanent water bodies. Several species can develop rapidly in temporary rain pools.[301] Most species have a wide distribution in Africa or are cosmopolitan. There are 22-26 damselfly species in six families. Two restricted range species are *Agriocnemis angolensis angolensis*, an endangered species which occurs in southern Angola, extending to the Namibian border rivers, and *Metacnemis valida*.[302] There are about 50 dragonfly species in four families. *Aeshna minuscula* from Otjiwarongo is one of seven southern African endemics, and is apparently rare in Namibia.

Of those orders where some taxa have aquatic larvae, only the Diptera and the Neuroptera have been found in Namibia. The flies (Diptera) are represented by twelve families, of which the largest and best known is the medically-important mosquito family (Culicidae). In Namibia, 52 species in eight genera have been recorded, but only five carry diseases: Rift Valley fever (*Aedes caballus* and *A. lineatopennis*) and malaria (*Anopheles funestus*, *A. arabiensis* and *A. gambiae*). *Anopheles fontinalis* and *A. namibiensis* have only been collected in Namibia and may be endemic.

The midges (Chironomidae) are more widespread in Namibia. The larvae live in benthic sediments. So far, 27 species in 18 genera have been described, largely from the Kaoko area. Most have a widespread African distribution, but *Archaeochlus biko* and *Knepperia gracilis* were described from Namibia and may be endemic. Very little is known about the Afrotropical horseflies (Tabanidae), which occur widely in Namibia. Three species are described only from this country and may be endemic; the others are widespread in Africa. Some species of biting midges (Ceratopogonidae) have truly aquatic larvae, while other species breed in damp habitats. Those with aquatic larvae may represent eight species in four genera in Namibia, most of which are widespread in Africa. At least three other genera are represented by undescribed species.

Female blackflies (Simuliidae) are important in central and eastern Africa, as the carriers of parasitic diseases. The most important vector of human onchocerciasis, *Simulium damnosum*, was previously thought not to occur in southern Africa, but has recently been identified from the Okavango River.

Fig. 2.63 *Trithemis* sp., Odonata. Courtesy E Marais

Fig. 2.64 *Zophosis amabilis*. Courtesy E Marais

Four other *Simulium* species have been collected from Namibia, mainly in the Okavango. Extensive sampling of the perennial rivers should yield at least 30 - 40 simuliids. The southern African endemic genus *Prosimulium* may also have additional undescribed species in Namibia, and needs further study. Not enough is known about other families in Namibia to merit comment.

Only one neuropteran family, the Sisyridae, has aquatic larvae. These are parasitic on freshwater sponges (see Porifera), and *Sisyra* spp. have been collected in the former Owambo[85] and Popa Falls, Okavango River. As freshwater sponges have a very limited distribution, *Sisyra* is also limited and of conservation concern.

The two orders with wholly aquatic species are the Coleoptera and Hemiptera. Both are important in freshwater systems. The adults of most species can disperse from one habitat to another, but the larvae are confined to water and thus more vulnerable to environmental degradation.

In the beetles (Coleoptera), many species have an aquatic lifestyle in littoral habitats, often associated with decaying vegetation. The largest aquatic family is the Dytiscidae or diving beetles, with at least 63 species in 20 genera in Namibia, compared with about 230 species in 38 genera in southern Africa. Most Namibian species are widespread in Africa, although some are southern African endemics. Several are Southwest Arid Zone endemics (*e.g. Yola endroedyi, Yolina brincki*), while others (*e.g. Hyphydrus esau*) occur only in the wetlands of East Caprivi and Botswana. *Canthyporus guttatus* and *Hydaticus fulvoguttatus* have only been collected from the Windhoek district and may be endemic. These species should all be regarded as of conservation concern.

The second most common family of beetles is the Hydrophilidae, with 14 known Namibian species in nine genera, ascompared to 80 southern African aquatic species in 16 genera. Seven species of whirligig beetles (Gyrinidae) are known here and are mostly widespread, although *Orectogyrus elongatus* is probably confined to northern Namibia and Angola, and *Aulonogyrus abdominalis* is endemic to southern Africa. Other poorly represented and easily overlooked beetle families are the Sperchidae, Hydraenidae, Limnichidae, Heteroceridae, Dryopidae, Georyssidae and Elmidae. Many beetles are confined to the northern permanent rivers in Namibia, or to the springs and ephemeral rivers of the northwest. Most beetles can fly from one waterbody to another and avoid desiccation when pools dry up.

The aquatic bugs (Hemiptera) are not well known in Namibia, but the most common and widespread families are backswimmers, Notonectidae, and water boatmen, Corixidae. Backswimmers occur in shady, clear patches of standing or slowly flowing water. They comprise the genus *Anisops* (at least ten species) and *Enithares sobria*. Other than a new species described from Namibia, all are fairly widespread in Africa. Ten corixid species in three genera are known from Namibia. Most are common and widespread, but *Micronecta hessei* and *M. browni* were described from Namibia and may be endemic. Less common families such as the Belostomatidae, Naucoridae, and Nepidae are represented by a few species each.

The best known semi-aquatic bugs are probably the water striders (Gerridae). Only three species have been recorded for Namibia, but are found throughout the country on almost all waterbodies. *Naboandelus, Neogerris* and *Tenagogonus* have also been shown on distribution maps for Namibia.[303]

Other semi-aquatic families, such as the Veliidae, Mesoveliidae, Hebridae, Pleidae and Hydrometridae, appear to have few species in Namibia. Some species are tiny and may be undersampled. Many are widely distributed in Namibia, and most are widespread throughout Africa.
— *Barbara Curtis*

Terrestrial insects

Southern Africa has a rich and varied insect fauna of 26 orders, with approximately 580 families and more than 100 000 species.[304] About 40% of the southern African savanna fauna is expected to occur in Namibia, and more than 60% of the Nama-Karoo fauna. Based on the very conservative estimate of 100 000 southern African insect taxa, it is thought that only between 5% and 20% of the Namibian fauna has been catalogued. Many insect groups still await taxonomic revision or more comprehensive collecting. Sampling to obtain voucher material will thus remain a priority for some time.

This synopsis of Namibia's terrestrial insect fauna was determined from more than 900 publications on African or Namibian fauna, and from holdings of the Namibian National Insect Collection (NNIC) at the National Museum of Namibia (section 2.7).[305] No foreign collections were examined, although some are known to contain unpublished records from Namibia. Retrieval of published data on Namibian insects is ongoing, and the NNIC database is constantly updated. The greatest obstacle to summarising these data is the scarcity of recent faunal and ecological reviews. This review should thus be regarded as indicative, rather than comprehensive.

Species richness

Table 2.26 summarises a provisional inventory of the insect fauna of Namibia. Dominant families of Namibian insect fauna reflect those in southern Africa as a whole, such as bugs (Hemiptera), grasshoppers and crickets (Orthoptera), beetles (Coleoptera), flies (Diptera), moths and butterflies (Lepidoptera) and wasps, bees and ants (Hymenoptera). As an absolute minimum, about 63% of families known to occur in southern Africa have been recorded in Namibia. However, many families in the NNIC have not yet been examined by specialists, and many identified species in other collections have not been published.

Due to a lack of baseline data for most taxa, insect richness in Namibia cannot be compared to that of the entire southern African region at a level higher than family, except for several well researched families. These include fishmoths (Lepismatidae) and some grasshoppers (Lathiceridae and Charilaidae). Other well known groups with distributions largely in Namibia include two small families of crickets (Bradyporidae and Schizodactylidae), mydas flies (Mydidae), three subfamilies of grasshoppers (Acrididae: Echinotroinae, Euryphyminae and Lithidiinae), thread-winged lacewings (Nemopteridae: Crocinae), tenebrionid beetles of the tribes Molurini, Adesmiini, Euchorini and Zophosini, the flightless dung beetle *Pachysoma* and the leaf chafer *Sparrmania* (Scarabaeidae), jewel beetles of the genus *Julodis* (Buprestidae), and snout beetles of the genera *Leptostethus* and *Hyamora*.

Fig. 2.65 Fog-basking tenebrionid beetle, Namib Desert. Courtesy MK Seely

Table 2.26 Synopsis of insect taxa in Namibia and southern Africa

	Families		Genera	Species	
	Namibia	Region		Namibia	Region
Springtails (Collembola)	2	?	2	2+	?
Proturans (Protura)*	0	?	0	0	?
Diplurans (Diplura)*	0	?	0	0	?
Bristletails (Archaeognatha)	1	1	1	1+	20+
Fishmoths (Thysanura)	2	2	16	53+	60+
Mayflies (Ephemeroptera)	4	11	8	9+	190+
Dragonflies, damselflies (Odonata)	10	11	41	77+	200+
Cockroaches (Blattodea)	3	3	23	50+	180+
Termites (Isoptera)	4	5	25	40+	210+
Mantids (Mantodea)	4	4	46	92+	120+
Earwigs (Dermaptera)	3	4	4	4+	50+
Hemimerins (Hemimerina)*	0	1	0	0	2
Web spinners (Embiidina)	?	3	2	2+	40+
Stoneflies (Plecoptera)	2	2	2	2+	20+
Grasshoppers, locusts, crickets (Orthoptera)	22	30	164	278+	780+
Stick insects (Phasmatodea)	?	4	5	12+	?
Booklice (Psocoptera)	?	16	1	2+	80+
Lice (Phthiraptera)	12	19	28	47+	1 090+
Bugs, leafhoppers, cicadas, aphids, etc. (Hemiptera)	62	87	389	729	3 900+
Thrips (Thysanoptera)	?	5	9	16+	230+
Alderflies (Megaloptera)*	0	2	0	0	7
Lacewings (Neuroptera)	11	12	50	99+	430+
Beetles (Coleoptera)	62	102	853	2 427+	17 500+
Scorpionflies, hangingflies (Mecoptera)	1	1	1	2+	30+
Flies (Diptera)	61	91	351	877+	6 300+
Fleas (Siphonaptera)	8	8	19	45+	100+
Caddis flies (Trichoptera)	?	18	10	15+	220+
Moths, butterflies (Lepidoptera)	50	73	445	819+	6 750+
Sawflies, wasps, bees, ants (Hymenoptera)	39	65	245	631+	3 850+
Total	363+	580	2 640+	6 331+	42 360+

* *Not recorded from, and unlikely to occur in, Namibia*

Many Namibian insect genera are highly distinct taxonomically and contain only a single species, as shown by the relatively low genera to species ratio (Table 2.27). Low ratios often reflect simple communities caused by a history of highly variable climates, barriers to colonisation by species, or uniform or harsh environments. In the Namib Desert, perhaps the most adverse habitat in Namibia, the monotypic genus is the exception rather than the rule. The low species to genus ratios may also reflect a poorly recorded or reviewed fauna.

Endemism

Table 2.28 gives the number of endemic insects, and the ratio of endemics to non-endemics in larger taxa for Namibia and the southern African region. There is high endemism in Namibia; only strict endemics (with 100% of the global distribution within Namibia's political borders) were considered. This highly distinctive, endemics-rich fauna has led to widespread acceptance of an arid southwest African biogeographic zone, the Namib-Karoo zoogeographical unit.[304,306]

Table 2.27 Ratio of species to genera of some large orders of Namibian insect taxa

Order	Species : Genera
Fishmoths (Thysanura)	3.3
Dragonflies, damselflies (Odonata)	1.9
Cockroaches (Blattodea)	2.2
Termites (Isoptera)	1.6
Mantids (Mantodea)	2.0
Grasshoppers, locusts, crickets (Orthoptera)	1.7
Lice (Phthiraptera)	1.7
Bugs, leafhoppers, cicadas, etc. (Hemiptera)	1.9
Thrips (Thysanoptera)	1.8
Lacewings (Neuroptera)	2.0
Beetles (Coleoptera)	2.8
Flies (Diptera)	2.5
Fleas (Siphonaptera)	2.4
Caddis flies (Trichoptera)	1.5
Moths, butterflies (Lepidoptera)	1.8
Sawflies, wasps, bees, ants (Hymenoptera)	2.6

Fig. 2.66 *Julodis egho kaokoensis.* Courtesy E Marais

These endemism data are preliminary, as many taxa so far recorded only from Namibia may occur in neighbouring countries. On the other hand, many truly endemic taxa probably have yet to be recorded, such as the insect fauna of wholly endemic host species, or fauna of island habitats such as springs, caves, inselbergs, or isolated dune systems. These island habitats support populations which may be extremely sensitive to disturbance. Although the fauna of caves in Namibia is relatively well studied,[294] inselberg fauna are only now coming under systematic focus. Fortunately, most inselbergs are not under any direct threat comparable to that faced by karst caves and wetlands.

Areas of high richness and endemism

The richness and degree of endemism of the Namib insect fauna vary among habitats. Northern coastal dunes (map 1.3) and the southern gravel plains have low insect species richness, whereas the southern dune sea between Lüderitz and Swakopmund and the central Namib gravel plains are species-rich habitats. The central Namib gravel plains also support numerous endemics. A zone between the Khomas highlands (Khomas Region) and the Etosha Pan also shows high insect endemicity, making central Namibia the most significant area for endemic insects.

In southern Namibia, the Karas Region (map 1.10), south of the Karas Mountains and in the *Sperrgebiet*, has high endemism. The northern Namib (Kaoko) escarpment features high endemism,[49,307] but the central and southern escarpment are poorly sampled. Numerous species appear to be endemic to northeastern Namibia, but may prove to extend into neighbouring countries as more sampling is done. Finally, island habitats such as the Waterberg Plateau, Brandberg, Huab dunes, and caves are likely to support endemics, and deserve more attention.

Table 2.28 ***Number of Namibian endemic insects and percentages of endemism in Namibia and the region***

Orders	Endemics	% Endemism	
		Namibia	Southern Africa
Springtails (Collembola)	1		
Proturans (Protura)*	0		
Diplurans (Diplura)*	0		
Bristletails (Archaeognatha)	1		
Fishmoths (Thysanura)	31	58.5	51.7
Mayflies (Ephemeroptera)	0		
Dragonflies, damselflies (Odonata)	0	0	0
Cockroaches (Blattodea)	5	10.0	2.7
Termites (Isoptera)	3	7.5	1.4
Mantids (Mantodea)	21	22.8	17.5
Earwigs (Dermaptera)	0		
Hemimerins (Hemimerina)*	0		
Web spinners (Embiidina)	1		
Stoneflies (Plecoptera)	1		
Grasshoppers, locusts, crickets (Orthoptera)	42	15.1	5.4
Stick insects (Phasmatodea)	1		
Booklice (Psocoptera)	0		
Lice (Phthiraptera)	5	10.6	0.5
Bugs, leafhoppers, cicadas, aphids, etc. (Hemiptera)	108	14.8	2.8
Thrips (Thysanoptera)	2	12.5	0.9
Alderflies (Megaloptera)*	0		
Lacewings (Neuroptera)	31	31.3	7.2
Beetles (Coleoptera)	762	31.4	4.4
Scorpionflies, hangingflies (Mecoptera)	2		
Flies (Diptera)	224	25.5	3.6
Fleas (Siphonaptera)	3	6.7	3.0
Caddis flies (Trichoptera)	3	20.0	1.4
Moths, butterflies (Lepidoptera)	121	14.8	1.8
Sawflies, wasps, bees, ants (Hymenoptera)	173	27.4	4.5
Total	1541		

Conservation status and protected areas

Small, fast-breeding insects may be more resilient to disturbance or environmental change than vertebrates, but they still face some large-scale threats. Major conservation problems faced by insects are related to habitat destruction and degradation. Habitat conservation in Namibia will protect many as-yet unidentified invertebrate species. Namibia's protected areas do not include all the centres of insect endemism, such as the *Sperrgebiet* (section 2.6).[50] Although no confirmed extinctions of insect taxa have been recorded in Namibia, extreme habitat disturbance through diamond mining in the *Sperrgebiet* is suspected to have exterminated some species. Some form of protection is also needed for island habitats such as inselbergs and caves which currently fall outside protected areas.

Major habitat alteration for mining, crop or livestock production, or water impoundment is the largest threat category for Namibian insects. Habitats may also be destroyed on a smaller scale by the development of human settlements and infrastructure. Other than in the *Sperrgebiet* and Cuvelai Basin, few of these activities are focused in particularly sensitive areas. However, the increasing fragmentation of habitats through expanded human settlement and infrastructure is a serious overall threat. Probably the most threatened endemic insect taxa in Namibia are those confined to aquatic and riverine vegetation, but the impact of riverine habitat destruction on Namibian insects is unknown.

Trade in insects is a significant threat to certain Namibian taxa, such as the extremely rare *Mantica horni, Mantichora* spp. and *Acraea braini* for which collectors pay up to US$10 000 per specimen (Table 2.4). The extent of this trade in Namibia is unclear.

In summary, the current conservation status of the Namibian insect fauna is fairly good, and threat levels are currently low. However, this assessment may change rapidly, given the realities of a fast growing human population, increased industrialisation and agronomic development, poor development coordination, and erratic political will to prescribe rural environmental protection measures. Due to the ecological importance of insects (Box 2.20), these measures are essential for supporting human development in Namibia's arid climate.

Box 2.20 Insects and ecological processes

The largest insect families in Namibia (Table 2.29) include decomposers, herbivores, predators and parasites. This reflects some dominant processes in Namibian ecosystems. Insect decomposers are often diverse in arid environments, for example, whereas bacteria, fungi and earthworms are dominant decomposers in wetter climes.[304] Termites and dung beetles are probably the most important decomposers in savannas (Box 2.5), although bacteria and fungi may be seasonally important in woodlands after rains.

The dominant herbivores in woodland are caterpillars, which are highly host-specific, while grasshoppers are the main insect herbivores in dryland savanna. Soil arthropods aerate the soil and allow nutrients and water to penetrate. Termite mounds in Namibian woodlands and floodplains often support distinctive vegetation communities, for example. Termites and beetle larvae dominate the soil fauna in arid savannas, while as ants, mites and springtails (Collembola) are important in wooded savannas. Pollinating insects in woodlands and savannas include very specialised bees and beetles, as well as opportunistic flies and wasps. Granivorous insects such as ants and seed-feeding beetles play a major role in savannas, although they may be less important than birds and rodents.

Any loss of insect diversity, especially in savannas and woodlands, threatens to disrupt the essential processes on which these ecosystems, and their human land uses, depend (see also Box 2.5). Habitat-level conservation is needed to ensure that these insect groups, which many people never notice, are not lost, and that the ecosystem functions they support remain intact.

Table 2.29 Ecological roles of large insect families with over 100 species in Namibia

Order	Family	Genera	Species	Trophic role
Grasshoppers (Orthoptera)	Acrididae	89	150	herbivores
Bugs (Hemiptera)	Lygaeidae	59	104	mainly herbivores
Beetles (Coleoptera)	Dytiscidae	27	103	aquatic predators
	Carabidae	74	153	predators
	Scarabaeidae	118	385	decomposers
	Tenebrionidae	131	551	decomposers
	Curculionidae	62	195	mainly herbivores
Flies (Diptera)	Bombyliidae	40	173	mainly parasitoids
	Asilidae	44	138	predators
Moths (Lepidoptera)	Noctuidae	79	147	herbivores
Wasps, ants (Hymenoptera)	Sphecidae	27	100	parasitoids
	Formicidae	32	129	mainly predators

Fig. 2.67 Courtesy P Tarr

Apart from their roles in ecological processes, some insects are important resources for people in Namibia. These include:

- highly nutritious food sources (termite alates, mopane caterpillars, locusts);
- sources of usable products (honey from bees, seeds collected from the stores of harvester ants, termite mounds as sources of clay, jewel beetles as ornaments, insect pupae as rattles and sources of poison).

Insects that carry disease or are agricultural pests (Appendix 9) cost Namibia substantial money for control or eradication measures and related extension services. The national economy would seemingly benefit from the eradication of these few harmful species. However, pest control techniques are seldom species-specific, so the potential ecological and long term economic costs from their use can be immense (Box 2.20).

Major constraints and recommendations

Namibia's major constraints in assessing and managing its insect diversity are a lack of basic knowledge about the fauna, ecological process and ecosystems, and a shortage of institutional and human capacity. Given our current poor understanding of Namibian ecosystems and lack of trained staff, environmental monitoring using insects is not recommended. Some initial steps can, however, be taken (Box 2.21).

— *Eugene Marais*

Box 2.21 Recommendations for improving insect diversity knowledge and conservation

- ***Clarify and promote Namibian biomes and habitats*** *by producing a biological atlas.*
- ***Direct research towards the support of management.*** *A priority list of data needed to model local ecological processes should be established and promoted by Namibian institutions.*
- ***Develop an official research framework*** *to ensure that appropriate programmes can be facilitated locally, both by Namibian and international agencies. Frameworks such as the South African ecosystem programmes have resulted in a mass of important data in a relatively short time.*
- ***Hasten the passage of a progressive legal framework*** *(Chapter 5) in which environmental impacts are considered early at an early stage of development planning.*

  For example, the production of crops involves widespread habitat destruction, but crop pest outbreaks and local biodiversity loss can both be minimised by establishing corridors of natural vegetation which provide habitat for natural enemies. Namibian agronomy would benefit from such landscape-level habitat mosaics incorporated at the design stage. Despite the long term economic benefits of such planning, it may incur higher immediate costs, and for that reason may not be adopted by land users without legal support.
- *Establish a programme to* ***train and recruit new specialists*** *to replace present scientists, to develop local expertise in underdeveloped disciplines, and to improve research capacity.*
- **Devise informal training and awareness strategies** to promote environmental literacy. These should not only address general ecological principles, but also the identification of taxa to encourage grassroots participation in biological monitoring, as was possible for the Southern African Bird Atlas Programme.[6]

Fig. 2.68 Selling mopane caterpillars. Courtesy E Marais

Freshwater fish diversity

Few systematic ecological surveys of Namibian freshwater fish had been done until recently. The pre-Independence era saw large sums spent on work, much of which remains unpublished. With the production of a South African red data book on fish, which included Namibia,[308] greater interest focused on fish ecology and distribution, especially in the five perennial rivers (maps 1.6, 1.7). Work in the last decade has produced sound data on the distribution of endemics, impact of human harvesting, introductions of alien species, and the conservation status of fish in rivers under pressure, such as the Okavango. Today, we have a relatively complete understanding of the species-rich Kunene and Okavango systems. This section distills the biodiversity aspects of these studies and highlights areas needing attention.

Despite its aridity, Namibia has about 115 freshwater species, including six aliens. Authors of three recent national studies of fish species richness[162,309,310] disagree on the total number of species, highlighting the speed with which research has recently progressed.

The largest tropical rivers (the Okavango and the interconnected Zambezi-Chobe-Linyanti system) share almost equal numbers of species (Table 2.30). The Kunene River has between 66[162] and 74 fish species,[309] depending on the uncertain taxonomy of two families. The Kunene and Okavango-Zambezi systems share 59 species,[162] confirming ancient links between these systems via the old Lake Etosha, prior to the Kunene River being diverted westwards to the Atlantic 35 000 years ago.

The Orange River, which is very large, highly regulated, turbid and temperate, harbours less than 20% of the species found in the tropical northern rivers. The Orange and its major tributary, the Fish River, are also more infested with aliens (Table 2.30).

The Cuvelai Basin (section 2.1) is a 7000 km² area of ephemeral, anastomosing shallow channels between the Kunene catchment in the west and the Okavango catchment in the east.[24] When rains in Angola flood its tributaries, fish in the permanently watered sections are swept up to 200 km into Namibia. This system supports 49 species, the highest richness after the perennial rivers.

Endemics

Endemicity of fish within Namibia's borders is very low (five species), which is rather surprising considering the numerous isolated wetlands where speciation could occur. By contrast, numerous 'river endemics' in our border rivers are shared with neighbouring countries. For example, five species are endemic to the Okavango system and three to the Zambezi. The Kunene River has at least five species unique to its catchment, which originates in the Angolan highlands. Two additional catchment endemics have recently been reported in the unpublished environmental assessment of the Epupa Hydroelectric Scheme.[12]

Fig. 2.69 *Marcusenius macrolepidotus*, a Kunene endemic. Courtesy E Marais

Fig. 2.70 Cave catfish *Clarias cavernicola*. Courtesy E Marais

Table 2.30 Synopsis of fish species in Namibian rivers and major wetlands

Habitat	Species	Endemics*	Aliens	Red data
Zambezi River system	81	1	—	2
Eastern Caprivi rainwater pools	1	1	—	1
Okavango River	82	—	—	1
Kunene River	74	—	—	—
Ephemeral western rivers	6	—	1	—
Cuvelai Basin	49	—	—	—
Tsumkwe/ 'Bushmanland' Pans	0	—	—	—
Karst caves	8	2	3	2
State dams	13	—	2	—
Lower Orange River	15	1	2	2
Fish River	15	—	3	1

** Endemic to Namibia, not to the rivers. Sources: Skelton,[308] Bethune & Roberts,[309] Hay et al.[162]*

The karst waters are permanent and mainly underground. Two karst sinkhole lakes, Lakes Otjikoto and Guinas, hold tiny world populations of two of Namibia's endemic fish, plus endemic amphipods.[254,294] The Otjikoto tilapia *Tilapia guinasana* was originally endemic to Lake Guinas, but was introduced to Otjikoto and is of conservation concern.[398] The endangered blind cave catfish, *Clarias cavernicola*, found only at Aigamas Cave, may have a global population of under 200 individuals.[311] The third Namibian endemic is the striped killifish, *Nothobranchius* sp., known only from two human-disturbed pools in the eastern Caprivi wetlands (see below). In the Orange River system, 42% of the 15 species are endemic to the river.[162] A species endemic to the lower Orange River is the Namaqua barb *Barbus hospes*. Finally, an Okavango-Zambezi basin endemic in Namibia is the broadheaded catfish *Clariallabes platyprosopos*, found below rapids at a few sites on these rivers.

Conservation concerns

Sixteen species of conservation concern are listed in Appendix 13. Four factors may lead to biodiversity loss in Namibia's fish fauna: 1) Overexploitation of all size classes by subsistence fisheries; 2) the translocation of species from one basin to another; 3) the hydrological regulation of rivers; and 4) the loss of riparian vegetation.

Skelton's review[308] listed six red data freshwater fish for Namibia. These are the three national endemics (*Tilapia guinasana, Clarias cavernicola,* and *Nothobranchius* sp.), and the three river system endemics occurring in Namibia (*Barbus hospes*, *Austroglanis scateri*, and *Clariallabes platyprosopos*). The first three are regarded as endangered, and the latter three as rare.

All Namibian endemics are endangered due to human interference. *Nothobranchius* is caught by humans in the two small rainwater pools where it occurs in Caprivi, and is threatened by road maintenance activities. The two karst endemics, both with tiny world populations, are gravely threatened by water abstraction, salinisation and pollution.[294]

Overexploitation of fish populations is of great concern in the northern rivers, where small-mesh nets, even mosquito nets, and year-round pressure simply remove all size classes from the Okavango[24,29] and Chobe Rivers.[17,312] In line with the general decline in fish found in the river by modern methods (below), yields using traditional methods declined by an alarming 49% between 1992 and 1994,[313] although river levels where then also lower. Several wetlands and rivers (Table 2.30) are 'polluted' by introduced alien fish. Most critical of these in terms of biodiversity loss is the introduction of species into the karst waters with their endemic fish and invertebrates. A more widespread species in the Karstveld area, *Pseudocrenilabrus philander*, became locally extinct before its ecology was known when the Otavifontein was concreted over by municipal authorities.[314] This species was ironically also lost from Lake Otjikoto when the endemic *Tilapia guinasana* was introduced from nearby Lake Guinas, presumably to safeguard the latter's tiny population. Adding insult to injury, the Mozambique tilapia *Oreochromis mossambicus* and two alien species were added to the same unique lake, to the detriment of the endemic tilapia.[308,315] These examples confirm the danger of ill-planned and wanton translocations or introductions into aquatic ecosystems.

Considerable work has been done on the problems of translocating species from one ecosystem to another via pipelines or canals. A canal and pipeline system in the northwest carries water from the Kunene River into the heart of the Cuvelai Basin.[24] In a comparison of species by two surveys 16 years apart, an additional 46 Kunene species had entered the canal or its associated permanent water bodies. Three of these, all cichlids, are now established in the *oshanas* and are believed to have migrated through the pipeline that links into Lake Olushandja. A similar pipeline is under consideration to supply Windhoek with water from the Okavango River as part of the existing Eastern National Water Carrier (ENWC), although it has become amply clear that fish can move through unlikely conduits, despite turbines and 50 mm inlet grids.

Alien fish invasion into the Okavango River is possible from a state dam, Omatako, where species of carp and particularly the Mozambique tilapia are found. With large floods, these species could travel north through the normally dry Omuramba Omatako. The tilapia is likely to cause genetic pollution of indigenous bream species in the Okavango River if it reaches there.[316]

Indirect interference with water levels and flooding regimes may have major impacts on the ability of fish to breed. Most Namibian fish (78%)[310] are floodplain-dependent for larval and juvenile stages, so the regulation of river flow is a serious threat to fish diversity. This is already true in the Kunene River at the existing Ruacana diversion weir, and is likely in the future if the proposed Epupa Dam is built. The one-metre fluctuations caused by the Ruacana weir appear to have caused major die-offs and a total lack of recruitment in three species of Kunene fish, as nests on shallow banks are suddenly exposed.[310] If additional dams on the Kunene increase daily fluctuations or reduce the size of annual floods, extinctions can be expected.

Reduced flooding of the Okavango River, if water is diverted to Windhoek's rapidly increasing population via the ENWC, is of great concern not only for Okavango species in Namibia, but also for the rich Okavango Delta downstream in neighbouring Botswana.

Namibia's only southern perennial river, the highly regulated Orange River system, has considerable conservation problems. Large quantities of fertiliser have entered the system from the Hardap Irrigation Scheme on the Fish River, choking the upper river with reeds and fragmenting the few open pools. The Lesotho Highlands Scheme, designed to supply South Africa's largest cities with water, will take large volumes of water away from the lower Orange River. The effects on fish will be reduced breeding, as natural flooding is reduced from the usual 2-3 months to 'flash floods' of 2-3 weeks.[317-319] Marine fish and birds at the river mouth, a Ramsar site, are also expected to be affected.

Finally, the loss of riverine vegetation such as floating or rooted macrophytes and fringes of *Papyrus* and *Phragmites* reed is a significant ecological problem for freshwater fish. These vegetation types act as feeding and breeding sites for many species, particularly on the Okavango River. Human pressure on that river has reduced fish populations directly, but this loss of habitat makes it difficult for fish to recover even if fishing is returned to a sustainable footing.

Fig. 2.71 Okavango fisheries. Courtesy P Tarr

Monitoring and future research priorities

The Orange River, despite its regulated state, is poorly known ecologically, with only two major fish surveys.[162,317] The Okavango River is best known, with 56 sites sampled along its 415 km border with Angola. Over 110 000 people, the densest concentration in Namibia, live within 5 km of the river, putting considerable strain on its biota.[312] An Index of Biotic Integrity (IBI) accounting for the health of the Okavango River on the basis of fish abundance and condition, habitat health and pollution[323] indicated that fish stocks and habitats have deteriorated significantly since 1984. Protection of these habitats allows for recovery, as suggested by a lack of decline in fish abundance or IBI in Mahango Reserve, which is protected. Studies such as these should be a priority for other rivers such as the Kunene, Zambezi-Chobe, Orange, and Cuvelai Basin (Box 2.23).

— Rob Simmons & Shirley Bethune

Box 2.22 The economic importance of inland fisheries

Three studies have assessed the economic importance of fish to local people in northern Namibia. Fishermen in the Okavango Region normally fish when floods are receding and fish become concentrated. These include cooperative efforts, often by women and children with traditional basket traps (Fig. 2.71).[320] About 53% of all people in the Okavango Region catch fish, and 91% eat them.[312] Maximum biomass per unit effort is achieved with cast nets followed by spear fishing.[313] Compared with annual subsistence yields of fish in other African rivers, the Okavango yields medium to low catches of 19-38 kg per hectare.[313,320,321] It is not known what percent of an individual's protein is provided by a typical annual catch, but Angolans fishing on the river said they had nothing to eat but the fish they caught.[320] Few artisanal fishermen sold their catches, but if an estimated price of N$3/ kg is used (at 1987 prices), the economic potential of the Okavango River fishery is put at N$ 1.8 million annually.[320]

The Cuvelai Basin oshanas, *which rely on a seasonal influx of floodwaters from Angola, show major economic potential. Fish in these ephemeral waters are essentially doomed, so sustainable fishing is not an appropriate concept on a local scale. People have dug some deep pits to retain the seasonal waters, although they normally catch all the fish in a short time, leaving none to supply protein later in the year or to 're-seed' the next flood. In a short 1976 study of fish swept south through the Cuvelai, van der Waal[24] estimated that about 4200 kg of fish were collected at seven culverts in a day by subsistence fishermen. If the* efundja *flood lasted 60 days, the yield would equal 250 tonnes along the one road sampled (see Chapter 4). If sold at the same price as quoted for Okavango fish, the potential along this one road could be N$750 000 in two months. Of course, other predators depend on this seasonal resource. Breeding pelicans* Pelecanus onocrotalus *removed an estimated 975 tonnes of fish from Lake Oponono, the southern junction of this system, in the major* efundja *in 1969.[23]*

In a study in eastern Caprivi,[322] fish catches per unit effort were much higher in the Zambezi (13.8 kg per 50 m of net per night) and Chobe (12.4 kg) than in the Kwando (3.9 kg) or Linyanti Rivers (2.4 kg). About 50% of households in the Katima Mulilo district and 10% in the Linyanti district do some fishing.[312] This involves about 8 000 people who fish for about 10 months per year until water levels become too high. The average income of the fishing households is N$ 474/ month, close to the average derived from other sources by other households. Households selling all or part of their catch have an average monthly income of N$ 270. All studies so far report a reduction in catches as fishing gear has moved from traditional baskets to nylon nets. Clearly, tighter controls are required to make these fisheries sustainable.

Box 2.23 Research priorities for fish conservation and monitoring in Namibian inland waters

Some of the highest research priorities to support the protection and sustainable use of freshwater fish include:

- *Harvesting potential of the Cuvelai fishery and adaptive indigenous fish farming*
- *Monitoring of the spread of Kunene species in the Cuvelai Basin*
- *Ecological studies of all Namibian endemic fish*
- *Ecological studies of the Orange River system and actions to mitigate the impacts of upriver developments*
- *Monitoring of ecological changes in all regulated Namibian rivers*

Amphibian diversity

Only anuran amphibians (frogs and toads) are found in Namibia. Although there is confusion in the taxonomy of several genera, Namibia has 50 recorded frog species (Table 2.31), with a final predicted richness of about 65 species.[324,325] Seventeen percent of all amphibian families, 4% of all genera, and 1% of all species are represented in the country, with some taxa especially well represented (Table 2.32).

As frogs generally depend on free water for breeding, Namibia's surface water limits most species to the five perennial rivers and the more reliable seasonal sources. Despite this constraint, many are arid-adapted and occur throughout Namibia, except for in the Namib mobile-dune seas.[325]

The occurrence of frogs in 14 catchments and areas has recently been summarised.[326] Species richness is greatest in the northeast, where the Okavango, Kwando and Zambezi Rivers drain large parts of Angola and Zambia (map 2.9). This area also has the highest mean annual rainfall in Namibia at 600-700 mm (map 1.1).

Fig. 2.72 *Bufo hoeschi*, an arid-adapted toad. Courtesy M Griffin

Most species, except *Breviceps macrops* and *B. adspersus*, need seasonally available water sources for breeding. Some species usually associated with permanent water, however, such as *Ptychadena subpunctata, P. mascarenienses*, and *Hyperolius nasutus*, can extend their distribution into otherwise unsuitable areas.[327,328] At the other end of the spectrum, some truly arid-adapted frogs such as *Phrynomantus annectens* and *Bufo hoeschi* depend entirely on the temporary accumulation of unpredictable rainfall.[329] The lowest richness occurs in the southeastern Kalahari, where a combination of low rainfall, high evaporation (maps 1.1, 1.2) and lack of habitat diversity makes the area unsuitable.[325]

Endemism

Six species of frogs are now regarded as endemic to Namibia, defined as at least 75% of the known range occurring within Namibia: *Phrynomantus annectans* and *Breviceps macrops* (Microhylidae), *Bufo dombensis, B. hoeschi*, and *B. jordani* (Bufonidae), and the recently described[330] Mpacha grass frog *Ptychadena mpacha* (Ranidae). The Mpacha grass frog is known only from the Katima Mulilo area, but is likely to be more widely distributed in surrounding parts of Zambia, Botswana and Zimbabwe. The taxonomy of the dwarf *Bufo* species is still not clear,[331,332] and revision of the group may alter these numbers. Other endemics are taxonomically stable with well known distributions. Map 2.3 (section 2.3) maps the distribution of endemic frogs as currently understood.

Table 2.31 Synopsis of amphibian and reptile richness recorded from Namibia[324]

Order	Families	Genera	Species	+ expected spp.	Est. % described
Frogs	7	18	50	22	75
Crocodiles	1	1	1	0	100
Turtles, tortoises, terrapins	5	12	18	3	?
Lizards	7	37	128	5	70
Worm lizards	1	3	11	1	70
Snakes	8	36	85	9	70

Table 2.32 Namibian frog genera in global perspective

Family	Genus	Species Namibian	Species Global
Order Anura (7 Namibian families, 25 global families)			
Pipidae	*Xenopus*	3	14
Bufonidae	*Bufo*	11	211
	Schismaderma	1	1
Microhylidae	*Breviceps*	2	13
	Phrynomantis	3	5
Ranidae	*Pyxicephalus*	1	2
	Tomopterna	5	13
	Rana	4	222
	Hildbrandtia	1	3
	Ptychadena	11	40
	Phrynobatrachus	2	66
	Cacosternum	2	7
Rhacophoridae	*Chiromantis*	1	3
Hemisotidae	*Hemisus*	1	8
Hyperoliidae	*Leptopelis*	2	49
	Kassina	1	13
	Hyperolius	2	112

Conservation status

Improving the accuracy of conservation status assessments of Namibia's frogs requires much better information on population trends. However, based on known distributions, frequency of sightings and collecting, and habitat requirements, all species have been assigned a provisional conservation status.[324] Table 2.33 summarises this provisional status for 52 species; Appendix 10 gives operational definitions of conservation status categories assigned to frogs, reptiles and mammals.

Twenty six species (*c.* 50%) are presently considered to be *secure* (Table 2.33). Twenty-seven species are possible candidates for the threatened categories (any status other than just *endemic* or *secure*) but the lack of data prevents a more accurate placement. As Namibia is a dry country, with a rapidly growing human population aspiring to greater industrialisation and intensified agriculture, all 20 species which depend on perennial waters can be considered *vulnerable* in the long term.

Enough data exists on the endemic marbled rubber frog *Phrynomantus annectans* to say confidently that its status is *secure*. However, a lack of almost all types of data on the other endemics makes it impossible to pinpoint their conservation status. One of Namibia's least known endemics is the desert rain frog *Breviceps macrops*. Although an estimated 80% of the range of this species occurs within Namibia, it appears genuinely rare here, more so than in South Africa's Namaqualand. A misfortune of this species is that it inhabits the same habitat (coastal sand dune hummocks) and distribution as do diamonds deposited by the Gariep (Orange) River. This has meant that major portions of its habitat have been destroyed by diamond mining.[217]

Frogs in Namibia's protected areas

Table 2.34 summarises the protection status of Namibian frogs in the country's protected area network. Nearly 14% of Namibia's land surface is proclaimed formal conservation area (section 2.6), made up of 21 reserves and parks ranging from tiny to very large (Box 1.9). The second largest park in Namibia, Etosha National Park, holds 35% of the country's frog species. By contrast the largest park, the Namib-Naukluft, has viable populations of only 6-8 species or about 15% of our frog fauna. As expected, the Okavango and Caprivi parks are the most species-rich areas, but the available habitat may be severely limited. For instance, the wetland Mahango, Mudumu and Mamili Parks cover small areas of about 245 km^2, 1010 km^2 and 320 km^2 respectively (Box 1.9). This is minimal insurance against local extinctions.

About 50% of Namibian species occur in three or more conservation areas, and only three species are found in ten or more conservation areas. However, about eight species, including three or four endemics, occur only marginally in conservation areas. The long term viability of these populations is not known. For instance, the dwarf bufonid endemics occur in semi-arid areas, areas particularly susceptible to desertification. Other areas of concern are along the Kunene River, where only 41 km of very arid and generally unsuitable terrain falls within the Skeleton Coast Park (Table 2.8). Only about 80 km of the Orange River is protected, and the Caprivi rivers are very poorly protected (Table 2.8).
— *Mike Griffin*

Box 2.24 Humans and frogs

The only Namibian frog regularly eaten by people is the giant bullfrog *Pyxicephalus adspersus*. These are in great demand in the north-central regions, where they are a seasonal source of food and income. In theory, this resource can be sustainably used, as the frogs are prodigious breeders, the tadpoles are non-specialized pond feeders, and the newly metamorphosed froglets are willingly cannibalistic. The result of this is that an otherwise 'useless' accumulation of temporary rainwater can produce a local seasonal delicacy. Adults emerge immediately after the season's first heavy rain and noisily announce their presence, making them easy to gather. If local traditional protection systems break down, however, all breeders could be collected before breeding, ensuring that harvests are unsustainable.

Malaria is a major human health risk in the north-central and northeastern regions (Box 1.4). A common method of reducing the incidence of this disease is to spray standing water with pesticides. Biocides are frequently used in the agricultural sector, and over time can only lead to the localised extinction of frogs, many species of which feed on mosquitos and agricultural pests.

Table 2.33 A provisional conservation status assessment for Namibian frogs*

Category	Pipidae	Bufonidae	Microhylidae	Ranidae	Rhacophoridae	Hemisotidae	Hyperoliidae	Total
Endangered	0	0	0	0	0	0	0	0
Rare	0	0	0	0	0	0	0	0
Vulnerable	0	0	0	0	0	0	0	0
Indeterminate	0	0	1	0	0	0	1	2
Insufficiently known	1	4	1	1	0	0	0	7
Endemic	0	3	2	1	0	0	0	6
Peripheral	1	3	0	12	1	1	0	18
Secure	1	5	2	12	1	1	4	26

**Number of species per family in each conservation status category (a species can occur in more than one category)*

Table 2.34 Protection status of Namibian frogs, including those expected to occur

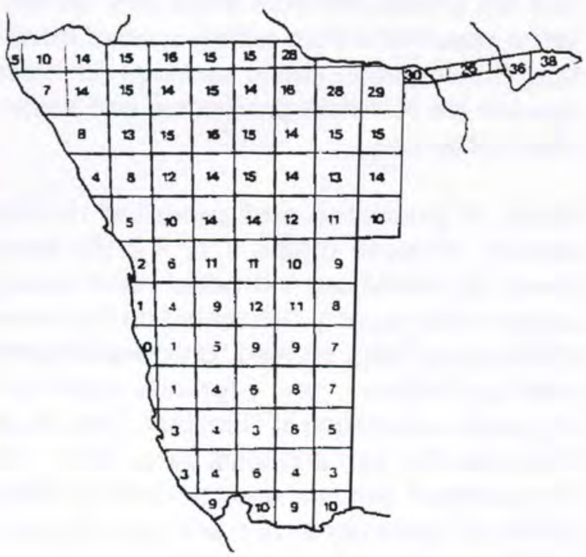
Park	Pipidae	Bufonidae	Microhylidae	Ranidae	Rhacophoridae	Hemisotidae	Hyperoliidae	Total
Mudumu and Mamili	2	7	3	17	1	1	4	33
West Caprivi	2	5	3	14	1	1	4	30
Mahango	2	5	3	12	1	0	6	29
Khaudum	1	4	3	8	0	0	3	19
Etosha	1	6	4	6	0	0	1	18
Skeleton Coast*	1	4	1	3	0	0	1	10
Waterberg	1	2	3	6	0	0	1	13
Daan Viljoen	1	2	3	6	0	0	1	13
von Bach	1	2	3	4	0	0	1	11
Namib Naukluft	1	4	2	2	0	0	0	9
Walvis Bay**	0	0	0	1	0	0	0	1
Hardap	1	1	1	4	0	0	1	8
Naute	1	0	1	2	0	0	1	5
Diamond Coast	0	0	2	1	0	0	0	3
Ai-Ais/Hunsberg	1	3	1	5	0	0	0	10

* *Skeleton Coast here includes the less well protected West Coast Recreation Area (Box 1.9, map 1.9).*

** *A proclaimed protected area used to extend from the Walvis Bay lagoon along the Kuiseb River to Rooibank.*

Fig. 2.73 Bullfrogs are a sought-after seasonal food resource in northern Namibia. Courtesy M Griffin

Fig. 2.74 Marbled rubber frog *Phrynomantus annectans*. Courtesy M Griffin



Map 2.9 Expected species richness of Namibian frogs. Reprinted with permission from Griffin.[325]

Reptile diversity

Namibia has a rich and distinctive reptile fauna, including many taxonomic specialties. The southern African region as a whole is noted for its species richness and endemism, and has become the most active and prolific region in Africa for reptile research.

Major sources of data for this account were the National Museum of Namibia collections (*c.* 12 000 specimens representing over 75% of Namibia's reptile species richness) plus an additional *c.* 23 000 museum specimens housed in South African, German, American, Austrian and British museums (in descending order of holdings). Postal questionnaires have yielded limited but useful data on easily recognised species, such as pythons, tortoises, monitor lizards and crocodiles.[333] An annotated bibliography[382] currently lists roughly 800 titles on Namibian reptiles.

Despite the extensive database, there is a paucity of data for many species. Taxonomic problems are slowly being resolved through morphometric and biochemical methods, while the distribution patterns of Namibian species are regularly refined. Yet many species are known only from a few very old museum specimens from widely spaced localities. Conservation status rankings for most species are therefore provisional and somewhat subjective.

Maps of predicted and potential reptile species richness (maps 2.10 - 2.16) were drawn by overlaying individual hand-drawn range maps, roughly delineated on the basis of the above data sources, unpublished and ongoing fieldwork, and inference based on 20 years' experience in Namibia. They thus differ from the bird and plant data, which are all confirmed records documented by atlas cards or specimens, but are regarded as highly reliable and conservative.

Species richness

There are 261 species of reptile currently known or strongly expected to occur in Namibia.[324] This total represents 56% of the southern African region's species diversity, 79% of its generic diversity, and 100% of its family diversity (Table 2.35); Namibia's land area covers *c.* 25% of the region. From an African perspective, Namibia supports *c.* 30% of the continent's species diversity, 55% of its generic diversity, and 91% of its familial diversity. With 129 species of Lacertilia, Namibia has one of the continent's richest lizard faunas.

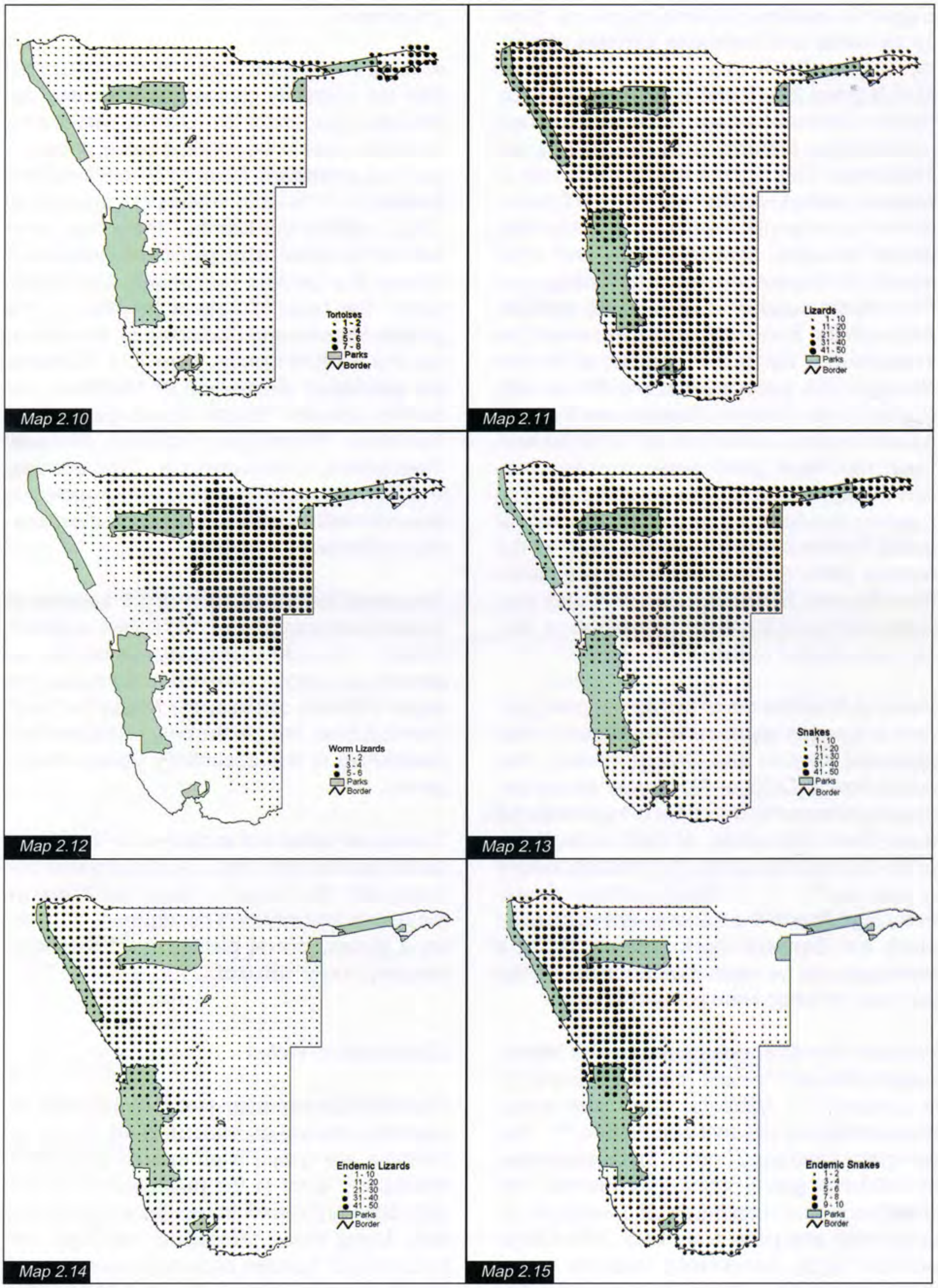
Table 2.35 Namibian reptile taxa in regional and global perspective

	Namibian	Southern African	Global
Orders	3	3	4
Families	22	22	48
Genera	89	113	905
Species	*c.* 261	*c.* 470	*c.* 6550

Biogeography

No thorough biogeographic analysis of Namibian reptiles has yet been published, although several papers have assessed the southern Kalahari fauna and its affinities with other areas.[335] Three relevant major works are also in progress by specialists in South Africa, Namibia and Zimbabwe.

Fig.2.75 Namibia's gecko fauna is exceptionally rich, with a high degree of endemism. Courtesy M Griffin



Maps 2.10 - 2.15 ***Patterns of species richness in terrestrial and freshwater Namibian reptiles:*** (2.10) tortoises and terrapins; (2.11) lizards; (2.12) worm lizards; (2.13) snakes; (2.14) endemic lizards; (2.15) endemic snakes.

Expected species richness maps are given for terrestrial and freshwater tortoises and terrapins (map 2.10), lizards (map 2.11), worm lizards (map 2.12), and snakes (map 2.13). Reptile distributions are influenced strongly by landscape features such as wetlands and inselbergs. The highest species richness of wetland-related reptiles[326] is found in Caprivi, where the perennial floodplains provide habitat for terrapins, aquatic snakes and other aquatic or riparian reptiles. The Orange and Fish Rivers support fewer aquatic species. Although the Kunene River's catchment lies in reptile-rich habitats in Angola, so far the Nile crocodile, water monitor and African softshelled turtle *Trionyx triunguis* are the only aquatic reptiles known from its Namibian sections; reports of green water snakes, probably *Philothamnus* sp., are unconfirmed. The Kunene mouth is an aggregation point for green turtles *Chelonia mydas*, due to the warmer water of the river providing a haven from the cold Benguela Current,[11] and supports a disjunct southern population of African soft-shelled turtles.

Rivers in Namibia are generally not good barriers to species distribution, as shown by the perennial Kunene and Orange Rivers. Reduced flow in October-November closes the mouths temporarily with silt and fragments the main stream into pools. At such times, these rivers are barriers to only the most sedentary of species.[336] Even during periods of relatively high flow in the Kunene, active species such as Damara rock agama *Agama planiceps* can be seen rock-hopping across the river between Namibia and Angola.

Western Namibia, dominated by the Namib Desert and escarpment (maps 1.3 and 2.1), is a mosaic of habitats, often with sharp boundaries and disjunct populations.[337] The two major sand seas (map 1.3) are separated by 290 km of gravel plains, interspersed with sheet rock and inselbergs and crossed by ephemeral and perennial rivers. Inselbergs provide highly specialised habitats within these otherwise uniform landscapes. Approximately 60 reptile species (*c.* 23% of all species and 50% of all Namibian endemics) are endemic to, or found mainly in, Namibia's Namib Desert (map 2.4).

Endemism

At least 55 species (22%) of Namibian reptiles are currently classed as endemic (defined as in Appendix 10). Lizards, with *c.* 35% endemism within the national fauna, show the greatest endemism, followed by tortoises (one species, *c.* 17%) and snakes (11 species, *c.* 13%). Within the lizards, there has been extensive local and regional speciation among the geckos (especially *Pachydactylus*), the lacertid lizards (especially the genera *Meroles* and *Pedioplanis*), the skinks, and the cordylid lizards. Map 2.14 illustrates the estimated distribution of Namibian endemic lizards. Eight lizard genera — *Narudasia, Rhoptropus, Ptenopus, Meroles, Pedioplanis, Cordylosaurus, Typhlacotias,* and *Palmatogecko* (including *Kaokogecko*) — are essentially endemic or show greatest species radiation in Namibia.

The predicted distribution of 11 species of endemic snakes (map 2.15) shows a similar pattern. Yet only *Pythonodipsas* can be regarded as a genus endemic to Namibia. The single endemic tortoise, the Nama padloper (*Homopus* sp. nov.) is the only Namibian representative of this essentially South African genus.

The overall pattern of endemism in the 55 endemic reptiles (see map 2.4) is correlated primarily with the mosaic of major substrates in the Namib and adjacent escarpment, such as sand dunes, gravel plains, sheet rock and elevated rocky habitats.

Conservation status

Proposed conservation status rankings for all reptiles known or expected to occur in Namibia are given in an interim annotated checklist,[324] prior to the publication of a red data book on Namibian reptiles and amphibians. Using these provisional rankings, the frequency of species occurring in all categories is given in Table 2.36. In addition, the superimposed potential distribution of 113 reptile species of conservation concern is shown in map 2.16.

Table 2.36 A provisional conservation status assessment for Namibian reptiles*

Category	Crocodiles	Turtles, tortoises and terrapins	Lizards	Worm lizards (Amphisbaena)	Snakes	Total
Endangered						0
Vulnerable		4	2		1	7
Rare			17	3	29	49
Indeterminate		4	1		4	9
Insufficiently known			9	1	19	29
Endemic		1	45		10	56
Peripheral	1	13	5		5	24
Secure		1	101	8	55	165
Not yet recorded or confirmed		4	9	3	9	25
Total	1	17	130	11	93	

** Number of species per family in each conservation status category (a species can occur in more than one category).*

Map 2.16 Distribution of reptiles of conservation concern

About 67% of Namibian reptiles are currently classed as of conservation concern, that is, all rankings other than just *secure*(defined in Appendix 10). Seven species are classed as *threatened* and a further 27 are in possible threat categories: *indeterminate, insufficiently known*, and *peripheral*. *Rare* is not regarded as threatened. Few species are known well enough for definite conservation status rankings to be assigned with confidence. Conservation rankings are subjective, and most species, including those assessed as *secure*, would be defined as *data deficient* under the latest IUCN red data guidelines.[338] By definition, species in this category require a high degree of protection until the species can be assigned confidently to a category.

Threats to reptiles

Unsustainable exploitation and alteration of habitat are the two major categories of threat. For example, in the early 1970s crocodiles were overhunted for their skins in the northern rivers. Strict control has since reversed this exploitation to the point where 'problem crocodiles' must be regularly removed by conservation staff. Since then, crocodile farming has become a profitable if risky business. However, such enterprises can be a convenient outlet for illegally acquired skins or live individuals unless carefully controlled.

Namibia's two former colonial administrators, which previously played major positive roles in the development of scientific research and establishment of parks, are ironically the primary sources of abuse related to the exotic pet trade. Namibian dwarf pythons *Python anchietae*, dwarf adders (*Bitis* spp.) and tortoises are all in high demand in Germany and South Africa, and traditional family links often facilitate this trade (Box 2.25).

Box 2.25 Tortoises: at greatest risk

Namibian tortoises are all edible and considered a delicacy by many Namibians. Historically, the practice of opportunistically gathering tortoises from the veld was probably a sustainable one. However, higher human populations, increased mobility and permanent settlement in previously unsettled areas may directly threaten tortoise populations today. In particular, the establishment of artificial water points allows the permanent settlement of other species known to eat small tortoises, such as cattle and baboons.

The human consumption of tortoises could historically be controlled by village elders or other authorities, and this may account for population trends today. For instance, commercial farms that never allowed local labourers and herders to use tortoises still have healthy populations today. Before the Mahango Game Reserve was proclaimed, it was a traditional king's hunting area, with controlled access and utilisation. Today it has a relatively high density of hinged tortoises *Kinixys spekii*, in a region where they are otherwise scarce. Tortoises, especially leopard tortoises *Geochelone pardalis*, are susceptible to electrified fences and jackal control measures.

The Namibian tortoise fauna of six species, including one endemic species and five of the 11 recognised genera, is the second largest national fauna in the world after South Africa, which has 13 species in 5 genera. Given that only c. 44 species are currently recognised in total, and all Namibian species are threatened, the tortoises are the reptile family of greatest national concern.

Fig. 2.76 Tortoises are under pressure in Namibia. Courtesy P Tarr

Fig. 2.77 Namibia has a rich and distinctive gecko fauna. Courtesy P Tarr

Habitat-specific threats

Many reptiles are substrate dependent and are therefore vulnerable to desertification, bush encroachment, and deforestation. Tree-dependent reptiles, such as the skinks *Mabuya binotata* and *Mabuya spilogaster*, and some arboreal geckos (*Lygodactylus*) will be directly eliminated from areas where deforestation occurs. Approximately 14 species of Namibian reptiles are water or wetland-dependent.[326] The vulnerability of these limited habitats in Namibia threatens all these species. Aside from the commercially exploited reptiles such as tortoises, pythons and monitor lizards, most threatened Namibian reptiles depend on wetlands.

Sandy substrates are a major feature of the Namibian landscape, and are critical habitat for numerous reptiles, including endemics. Some of these habitats are reasonably safe from desertification, bush encroachment, and deforestation, but may be susceptible to emergency grazing and large scale mineral extraction operations. Rocky habitats also need protection, as they support species of conservation concern. At a small scale, specialised niches are easily destroyed by the prying apart of rock crevices by collectors and scientists. Although this habitat alteration is insignificant to widespread species, highly restricted range species on inselbergs, such as *Cordylus pustulatus*, or montane slopes, such as *Cordylus campbelli*, are extremely vulnerable to this type of habitat destruction.

Fig. 2.78 A broad-headed cobra in the Eastern National Water Carrier. Snakes are worst affected by this canal. Courtesy M Griffin

Open canal sections of the Eastern National Water Carrier (Fig. 2.78) create a 203 km long trap for at least 40 species of reptiles in central Namibia.[339] Annual reptile mortalities are estimated at a minimum of 50 000 individuals, and these rates have not declined in the 12 years since completion of the canal.

Alien species

Alien reptiles in Namibia are not a significant conservation problem, although in certain cases the translocation of tortoises and other reptiles may cause genetic pollution (Box 2.26). Most aliens introduced to Namibia are thought to be non-invasive.

Box 2.26 Travelling tortoises

The practice of travelers picking up tortoises and translocating them to alien localities is a common phenomenon, today as well as in the past.[340] Individual angulate tortoises *Chersina angulata* thrive in gardens in Swakopmund and Walvis Bay, nearly 500 km north of the closest natural populations. All southern African tortoise species appear to be translocated by people, and a southeast Asian species, *Cuora trifasciata*, was recently found in the Khomas highlands. Leopard tortoises are particularly prone to these long distance removals, and this has undoubtedly resulted in genetic pollution of local populations. Even tortoises in some conservation areas cannot be assumed to be genetically characteristic of the area: parks are often used as dumping grounds for vagrants and confiscated animals, and many leopard tortoises of unknown origin occur in the Daan Viljoen Game Reserve and the Namib-Nauklauft Park.

Protection status

Table 2.37 summarises the known and expected occurrence of the Namibian reptile fauna within the state protected area network. These data tell us little about the viability of such populations. Reliable population data on most Namibian reptiles are unavailable, and will remain so for some time. However, about 90% of Namibian reptile species are included, sometimes marginally, within the protected area network. Roughly 65% of species occur in three or more reserves, with *c.* 23% in 10 or more reserves. Despite this, several important areas are neglected in the conservation network, especially the eastern margin of the Namib Desert and its escarpment from the Erongo Mountains to the Kunene River (section 2.6). This region carries a high proportion of endemics (see maps 2.2-2.7, 2.14, 2.15), and although many endemics occur marginally in the Skeleton Coast and Etosha Parks, they need additional protection in their core range, as do other major taxa in Namibia.[49,50] Perennial rivers are also poorly protected (Box 2.8). Conservation problems of mammals (below) apply well to reptiles.

Other poorly protected species include the cordylids, of which at least three endemic species — *Cordylus pustulatus, C. campbelli,* and *C. namaquensis* — occur only on private land, plus some geckos endemic to the Kunene and Erongo Regions. Proclaiming sections of the northeast Kunene Region and *Sperrgebiet*, as recently proposed,[50] may ensure the viability of resident endemic species which are presently marginally protected or unprotected (Box 2.27).

The Nature Conservation Ordinance (No. 4 of 1975) lists the Nile crocodile, the two monitor lizards, two pythons and all tortoises as 'Protected Game' in Namibia (Chapter 5). No reptiles are classed as 'Specially Protected,' 'Huntable Game,' or 'Problem Animals.' All other reptiles are defined as 'Wild Animals,' which confers little protection. Marine turtles were not included in the Nature Conservation Ordinance, but are now fully protected by new marine legislation. The disjunct population of African soft-shelled turtles at the

Kunene mouth is also fully protected by these laws.

In summary, Namibia's reptiles are fairly diverse and arid-adapted, and reach their highest richness in Namibia's northeast. Because many inhabit desert regions, few are of immediate conservation concern. However, commercial exploitation of some species and the lack of formal protection of many endemics in the northwest must be addressed by future conservation actions.
— Mike Griffin

Fig. 2.79 *Meroles suborbitalis*, a gravel plains specialist in a genus virtually endemic to Namibia. Courtesy M Griffin

Table 2.37 Protection status of 248 indigenous Namibian reptiles*

Protected area	Crocodiles	Turtles, tortoises and terrapins	Lizards	Worm lizards (Amphisbaena)	Snakes	Total
Mudumu & Mamili	1	7	21	6	46	81
West Caprivi	1	7	23	6	40	77
Mahango	1	6	24	5	36	72
Khaudum	0	3	27	5	31	66
Etosha	0	3	53	4	49	109
Skeleton Coast**	1	6	45	0	25	77
Waterberg	0	3	33	6	41	83
Daan Viljoen	+	3	37	4	35	79
von Bach	0	3	36	3	34	76
Namib Naukluft	0	10	55	2	33	100
Walvis Bay***	0	5	30	0	15	50
Hardap	+	3	32	3	24	62
Naute	0	4	39	1	22	66
Diamond Coast	0	5	21	0	12	38
Ai-Ais/Hunsberg	0	5	43	0	26	74
Total species	1	17	126	12	92	248
Total species in parks	1	16	108	11	83	219

* *Excludes proclaimed areas of under 1000 ha.*
** *Skeleton Coast here includes Cape Cross Seal Reserve and the West Coast Recreation Area (map 2.8).*
** *A proclaimed protected area used to extend from the Walvis Bay lagoon along the Kuiseb River to Rooibank.*

Box 2.27 The need for partnership in developing new protected areas

The national protected area network is not as inviolate as it should be, and its boundaries were in the past repeatedly changed for spurious or ideological reasons (see section 1.2).[50] As many of the present areas border commercial or communal lands, pressure is high to open these areas for regular emergency grazing or reallocation in terms of land reform. This book demonstrates the need to extend the present protected area network, in terms of Namibia's commitment to the Convention on Biological Diversity, to include specialised habitats and species, especially endemics. However, this requires cooperation and partnership between the formal and informal sectors. Recent initiatives along this line, including private game reserves, commercial and communal conservancies, and controlled access mining concessions (Chapter 1 and section 2.6) are examples of pragmatic ways to safeguard the greatest possible array of Namibia's rich biota, including its reptiles, for the future. However, new approaches need rigorous monitoring and analysis. For example, most private initiatives cater for tourists, and land management for these purposes may lead to inadvertent biodiversity loss.
— Mike Griffin

Fig. 2.80 Barechecked babbler, a Namibian endemic. Courtesy K Bartlett

Fig. 2.81 Birds of prey are an important group of threatened birds in Namibia. Courtesy K Bartlett

Table 2.38 Taxon richness in Namibia's eight dominant bird families, and the proportion of species for which Namibia supports about 40% or more of the world population

Family	Subspecies	Species	Genera	% species with >40% of world population in Namibia
Ploceidae (sparrows, weavers, etc.)	63	49	21	16
Sylviidae (warblers, cisticolas, etc.)	59	41	15	24
Accipitridae (vultures, eagles, etc.)	48	46	25	4
Alaudidae (larks)	43	20	8	60
Turdidae (thrushes, chats, robins, etc.)	35	24	12	38
Laniidae (shrikes)	29	19	11	21
Scolopacidae (sandpipers, snipe, etc.)	24	24	9	0
Motacillidae (wagtails, pipits, etc.)	24	12	3	17

Bird diversity

The Afrotropical region, south of the Sahara, is second only to the neotropics in terms of its bird richness. Species richness in birds is associated with tropical forest cover, the length of isolation of a landmass, the extent of archipelagos and ecological 'islands' such as mountains, wetlands, and valleys, and with various measures of habitat diversity.[341]

The southern African avifauna, south of the Kunene and Zambezi Rivers, consists of 920 species in 91 families.[6,342] Of these, 658 species (72%), representing about 817 subspecies, have been recorded in Namibia.[6,343,344] Namibia's avifauna is fairly sparse compared with equatorial areas, but its arid endemics make up a diverse and varied group. Eight dominant families contain about 40% of the subspecies and 36% of the species; six of these families are passerine (Table 2.38). Over 60% of larks (Alaudidae) are endemic to the region. Other well represented families with arid zone affinities include the Falconidae (14 spp.), Phasianidae (12 spp.), Fringillidae (9 spp.), Otidae (8 spp.) and Glareolidae (8 spp.). Breeding residents make up the majority of Namibia's bird species (70%), although not all have yet been recorded breeding here. In arid regions, many species described as 'breeding resident' are highly nomadic (Table 2.39).

Namibia's birds can also be classified by their biogeographic distribution. Widespread *Cosmopolitan* species, which occur in other regions of the world such as the Palaearctic, account for about 24% of Namibia's 658 bird species. *Ethiopian* species, widely distributed across Africa, account for 54%. *Southern African endemic* and near-endemic species, including the so-called 'southwest arid' species, constitute about 14%. For many species in this category, Namibia supports over 40% of their world populations. Finally, *Namibian endemics*, which constitute only 2% of the country's avifauna, have at least 90% of their world populations within Namibia. We have international responsibilities to ensure the conservation of species in the last two categories. Species in these categories, as well as special cases for which we should take responsibility, are listed in Appendix 11.

Table 2.39 Composition of Namibia's birds

Status	Species	Percent
Breeding residents, incl. nomads	459	70
Palaearctic migrants, nonbreeding	70	11
Intra-African migrants, breeding	47	7
non-breeding	7	1
Pelagic birds	30	5
Vagrants	45	7
Total	658	100

Bird richness is unrelated to the area of a given biome (Fig. 2.82). For example, the two largest biomes (the Marine biome, from *c.* 3 nm - 200 nm offshore, and the slightly larger terrestrial Savanna biome covering over 60% of the land area) support only about 5% and 47% of Namibia's bird species, excluding vagrants. Disproportionately rich biomes are the Coastal region, which extends out to sea for about 3 nm and includes the offshore islands, and the inland wetlands, which cover <5% of the land area. These biomes support 7% and 24% of all species respectively.

The only terrestrial system which supports disproportionately high species richness (45%) is the Woodland biome, which covers roughly 20% of Namibia. The narrow riparian belt along the perennial rivers in the north of the country supports an additional 23 species (4%). If species from both woodland types are combined, this biome supports 49% of all Namibian bird species, while the deserts (<100 mm mean annual rainfall) comprise about 16% of the country and support about 16% of the bird species. The majority of Namibian and southern African endemics occur mainly in the savannas (30% of all birds in that biome) and in the desert (30%).

Data sources

In the 1970s, Namibian ornithology shifted from purely descriptive to ecological and conservation biology studies. Two long term national projects were initiated. The first, to gather data on distribution and abundance, was published in 1997 as part of the Southern African Bird Atlas Project[6] after 18 years of data collection. The second project, to collect breeding data via a nest record scheme, was begun in 1969[345,346] and is ongoing.[347] A conservation status assessment based on these data was initiated, assigning each species to one of three main categories: *threatened*, *lower risk* and *secure* (below).

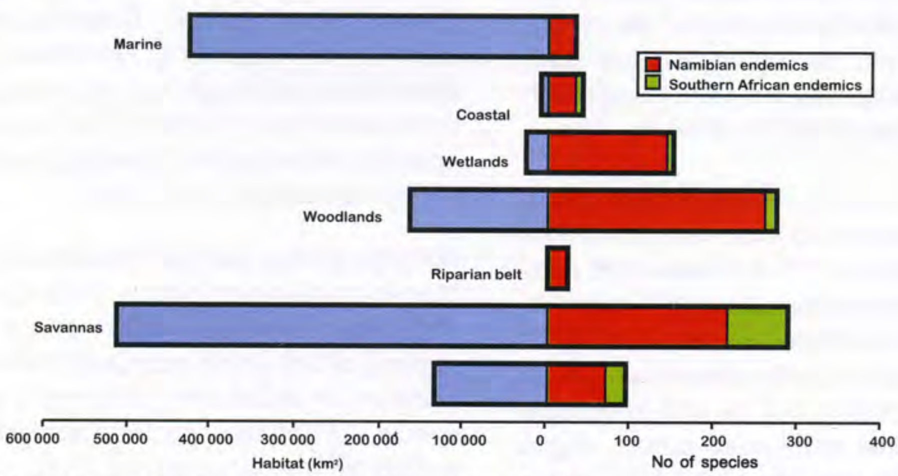


Fig. 2.82 Area of biome and number of Namibian bird species. Namibian and southern African endemic bird numbers are distinguished.

As Namibia now has good overviews of distribution and conservation priorities for various groups, several projects have been established to collect data on population trends and conservation threats facing birds of conservation concern. These include road counts of birds of prey since 1977[348] and focused monitoring of wetland birds,[11,349-356] now carried out as part of a pan-African wetlands programme.[357] Other groups and species of immediate concern, such as cranes[358,359] and oxpeckers,[360] have been monitored on an irregular basis. A large and diverse geo-referenced, fully computerised avifaunal information system is now being established, containing bird atlas, museum specimen, nest record, raptor road count, wetland and coastal survey data. Updated checklists have been generated for important areas of Namibia, such as protected areas and key regions. Finally, a wide range of studies has been undertaken on threatened, endemic and arid-adapted species to determine their status, conservation needs, and basic breeding biology.[23,361-378]

The main emphasis during the 1990s has been the determination of population size, dynamics and distribution of endemic and red data birds.[51,52,89,371-375] The ornithology programme of the MET encourages and supports the work of visiting scientists, particularly in important areas such as behaviour, basic ecology and evolution which cannot be easily funded within national priorities. Its own work emphasises monitoring and analysis of wetland, shorebird and endemic species.

Fig. 2.83 Waterberg Plateau Park protects part of a Namibian 'hotspot' for bird richness. Courtesy P Tarr

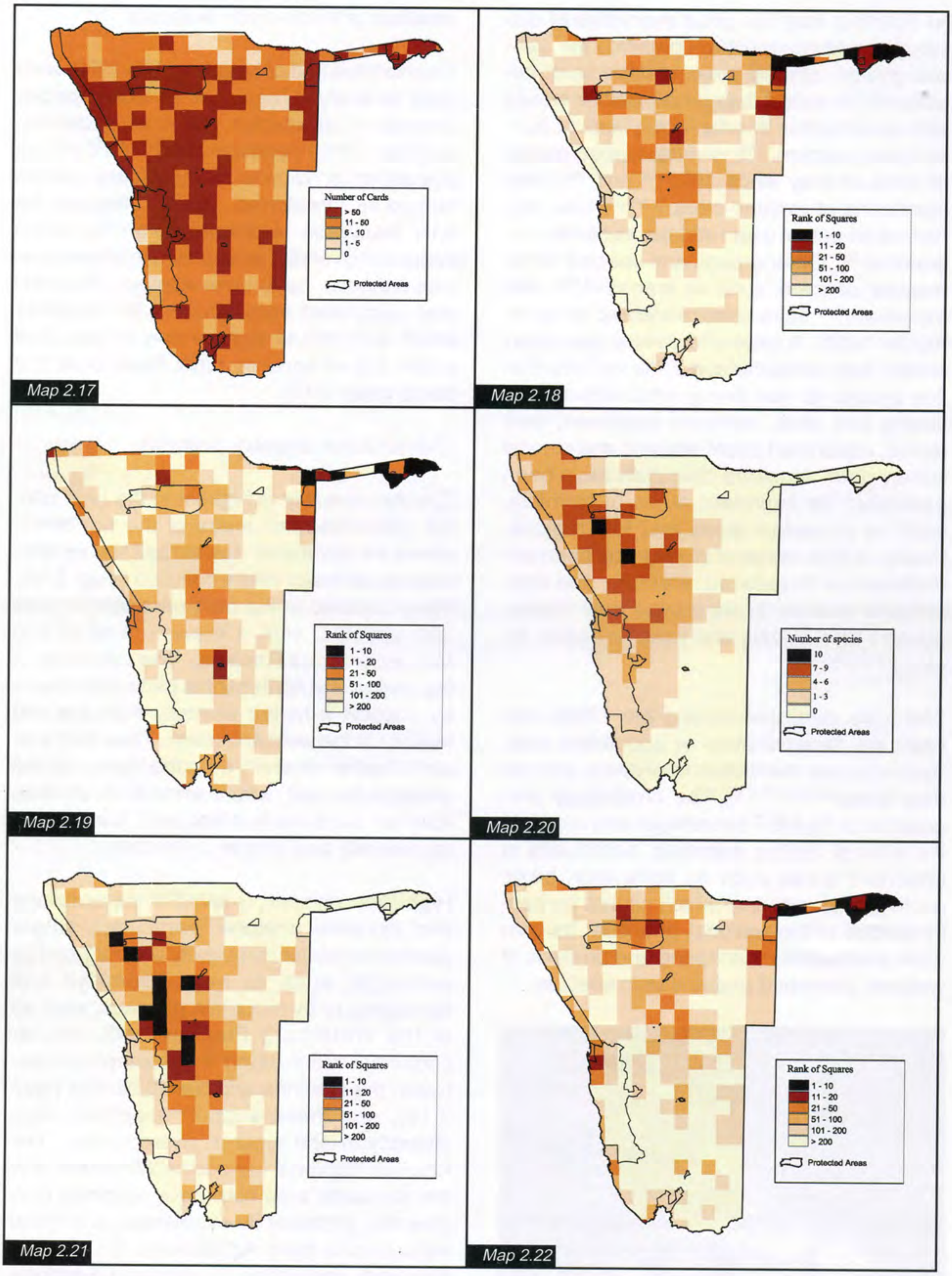
Analysis of biodiversity 'hotspots'

The Namibia bird atlas data (1977-1995) were used to analyse 'hotspots' of avian species diversity for all species, Namibian endemics, southern African endemics with >40% of their population in Namibia, and red data species ranked as *threatened*. So far, birds are the only Namibian terrestrial taxon for which indices of diversity, as opposed to simple species richness, have been applied. The indices calculated here account for observer effort, and should thus be free of bias. Just under 7% of squares have fewer than five cards (map 2.17).

Overall avian diversity hotspots

Species diversity is highest in the high rainfall (500-700 mm) areas of the northeast, where the woodland, riparian belt and wetland habitats of major rivers coincide (map 2.18). Many squares in the northeast contain over 300 species, with a maximum of 412 in Mahango Game Reserve. The savannas in the central and north-central parts of the country support a higher diversity than the arid regions to the west and south. They also support a higher diversity than the higher rainfall areas to the east, where woodlands on deep Kalahari sand are nutrient poor, low in habitat diversity and simple in structure.

High avian diversity is found at the woodland and savanna ecotone, particularly where additional habitat complexity is introduced by wetlands, such as near Tsumkwe and Namutoni, or by mountain plateaus, such as at the Waterberg Plateau Park. Similar ecotones occur along the escarpment between the savanna and Namib biomes (map 2.1b), and these support especially high diversity in and around rivercourses. The Khomas highland, centred on Windhoek, and the Mariental area both have relatively high diversity, probably due to numerous artificial water bodies there. Additionally, the Khomas highland, consisting of Highland Savanna (map 1.8), is at the interface of the Kalahari to the east, Karoo to the south, Thornbush Savanna to the north, and escarpment to the west. Birds from all these biomes and vegetation types occur around Windhoek.



Maps 2.17 - 2.22 ***Data coverage and avian species diversity in Namibia.*** Maps indicate (2.17) coverage by Southern African Bird Atlas[6] cards per half degree square, and patterns of (2.18) overall bird diversity; (2.19) wetland bird diversity; (2.20) Namibian endemic and near-endemic birds; (2.21) southern African (South West Arid) endemic birds; (2.22) red data birds.

Wetland hotspots

The similarity between overall avian diversity (map 2.18) and wetland bird diversity in Namibia (map 2.19) is striking. Both show hotspots of diversity in the Caprivi, Okavango and eastern Otjozondjupa Regions. The Cuvelai - Ekuma River - Etosha complex is important for birds, as are the coastal wetlands, Orange and Kunene River mouths, and artificial impoundments in the Windhoek and Hardap areas. Yet wetland species do not completely explain the hotspots of diversity in the northeast, since terrestrial species diversity is inherently rich there.[7]

Endemic and near-endemic hotspots

Fourteen species are endemic or near-endemic to Namibia (Table 2.40). Four are confined to the Namib Desert: one to the dune sea and interdune hummock areas from the Kuiseb to near Lüderitz (dune lark), two to the gravel plains and interdune plains (Gray's lark, Rüppell's korhaan), and one as a breeding near-endemic to the coastal plains and salt pans of the Namib (Damara tern). The other ten species are found in a north-south belt of dry savanna and escarpment running from southern Angola to about 21°S (Omaruru) for the barecheeked babbler, to the Windhoek area for Hartlaub's francolin, violet woodhoopoe and Carp's tit, to Rehoboth for Rüppell's parrot, to the Naukluft mountains for Herero chat, rockrunner, Monteiro's hornbill and whitetailed shrike, and across the Orange River for rosyfaced lovebird. Species with ranges extending slightly into adjacent countries, but with core populations in Namibia, are Bradfield's swift, Barlow's lark and chestnut weaver.[6]

The dune lark, Damara tern and Gray's lark have the most restricted ranges in Namibia, while the violet woodhoopoe has the smallest population size at about 2000 birds (Table 2.40). The woodhoopoe also has the smallest proportion of its population contained in protected areas, probably fewer than 100 individuals.

The zone with the greatest number of endemic species is shown in map 2.20. The greatest overlap of endemic species occurs in two half degree squares (1914D and 2015D), with ten endemic species each. These two squares occur on the eastern edge of the transitional escarpment zone, and both contain major rivercourses.

Southern African endemic hotspots

Over 100 species endemic to southern Africa occur in Namibia. Of these, about 90 species have 40% or more of their world population within Namibia, and are predominantly arid dwelling (Appendix 11). While few southern African endemics occur in the hyper-arid desert, their greatest diversity in Namibia is centred on the arid savanna and Karoo systems and extends into the escarpment zone. The highest species richness occurs on the mountainous, rocky and stony components of the dry savannas and Karoo, between rainfall isohyets of 100 and 400 mm and 600 - 1800 m altitude (map 2.21).

Red data bird hotspots

At the global level, 11% of bird species are threatened with extinction, compared with 25% of mammals, 20% of reptiles, 25% of amphibians and 34% of (mainly freshwater) fish.[379] The term *threatened* covers the three categories of *critically endangered* (168 species, 2%), *endangered* (235 species, 2%) and *vulnerable* (704 species, 7%). Another 9% of the world's avifauna is near-threatened.

Box 2.28 Bird conservation status terms

Conservation status rankings of Namibian birds are based on a weighted combination of number of different habitats and area occupied, population size, breeding rate, trends in population size, and threats from human activities. Birds were placed in one of five categories: *critically endangered* - species in danger of extinction in Namibia if causal factors continue to operate, *endangered* - species likely to move into the critical category if causal factors still apply, *vulnerable* - species with small, localised or declining populations, but not yet endangered, *lower risk* - species requiring regular monitoring, such as endemics and restricted range species, and *secure* - species not considered at risk, with stable and viable populations in Namibia.

Table 2.40 Population parameters for Namibia's 14 endemic birds: habitat, range size in quarter degree squares (QDS), and population estimate. The proportion of the population in protected areas (P), freehold farmland (F) and communal tenure farmland (C) is given.[6,52,54,375]

Species	Habitat	No. QDS	Population size	% in P	% in F	% in C
Hartlaub's francolin	rocky slopes, escarpments	278	27 000	8	75	17
Rüppell's korhaan	gravel plains	324	100 000	23	30	47
Damara tern	coastal gravel plains	54	13 000	100	0	0
Rüppell's parrot	savannas & rivercourses	195	30 000	11	64	25
Rosyfaced lovebird	arid & semi-arid savannas	440	350 000	9	76	15
Violet woodhoopoe	large trees - large rivers	131	2 000	2	76	41
Monteiro's hornbill	hilly savanna woodland	353	340 000	5	71	24
Dune lark	vegetated Namib dunes	35	20 000	96	4	0
Gray's lark	gravel plains	71	100 000	78	3	19
Carp's tit	semi-arid savannas	356	500 000	5	67	28
Barecheeked babbler	mopane hills - rivers	129	80 000	40	51	9
Herero chat	hillsides, granite outcrops	160	110 000	2	61	37
Rockrunner	rocky hillsides	350	100 000	8	63	29
Whitetailed shrike	hilly savanna	396	1 500 000	2	65	33

Eighty-six (13%) of Namibia's birds are considered threatened at the national level (see Box 2.28). These consist of 12 *critically endangered* species (2%), 22 *endangered* species (3%), 52 *vulnerable* species (8%) and 76 species at *lower risk* (12%) (Appendix 12).

The IUCN[379] lists eight globally threatened and 14 lower risk bird species as occurring in Namibia, or 1% and 2% respectively of all Namibia's bird species. Of these, none is critically endangered at the global level. One, blackfaced lovebird, is endangered and the other seven are vulnerable (Table 2.41). Birds in both the global and national high-risk categories are priorities for conservation action. Based on this assessment, Namibia's 'Top 12' bird priorities are slaty egret, Cape griffon, wattled crane, blue crane, blackfaced lovebird, African penguin, Cape gannet, crowned cormorant, African oystercatcher, Damara tern, lesser flamingo and Cinderella waxbill. Habitat degradation or loss jeopardises many of these species; the Cape griffon is imperilled by poisoning (section 2.5), and hybridisation and the pet trade are likely to be the major risks to blackfaced lovebirds.

An analysis of Namibian biomes supporting red data species (Table 2.42) illustrates that wetland habitats contain the greatest number of threatened species, constituting 23% of all wetland birds. The associated riparian belt has 12 threatened birds or over 50% of the species that are restricted in Namibia to this habitat. This high figure reflects both the small populations of birds falling within this category, and the environmental degradation resulting from high population pressure of humans and elephants. Eight coastal birds (20% of all coastal birds) fall into the three most threatened categories, while representation of red data birds in other biomes is less than 7%.

Over 80% of threatened birds in Namibia are non-passerine species. The taxonomic groups represented largely reflect the threatened wetland and coastal habitats. The riparian belt can be broadened to include woodland species with a restricted distribution along the borders of Namibia. These can be considered as a 'peripheral' group of red data species. Together the wetland, coastal and peripheral red data birds account for about 85% of Namibia's threatened bird species.

One important group missing from this analysis is the scavenging birds of prey, consisting of seven species (70% of all scavenging raptors). If we add these birds to the analysis, these four bird groups together account for 93% of all Namibia's red data species. Scavengers are threatened directly by poisons on farms and by shooting.[368,369]

Table 2.41 Namibian birds listed by the IUCN[379] as globally threatened (Critically Endangered: CR, Endangered: EN and Vulnerable: VU) and as at Lower Risk (LR), and their conservation ratings.

Species	Rating: Global	Rating: Namibian	Comments
Slaty egret *Egretta vinaceigula*	VU	EN	Small declining fragmented population
Cape griffon *Gyps coprotheres*	VU	CR	Single population, rapid decline
*Lesser kestrel *Falco naumanni*	VU	LR	Declining population and range
Wattled crane *Grus carunculatus*	VU	CR	Small declining population, habitat loss
Blue crane *Grus paradisea*	VU	EN	Small fragmented declining population
*Corncrake *Crex crex*	VU	LR	Declining population, loss of habitat
Blackcheeked lovebird *Agapornis nigrigenis*	EN	CR	Small single subpopulation, declining
#Red lark *Certhilauda burra* (dune lark *C. erythrochlamys)*	VU	LR	Small single population
African penguin *Spheniscidae demersus*	LR	CR	Major population decline (90%)
Cape gannet *Morus capensis*	LR	EN	Population decline
Crowned cormorant *Phalacrocorax coronatus*	LR	EN	Small single subpopulation (~6000 birds)
Bank cormorant *Phalacrocorax neglectus*	LR	LR	Small population (~ 18 000 birds)
Lesser flamingo *Phoeniconaias minor*	LR	EN	20% decline, species susceptible
*Pallid harrier *Circus macrourus*	LR	LR	Large decline in population
**Black harrier *Circus maurus*	LR	LR	Small single population, habitat fragmentation
African oystercatcher *Haematopus moquini*	LR	VU	Small population (~4800 birds) habitat disturbance
*Blackwinged pratincole *Glareola nordmanni*	LR	LR	Population declining
*Great snipe *Gallinago media*	LR	LR	Population declining
Damara tern *Sterna balaenarum*	LR	EN	Small (13 000) population, habitat pressure
Sclater's lark *Spizocorys sclateri*	LR	LR	Small population, habitat quality declining
Herero chat *Namibornis herero*	LR	LR	Small (110 000) single population
Cinderella waxbill *Estrilda thomensis*	LR	EN	Small single subpopulation

** Species breeds in the Palaearctic region and declines due to threats on breeding grounds there*
*** Breeds in South Africa, nonbreeding birds migrate to Namibia and other regions of southern Africa*
 # Red lark complex has been divided into red lark of the northwestern Cape, RSA; dune lark of the Namib Desert, Namibia; Barlow's lark C. barlowi, *of coastal succulent Karoo, southern Namibia to Port Nolloth, northwestern Cape, RSA; and Karoo lark* C. albescens, *distribution western and central Cape, RSA.[6] The Namibian rating refers to the dune lark; the new Barlow's lark is likely to be similarly classified.*

The last six species not assigned to one of the above four groups consist of large species occurring at low density which are either hunted (ground hornbill, blackbellied korhaan) or are persecuted because they prey on livestock (martial eagle). Other species occur naturally at low densities (bat hawk, Cape eagle owl) or are vulnerable to cattle dips and have become extinct in adjacent countries (yellowbilled oxpecker).

The distribution of these red data species (map 2.22) clearly reflects the combination of wetland, peripheral and riparian groupings in the Caprivi region, where all the highest ranking squares cluster. Worthy of note is the influence of wetland species on red data hotspots along the Okavango and Kunene Rivers and in the *oshana* - Etosha and Tsumkwe pans. The combination of coastal and wetland red data species is apparent at the deltas of ephemeral rivers on the Skeleton Coast, at Walvis Bay and Sandwich Harbour, and the perennial river mouths of the Kunene and Orange.

Fig. 2.84 Rüppell's korhaan. Courtesy K Bartlett

Table 2.42 ***Number of red data birds (CR: Critically Endangered, EN: Endangered, VU: Vulnerable) in each biome, and the proportion that this constitutes of all species in that biome.***

Habitat	Number of species				Percent birds
	CR	EN	VU	Total	in each biome
Deserts	0	0	0	0	0
Savannas	2	0	0	2	1
Woodlands	1	4	4	9	7
Riparian belt	1	4	7	12	52
Mixed terrestrial	0	2	19	11	3
Coastal	1	2	5	8	20
Wetlands	7	10	17	34	23
Total	12	22	52	86	

Conclusions

For a rapidly developing nation, Namibia's avifauna is especially well researched, with well defined conservation and biome-specific priorities. Geo-referenced databases have recently speeded up syntheses of these groups, allowing detailed analyses of priority areas (Box 2.29). Wetlands and their avifauna consistently emerge as priority habitats for conservation work. While it is not rich by equatorial standards, our large arid-adapted avifauna makes Namibia a fascinating region for both single-species endemics studies and a platform for further work on conservation biological, ecological and evolutionary aspects. Such studies are building creatively on the solid groundwork laid by previous ornithologists in Namibia.

— CJ Brown, Alice Jarvis, Tony Robertson & Rob Simmons

Mammal diversity

Not only does Namibia have healthy numbers of an impressive array of large, well-known mammals, some of which are greatly threatened in other countries, it also supports a rich fauna of small, lesser known mammals. Some of these were recorded as far back as the late 1700s, which is remarkable in view of the country's forbidding reputation among early travellers. In the 1920s and 1930s, the first modern systematic survey of Namibian mammals was carried out.[381] Since then, the fauna has become increasingly well known, and numerous synthesis works on this fauna are in progress. Namibia is, so far, the only southern African country not to have produced a modern atlas of its mammals.

Data sources

Data on Namibian mammals are available from *c.* 45 000 known museum specimens, many of which may remain inaccessible in European institutions. Conservation status and taxonomic assessments depend on this material, but only the recent development of analytical biochemical techniques and advanced statistical methods have resolved long-standing taxonomic problems. There is still a paucity of data on biogeography and conservation status for most species. Irregular official questionnaires access some data, much of it anecdotal and unquantifiable. Surveys targetting commercial farmers have established population and distribution trends for large mammals on commercial farmlands (section 2.5). Monitoring and census programmes are now established in most conservation areas and some communal areas, and focus primarily on large mammals.

An annotated bibliography of Namibian mammalogy[382] lists about 1300 titles relating directly to Namibia. In addition, 30 of the 530 species accounts published by the American Society of Mammalogists cover indigenous Namibian mammals.

Box 2.29 Important Bird Areas (IBAs) in Namibia

The Important Bird Areas (IBA) project is an initiative of BirdLife International and its national partners to identify and protect the most important areas for birds in each country of the world. Its aim is to develop a network of protected sites, critical for the long term viability of bird populations across the range of each species. To this end, southern Africa has recently produced a document on all IBAs in the region.[380] Namibia's most important IBAs were selected by the Ornithology Programme of the Ministry of Environment (MET) and other professional ornithologists in Namibia.

What are IBAs? They are discrete regions in which

- *significant assemblages of birds occur (nationally = 5000; globally = 20 000), or*
- *significant numbers of restricted-range or biome-specific birds occur, or*
- *significant numbers of threatened birds occur (globally and nationally threatened red data species, or*
- *1% of the world population of any species occurs.*

Identification of IBAs can help prioritise conservation efforts and resources, and add to a global effort to recognise the relatively small areas where most of the world's birds are concentrated.

Which birds are most 'important?' These include species identified in red data lists as globally threatened. The selected IBAs include 21 sites, ranging from large conservation areas (Namib-Naukluft Park) to small unprotected sites (Mercury Island). Each species identified as threatened in some way is covered somewhere by this shortlist. The list is not exhaustive, but should capture c. *90% of Namibia's important areas for birds. Of the 21 sites, 17 support globally threatened species and thus qualify as Globally Important Sites. The remaining four sites contain Namibian red data birds. The sites are predominantly coastal, reflecting the importance of the Benguela Current and coastal wetlands for resident and migrant birds.*

Important Bird Areas in Namibia and their conservation status

IBA	Protected status	IBA status
1. Sperrgebiet	By mining corporation (partial Ramsar)	Global
2. Bushmanland	None: proposed conservancy	Global
3. Lüderitz Bay islands	None	Global
4. Possession Island	None: staffed by Ministry of Fisheries	Global
5. Mercury Island	None: staffed by Ministry of Fisheries	Global
6. Ichaboe Island	None: staffed by Ministry of Fisheries	Global
7. Walvis Bay	None (Ramsar)	Global
8. 30 km beach	None	National
9. Sandwich	Namib-Naukluft Park, Marine Reserve	Global
10. Mile 4 Saltworks	Private Nature Reserve	Global
11. Cape Cross	Cape Cross Seal Reserve	National
12. Kunene River mouth	Skeleton Coast Park	National
13. Epupa-Ruacana	None	Global
14. Hobatere (endemics)	None	Global
15. Etosha	Etosha National Park (Ramsar)	Global
16. Mahango	Mahango Game Reserve	Global
17. East Caprivi	Partial (Mudumu & Mamili National Parks)	Global
18. Brandberg	National Monument	Global
19. Naukluft	Namib-Naukluft Park	Global
20. Hardap Dam	Hardap Recreation Resort	National
21. Waterberg	Waterberg Plateau Park	Global

Included here is Namibia's best site for endemic birds, Hobatere, just southwest of Etosha National Park. This area, encompassing just three 1/4 degree squares, contains 1% of the world's Herero chats. All of Namibia's 14 endemic birds are contained within these IBAs.
— *Rob Simmons*

Conservation status rankings for the majority of mammal species are entirely provisional, as quantitative data are sparse. The species richness map (map 2.23) was generated by overlaying hand-drawn range maps delineated using a combination of the above museum and literature data, ongoing fieldwork, and intuition and inference gained over the past two decades.

Species richness

Two hundred fifty mammal species (217 known plus 33 expected), including cetaceans, are believed to occur in Namibia.[383] These taxa represent 74% of the southern African region's mammal species richness, 83% of its generic richness, and 98% of its familial richness. Namibia supports 24% of the African continent's mammal species richness, 49% of its generic richness, and 83% of its familial richness (Table 2.43).

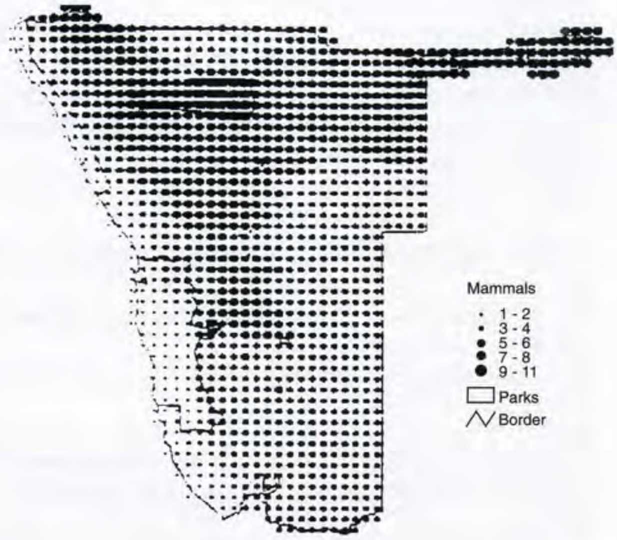
Table 2.43 Taxon richness of indigenous Namibian mammals in regional, African, and global context*

Taxon	Namibian	Southern African	African	Global
Species	250	338	1052	4629
Genera	147	178	301	1135
Families	45	46	54	136
Orders	14	15	15	26

**Source: Griffin[384]*

Biogeography

The Namibian mammal fauna has long been recognised as distinct, encompassing a major share of the Southwest Arid biogeographic Zone.[385] Rautenbach[386] described three biotic zones: Namib Desert, Southwest Arid, and Southern Savanna Woodland. Coetzee[387] renamed these divisions 'mammalian zoogeographical provinces,' and identified six subprovinces, made up of 11 districts which resemble Giess's vegetation zones.[5]



Map 2.23 Expected species richness distribution of 208 terrestrial Namibian mammals, showing major protected areas.

Map 2.23 illustrates the expected current species richness patterns of 208 species of Namibian terrestrial mammals. Additionally, Coetzee[387] outlined the expected distribution of 150 species. The gross distribution pattern is characterised by relatively low richness in the southwest and high richness in the northeast, reflecting the mean rainfall gradient (map 1.1). In addition, three physiographic features influence these patterns. 1) The south-central and northern Namib sand seas, with their unstable substrate and homogenous habitat, limit local species richness. These effects are partly ameliorated by inselbergs and ephemeral rivers, which allow rupicolous and vegetation-dependent species to invade otherwise unsuitable regions.[337,388] 2) The western escarpment dividing the Namib plains from the central mountainous plateau is considered the only major barrier to Namibian mammal distributions.[387] 3) High mammal richness in the Caprivi is greatly enhanced by the three major river systems running through the region. The Okavango, Kwando, and Zambezi Rivers drain major portions of Angola and Zambia, and support marginal populations of many tropical African species.[389]

Relationships between the Southwest Arid Zone mammal fauna, of which Namibia is the 'majority shareholder,' and the Somalia arid region mammals, are not well understood.[390] For example, Damara dik-dik *Madoqua kirkii* in the two regions are probably genetically distinct species,[391] while the southern African rodent genus *Gerbillurus* has been tentatively separated from the north and east African *Gerbillus* since 1975.[392] Another ten taxa have such disjunct distributions, but none of these is endemic to Namibia.

Namibia's marine mammals comprise two or three pinneped and *c.* 39 cetacean species, comprising a marginal proportion of the southern Atlantic community (Chapter 3).

Endemism

Currently 14 mammal species are considered endemic to Namibia (defined in Appendix 10; see Table 2.44). Of these, 11 are rodents and small carnivores whose biogeography and taxonomy are poorly known. Expected ranges of all 14 species follow a north-south pattern. The distributional margins of these species in southern Angola and South Africa are poorly documented. Most endemic mammals are associated with the Namib and escarpment, and at least 60% are rock-dwelling. The Namib dune gerbil *Gerbillurus tytonis*, endemic to the central Namib sand sea, is the only truly sand-dwelling species.[393] Another area of high endemism is Brukkaros Mountain, an isolated volcanic crater (map 1.4), although this aggregation may be biased by patchy sampling in adjacent areas.

Table 2.44 Endemism in Namibian mammals in regional and African context*

Taxon	Namibian	Southern African	African
Species	1%	17%	93%
Genera	0%	7%	78%
Families	0%	0%	33%
Orders	0%	0%	3%

**Source: Griffin,[384] based on 100% endemism for comparative purposes*

The endemic mammal fauna is perhaps best characterized by the endemic rodent family Petromuridae (the monospecific dassie rat, *Petromus typicus*), and the rodent genera *Gerbillurus* (with all four species endemic to or found extensively in Namibia) and *Petromyscus* (with four of the five species endemic to or found extensively in Namibia).

Conservation status

Prior to the publication of a red data book on Namibian mammals,[394] an interim guide has proposed provisional conservation status rankings for Namibian mammals.[324] Numbers of species in each category are summarised in Table 2.45; Appendix 10 defines conservation categories.

Approximately 50% of Namibian mammals are provisionally considered as of conservation concern, meaning categories other than *secure*. Ironically, the category *secure* includes many species in which considerable conservation effort is invested, such as springbok, kudu and gemsbok. A further 19 species (8%) are assigned to definite threat categories, while 94 species (38%) are assigned possible or probable threat categories. Note that most species (including *secure* ones) would be defined by recent IUCN criteria as *data deficient*.[338] Species in this category require protection equal to those in known threat categories until they can be studied and confidently ranked. *Rare* is not considered a threat category in Namibia.

Fig. 2.85 *Petromus typicus*, the dassie rat, is the only species in this endemic Namibian family. Courtesy M Griffin

Table 2.45 ***Provisional conservation status* of indigenous Namibian mammals.*** Data indicate number of species per category, and a species may occur in more than one category.

Order	EN	VU	RA	IND	INS	ENDM	PERI	SEC
Insectivora	—	—	—	—	1	—	3	4
Chiroptera	—	—	—	2	2	2	16	28
Primates	—	—	—	—	1	—	2	2
Carnivora	1	4	4	10	4	2	17	14
Cetacea	—	—	—	6	6	—	38	1
Proboscidea	—	1	—	—	—	—	1	—
Perissodactyla	1	—	—	—	2	1	2	1
Hyracoidea	—	—	—	—	—	—	—	2
Tubulidentata	—	—	—	—	—	—	—	—
Artiodactyla	2	9	1	3	6	—	18	10
Pholidota	—	1	—	—	—	—	—	—
Rodentia	—	—	3	—	1	9	12	39
Lagomorpha	—	—	—	—	—	—	—	5
Macroscelidea	—	—	—	—	—	—	1	5

** EN = Endangered; VU = Vulnerable; RA = Rare; IND = Indeterminate; INS = Insufficiently known; ENDM = Endemic; PERI = Peripheral; SEC = secure. Categories as in Griffin*[324]

Conservation threats

The distribution of smaller mammal species has probably changed little, if at all, in historical times. Most larger species, especially large edible species, those of commercial value, and large predators, have suffered huge range reductions. Plains zebra *Equus burchelli* and lion *Panthera leo* have both experienced range reductions of over 95%. Yet other potentially vulnerable species such as springbok *Antidorcas marsupialis*, gemsbok *Oryx gazella*, and leopard *Panthera pardus* have not experienced major range reductions. Kudu *Tragelaphus strepsiceros* require surface water and do well in bush-encroached areas, and may have expanded their range through human activity.[395]

Detrimental habitat changes were not just confined to commercial farming areas; ungulate populations in communal areas have also suffered. Several species recorded in the early 1930s in the former Owambo[85,381,396] have been extinct there for at least 20 years. As a general pattern, vulnerable populations receded in a northeasterly direction, leaving the northeast regions as the only haven for many species which were once widespread. Habitat alteration and overutilisation are the two primary processes threatening mammals.

The black rhino *Diceros bicornis* is a classic example of a species hunted to near extinction. Dedicated efforts over the past 30 years, however, have helped safeguard the nominate subspecies, and the black rhino is now a major conservation flagship (Boxes 2.6 and 4.12). Since 1990, a major trade in Namibian Cape pangolins *Manis temminckii* has developed which threatens this genuinely rare and vulnerable species (Table 2.45).

In 1967, Ordinance 31 helped redress the overharvesting of game mammals on private land by shifting ownership of game from the state to landowners. Landowners could then commercialise game species which were previously perceived to compete with livestock. The Nature Conservation Amendment Act of 1996 gives similar rights to those living in communal areas (Chapter 5), with the hope that rural people realise the value of wildlife and manage it sustainably. In practice, however, decentralisation of wildlife management does not always promote sound biodiversity principles. On the introduction of Ordinance 31, private landowners demanded animals to restock or to supplement existing populations. As such animals were not always locally available, landowners imported genetically alien stock such as roan antelope *Hippotragus equinus* from other countries, facilitating crossbreeding with local animals.

While bush encroachment may benefit species such as kudu, dik-dik, and even cheetah,[70] deforestation is a direct threat to the survival of tree-dependent species such as bushbabies or galagos *Galago moholi*, vervets *Chlorocebus aethiops*, *Thallomys* tree rats, tree squirrels *Funisciurus congicus* and tree roosting bats in the genera *Scotophilus*, *Kerivoula*, *Nycteris* and *Epomophorus*. Deforestation is most noticeable in arid regions, but is also a major problem in more mesic regions. Of the 470 km of Okavango River frontage in Namibia, less than 30 km are still pristine. Deforestation affects both tree-dependent and wetlands-dependent mammals. Ten percent of Namibia's mammal species depend on, or are restricted to, wetland habitat, and a further 10% depend on seasonally available freshwater.[389] As all inland wetlands habitats are under some degree of threat, all wetlands-dependent species are ultimately at risk.

Extinctions

Early accounts of the occurrence and distribution of mammals in Namibia were often vague and inaccurate,[397] and at least ten species were recorded as occurring in Namibia with no subsequent evidence. These early accounts may have recorded vagrant individuals or decling populations of marginal species, but some records were entirely unsubstantiated speculation. Nevertheless, white rhinos *Ceratotherium simum*, Cape warthogs *Phacochoerus aethiopicus*, the quagga *Equus quagga*, and the yellow-winged bat *Lavia frons* have all gone extinct in Namibia within historic times. The waterbuck *Kobus ellipsyprymnus* has also probably gone extinct in the last few years, although it may re-establish itself from surrounding areas once poaching pressure is relaxed.

Protection status

Table 2.46 summarizes the known and expected occurrence of Namibian terrestrial mammals within formal conservation areas. Despite the way in which these areas were chosen, over 95% of Namibian terrestrial mammals are expected to occur, at least marginally, within the present network. Over 80% of the species occur in three or more protected areas, and 59 species (28%) occur in ten or more conservation areas. Data on species occurrence are fairly precise, but again, population size and viability are often unknown. Such data are critical for implementing sound conservation strategy.

Important habitats neglected in the current network include rivers and associated riparian vegetation, which are particularly vulnerable to local alteration. Although nearly 40 km of the Kunene River is protected within the Skeleton Coast Park (see Box 2.8), this section has little riparian vegetation, while about 80 km of the Orange River frontage included within the Ai-Ais/ Hunsberg Complex is under threat by private commercial interests. In the northeast, the 152 km of the Zambezi River bordering Caprivi and its associated wetlands, has no protection status at all, and the Okavango River and Kwando-Linyanti-Chobe complex have only 12 km (3%) and 85 km (18%) under protection respectively.

The western escarpment and adjacent mountainous plateau hold the majority of Namibian vertebrate and probably plant endemics (maps 2.2 - 2.7), yet most of this unique and valuable region is poorly protected (section 2.6). The Brukkaros Crater, an evolutionary hotspot for the Namibian endemic rodent genus *Petromyscus*, is not included in the current protected area network. The central Kalahari Desert, a major landscape of eastern Namibia, is unprotected (map 2.8). Fortuitously, few Namibian mammals are specific to the area and many occur in a variety of adjacent landscapes which are protected.

Namibia's marine mammals (see Chapter 3) are of greater concern. These are fully protected by the Ministry of Fisheries and Marine Resources as far as the 200 nm exclusive economic zone. However, the large populations of baleen whales present in our waters prior to the slaughter and collapse of whale populations in the early 1800s and early 1900s have yet to recover. Dolphins have also suffered from exploitation. During the 1980s, dried meat from Namibian Benguela dolphins *Cephalorhynchus heavisidii* sometimes appeared in Cape Town markets, and these dolphins were rumoured to be harvested and shipped to Asian markets. Both practices are partially confirmed by regular records of slashed and flayed carcasses on Skeleton Coast beaches.[398]

Cape fur seals *Arctocephalus pusillus*, of which Namibia has approximately 67% of the world population,[399] are regularly harvested at two sites. This species, plus two vagrant seals from the Antarctic convergence, are well protected along the Namibian coast: about 1400 km of the 1500 km of the Namibian coastline (plus all islands) are under formal or informal protection.

Table 2.46 Protection status of 237 indigenous Namibian mammals

	Mammalian order**														
Protected area*	Ins	Chi	Pri	Car	Cet	Pro	Per	Hyr	Tub	Art	Pho	Rod	Lag	Mac	Total
Mudumu & Mamili	6	36	3	25	—	1	1	—	1	20	1	26	2	1	123
West Caprivi	4	35	3	27	—	1	2	—	1	18	1	25	2	1	120
Mahango	4	28	3	26	—	1	1	—	1	17	1	24	2	1	109
Khaudum	2	24	3	23	—	1	1	—	1	13	1	21	1	1	92
Etosha	4	22	2	25	—	1	3	1	1	14	1	23	3	2	102
Skeleton Coast***	2	18	1	26	+	1	2	1	1	8	—	21	3	3	87
Waterberg	4	14	2	19	—	—	1	1	1	15	1	22	1	1	82
Daan Viljoen	3	10	1	14	—	—	1	1	1	10	1	20	2	1	65
von Bach	3	10	1	14	—	—	1	1	1	7	1	18	2	1	60
Namib Naukluft	3	14	1	21	+	—	1	1	1	8	—	23	4	3	80
Walvis Bay****	2	13	—	12	+	—	—	—	1	4	—	12	1	2	47
Hardap	2	11	1	16	—	—	1	1	1	8	1	22	3	3	70
Naute	1	12	1	16	—	—	—	1	1	6	1	21	3	3	66
Diamond Coast	—	4	—	11	+	—	—	—	—	1	—	7	1	1	25
Ai-Ais/Hunsberg	1	16	1	20	—	—	1	1	1	7	—	22	2	4	76
Total species	8	43	4	38	40	1	2	2	1	28	1	53	5	6	237
Total species in parks	8	28	3	38	—	1	2	2	1	26	1	47	5	5	—

** Excludes proclaimed areas of under 1000 ha. ** Ins = Insectivora, Chi = Chiroptera, Pri = Primates, Car = Carnivora, Cet = Cetacea, Pro = Proboscidea, Per = Perissodactyla, Hyr = Hyracoidea, Tub = Tubulidentata, Art = Artiodactyla, Pho = Pholidota, Rod = Rodentia, Lag = Lagomorpha, Mac = Macroscelidea. *** Skeleton Coast here includes Cape Cross Seal Reserve and the West Coast Recreation Area (Map 2.8). **** A proclaimed protected area used to extend from the Walvis Bay lagoon along the Kuiseb River to Rooibank.*

Fig. 2.86 The sable antelope is a charismatic mammal sought after by trophy hunters and game farmers. Courtesy R Simmons

Fig. 2.87 Namibia's 50 or so bat species may be highly vulnerable to deforestation and pesticides. Courtesy M. Griffin

Formal conservation areas are by no means the only way of conserving biodiversity, including mammal species. From an overall national perspective, informal areas such as conservancies and private game reserves, particularly those adjoining formal areas or enveloping habitats or species of particular concern, can increase the protection of some populations to the point of long term viability. Recent private initiatives adjoining the Naute Recreation Resort and Ai-Ais/ Hunsberg Complex have effectively doubled the area set aside for biodiversity protection in this area, and the long term viability of cheetah in Namibia may be in the hands of sympathetic private landowners.

Market incentives, if strongly guided and controlled by a competent conservation authority, can also be an invaluable tool in a coordinated national programme to preserve biodiversity. However, even private game reserves, which cater to the expectations of the ecotourist or trophy hunter, and manage resources to optimise those expectations, often neglect or unwittingly eliminate other less visible components of biodiversity, leaving these areas with conservation values equal to those of open-air zoological gardens.

Legislation

The Nature Conservation Ordinance (No. 4 of 1975, and subsequent changes) lists ten species of Specially Protected Game. These include nine ungulates and the elephant *Loxidonta africana*. There are 21 species of Protected Game: ten carnivores, 17 antelope, the aardvark *Orycteropus afer*, Cape pangolin, southern African hedgehog *Atelerix frontalis* and the lesser galago. In addition, six ungulates are designated Huntable Game, and the Hamadryas (chacma) baboon *Papio hamadryas*, rock dassie *Procavia capensis*, black-backed jackal *Canis mesomelas* and the caracal *Caracal caracal* are proclaimed problem animals. All other mammal species are defined as 'Wild Animals' with a greatly reduced protection status.
— *Mike Griffin*

2.10 Namibia's unwanted biodiversity: alien invasive species

Compared to some countries in Africa, Namibia has comparatively modest problems with *alien invasive* species (species which are introduced from elsewhere, did not occur here naturally, and can outcompete and displace indigenous species).[400] However, the modest scale of Namibia's problem may mean that we can control many alien invasives in this country before they become widely established. Of lower organisms, the only real information is on agricultural pests and pathogens (Appendices 5, 6 and 9, which list mostly alien species). These organisms affect human enterprise and food security, but they may or may not have broader ecological impacts. This section therefore focuses on what we know of alien invasive plants and animals, some of which are of significant economic and ecological concern.

Alien invasive plants

As an arid country, Namibia does not have to cope with the problem of invasive alien plants to the same extent as do more mesic regions, such as South Africa's Cape fynbos.[401] Nevertheless, alien invasive plants do occur in Namibia and must not be allowed to spread.[402] Areas most affected and prone to invasion are rivers (both perennial and seasonal), especially those close to human habitation. This means that invasions occur across national borders. Control programmes thus require national and regional cooperation to be effective. South African agencies make huge and costly efforts to control the spread of alien invasive plants, partly because of their damaging effects on catchment management and water supply.[400] The control programmes of other neighbouring countries, if any, are unknown.

The only comprehensive published data available on alien invasive plants in Namibia were collected during a two-day workshop held in 1984.[402] That report identifies problem alien plants in Namibia and gives some qualitative estimates of distribution, severity and ecological threats. From National Herbarium records, other published taxonomic papers and species lists for the southern African region,[228,231,232,403-407] subsequent information on alien species within Namibia was gathered. The reliability of some of these sources is questioned by Namibian botanists, and this account should be regarded as preliminary until a proper scientific survey has been done.

Namibia has no official list of alien invasives or noxious weeds, and no effective legislation to govern their introduction and control. The National Herbarium has a list of naturalised alien plants, but the categorisation of invasive species is incomplete. Scheepers[408] lists ten important alien invasive plants in Namibia (Box 2.30). More objective, scientific research is needed to confirm and amend this priority list, using established methods.[409] By far the largest number of alien plants are dicotyledons, with several monocotyledons and one pteridophyte (Table 2.47).

Box 2.30 Ten important alien invasive plants in Namibia[408]

Salvinia molesta
Prosopis spp.
Nicotiana glauca
Datura innoxia
Opuntia ficus-indica
Melia azedarach
Lantana camara
Ricinus communis
Argemone ochroleuca
Dodonaea angustifolia

Alien invasive plants were often purposely introduced to Namibia for specific reasons: *Prosopis* for production of firewood, fodder and as a shade tree;[410,411] *Opuntia* as livestock feed, for its fruit and as an ornamental;[410] *Melia azedarach* as ornamental and shade tree.[410,412] Others have been introduced accidentally through movement of livestock, livestock feed or by water along rivercourses from outside the country: *Datura*, *Argemone*, *Nicotiana glauca, Xanthium spinosum*.[412,413] Table 2.48 shows the regions of origin of naturalised alien plants found in Namibia. Wells *et al.*[412] summarise the history of alien plant introductions into southern Africa.

Table 2.47 Taxonomic summary of naturalised alien plants in Namibia

Family	No. of species	% of total
Asteraceae	28	13.5
Poaceae	23	11.1
Fabaceae	23	11.1
Solanaceae	14	6.8
Amaranthaceae	13	6.3
Chenopodiaceae	10	4.8
Amaranthaceae	9	4.3
Malvaceae	8	3.9
Polygonaceae	5	2.4
Other families with 4 or fewer spp. per family	74	35.7
Total dicotyledons	178	86.0
Total monocotyledons	28	13.5
Total gymnosperms	0	0
Total pteridophytes	1	0.5
Total	207	

Distribution and abundance

The distribution pattern of naturalised alien plant species in Namibia generally reflects the distribution pattern of rivers, human habitation or disturbance.[402] Very few alien species are collected for herbaria, but distribution data urgently need to be updated and gaps filled. Very few quantitative data exist on the density and size of alien plant populations or their impact on natural vegetation in Namibia.[402] Few reports contain quantitative data.[413] Others indicate the size of the areas infested, but no densities.[415] Only Tarr and Loutit[414] state densities as well as methods. The limited data show that large, dense, populations which have replaced natural vegetation occur around Windhoek, Katima Mulilo, Waterberg and almost all westward flowing rivers, particularly the Kuiseb, Omaruru and Ugab Rivers. Along all other major rivers, alien vegetation seems limited to either few species, such as *Prosopis* on the Nossob and Olifants Rivers,[416] or very localised populations.

The distribution patterns of herbaceous naturalised aliens are extremely variable over time. Populations and seed of species like *Argemone* and *Datura* in riverbeds can be washed downstream by floods to establish themselves elsewhere. Dams in rivers also stop seeds from washing down into the ocean and contribute to the establishment of new populations. The location and density of such populations is therefore highly variable. Woody, perennial species are not displaced as easily.

Table 2.48 Origin of naturalised alien plant species in Namibia

Region of origin	No. of species	% of total
Americas	80	38.6
South America		
(included in above)	53	25.6
Europe & Asia	65	31.4
Australia	5	2.4
Others*	57	27.5
Total	207	

** includes unknown, uncertain, cosmopolitan, pantropical*

Control measures

Namibia has no national policy or programme on the introduction or control of alien plants. As biodiversity conservation is now an explicit objective of Namibia's state protected areas, the control of alien invasives is implicitly contained in park management plans.[417] In the late 1980s efforts were made in national parks, particularly Etosha, to control alien plant species, mainly by mechanical means.[417] Since then, there has been no concerted effort to control alien invasives in park areas.

On privately owned farmland and in communal areas, there is no control over the spread or introduction of aliens. The only method of control over introduction of new alien species is through the phytosanitary control system, which has inadequate facilities, enforcement powers and staff numbers.

In some municipal areas, local laws exert some control. The City of Windhoek, for instance, has included the removal of *Prosopis* as a prerequisite for urban property buyers and developers since 1995. Prior to this date, the buyer undertook contractually to remove *Prosopis* from a property. These provisions were not retroactive.

To control the spread of alien plants in Namibia, national legislation and policy are needed to prohibit the introduction, sale or propagation of species listed as problem aliens. The legislation should also oblige landowners to eradicate listed species on their property. A national effort at controlling alien vegetation would be futile, however, if no control measures were taken in neighbouring countries. A regional policy or law for the SADC Region would be ideal, and in the interim Namibia should attempt to reach agreements with its immediate neighbours.

Broader implications

The most obvious effects of invasion of natural vegetation by alien species are changes in habitat, species and even genetic diversity.[418] Invasions of *Prosopis* in Namibia displace indigenous species almost entirely. Also, ecological processes depend on species composition and interactions, both of which may be affected by severe invasion and displacement.[418] These issues have not been analysed in Namibia, but highly specialised plants and their associated organisms are expected to be most vulnerable to invasion by alien species.[418]

Alien control methods can themselves have negative effects on natural vegetation.[418] Very few control measures against invasive alien plants have been taken in Namibia, and no scientifically sound publications exist on their environmental impacts.

The economic implications of alien invasive species on Namibian agriculture are potentially significant. Arable weeds, which very often are alien species, can cause considerable crop losses,[419-421] although this has not been analysed in Namibia. Alien invasive plants can also have negative impacts on rangelands, due for instance to livestock poisonings by species such as *Melia azedarach*,[422] loss of indigenous forage species, or structural changes which make rangelands inaccessible to livestock.[423]

Finally, Namibia promotes itself as a country of pristine beauty. The effect of invasions by alien species and associated changes in indigenous vegetation, should these become more widespread or severe, could affect the tourism industry significantly.

Legislation

Existing legislation in Namibia is outdated and inadequate. Enforcement of existing laws such as phytosanitary control measures is inadequate, mainly due to lack of qualified staff. The lack of quarantine facilities need not be a problem, as facilities are available in South Africa for the few introductions into Namibia which need quarantine measures. This will be more cost effective than maintaining and staffing a Namibian station. Legislation on the control of alien plants in neighbouring countries is not uniform and should be harmonised along the lines of legislation governing seeds (Box 2.31).
— *Herta Kolberg*

Box 2.31 Recommendations for controlling alien invasive plants

- *initiate a quantitative survey to identify all naturalised aliens, their distribution in Namibia, and (in the case of aliens with severe negative impacts) sources and methods of their invasion;*
- *conduct and encourage research on the impacts of alien plant species on the habitats they occupy;*
- *initiate appropriate control programmes where necessary, taking into account any likely impacts;*
- *revise and update national legislation;*
- *strengthen the phytosanitary control section of the Ministry of Agriculture, Water and Rural Development and any support services needed;*
- *address at SADC level the need for regional harmonisation of control methods and legislation for alien invasive plants.*

Alien invasive animals

Alien animals can invade some habitats and not others, depending partly on the presence of potential competitors, predators and parasites. Freed of organisms which may have limited them in their original habitat, alien species in new environments can become invasive. Namibia's policy is to eliminate alien animal species from natural habitats wherever feasible, and to restrict the introduction of species which could become invasive.

About three snails, one slug, six fish, three birds and eight mammals, as well as at least five livestock parasites and an unknown number of insects, are known to be alien invasive species in Namibia[162,402,425] (Table 2.49, see also Appendix 9). Little relevant animal research has been done since Namibia's 1984 workshop on alien invasives,[402] so rather than repeat these data, this brief account looks at broad conservation concerns.

Biological control agents

The success of using natural biological pests in the control of invasive aliens such as Kariba weed *Salvinia molesta* (Box 2.8) and *Opuntia* cacti is well known.[424] However, as we always have incomplete understanding of ecosystem function and species composition, the choice of biological control agents is extremely risky. For example, once mice had become established on many oceanic islands through human carelessness or intent, cats were often introduced to control them, and themselves became significant pests. The use of influenza viruses to control these cats on sub-Antarctic islands, and rabbits in Australia, is fraught with unknowns, even though many viruses do not infect unrelated hosts.

Genetic pollution

Genetic pollution through hybridisation is known or suspected in Namibia from fish (*Oreochromis mossambicus* freely interbreeds with other tilapia), birds (the domesticated ostrich is a slurry of genes from northern and southern African subspecies) and mammals (see Boxes 2.11 and 2.32). The African wild cat *Felis sylvestris* interbreeds freely with domestic cats throughout Namibia, making it unlikely that this species remains genetically distinct anywhere but the most isolated areas (Box 2.32). Deliberate interbreeding of local and alien subspecies may often be rationalised as producing more robust hybrids, but there are likely to be frequent cases where preservation of the integrity of local Namibian genepools has to be judged more important. This is particularly so where distinctive Namibian animals with economic value are involved (see Box 2.11).

The cross-basin transfer of water in Namibia, raised in sections 2.1 and 2.9, is of great concern to biodiversity conservation in this country. Such water supply infrastructure makes the introduction of alien invasive aquatic species virtually inevitable. In the case of water supply pipelines and canals from the Okavango River, it also raises the possibility of bilharzia parasites and their snail hosts being introduced to Windhoek and the country's central storage dams. The introduction of invasive aliens may be one of the most insidious forms of biodiversity loss, because these species frequently go unnoticed until genetic pollution or establishment occur and eradication becomes impossible. There is little consultation between government ministries, development projects and NGOs about the invasive potential of some deliberate imports.[402] The eradication of invasive aliens from our fragile arid ecosystems should remain a priority, as should the prevention of the introduction of new aliens.

— *Mike Griffin & Rob Simmons*

Box 2.32 Invasive alien mammals

Six alien (and feral) and eight invasive alien mammals are found in Namibia.[426] Mus musculus *has become established at four or more habitations along the Skeleton Coast, and donkeys remain a problem along the lower Orange River. The ecologically important winter-rainfall area of the* Sperrgebiet *contains six of the eight alien invasive mammals (*Mus musculus, Rattus rattus, Oryctolagus cuniculus, Felis catus, Equus asinus *and* Equus caballus*).*

The primary area of concern, however, is genetic pollution. The cross-breeding of Felis domesticus *(domesticated or feral) with local African wild cats* F. sylvestris *is a widespread problem, and nothing is done to prevent hybridisation except in conservation areas. Indeed, hybrids are a source of pride to their owners. The black-footed cat* Felis negripes, *always rare in Namibia,*[381] *may also be under threat from hybridisation with* Felis sylvestris/domesticus *hybrids.*[69] *Despite clear policy on conserving local genetic integrity and the translocation of game species within Namibia, policies are unfortunately not always effectively implemented (Box 2.11).*[144]

Fig. 2.88 Water supply infrastructure is responsible for invasions of aquatic alien species. Courtesy M Griffin

Table 2.49 Namibia's most important known invasive alien animal species

Parasites*	Earthworms	Molluscs	Fish	Birds	Mammals
Oestrus ovis *Damalinia* spp. *Linognathus* sp. *Haematopinus* sp. *Taenia saginata* *T. solium* *Gasterophilus intestinus*			*Oreochromis mossambicus* *Cyprinus carpio* *Micropterus salmoides* *Poicilia reticulata* *Xiphophorous helleri* *Carassius auratus*	*Passer domesticus* *Columba livia* *Sturnus vulgaris*	*Felis catus* *Mus musculus* *Rattus norwegicus* *Rattus rattus* *Oryctelagus cuniculus*
9 species	unknown	4 species	8 species	3 species	8 species

* *Parasites of livestock. The tilapia* O. mossambicus *is at present found naturally in southern Namibia, but if introduced into northern regions would become invasive.*

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Alison Sakko

Courtesy P Tarr

3.1 Characteristics of marine environments

Species richness is typically related to the complexity and stability of the environment:[1,2] groups of individuals become reproductively isolated and adapted to particular ecological niches within a habitat, precipitating speciation.[3] The greater the diversity of these niches, especially in a relatively constant environment, the greater the opportunity for speciation, and the greater the resultant species richness.

The oceans of the world are often seen as vast, stable, homogeneous masses of water offering little in the way of diverse or complex habitats. In contrast to other major environments, such as land and freshwater, oceans are physically continuous. All marine water circulates, making it possible for species to disperse over vast distances. Seawater temperatures vary much less than do air temperatures over land, while the chemical constitution of seawater is remarkably constant, so much so that its salinity and other chemical traits are thought to play a very small role in marine ecology.[4,5]

Because of this apparent evenness, the potential for speciation and diversification seems low. This is indeed partly true of the open ocean, which despite its vastness is home to a paltry 2% of the world's marine species[4]. However, the apparent homogeneity of other marine habitats belies the complexity of chemical and physical processes which occur below the surface largely out of view. Currents, tides, waves, mixing of waters, upwelling and the effects of relief features on the ocean floor combine to create remarkably varied and variable habitats.

Littoral and pelagic habitats are among the most biologically patchy and variable of all. The Committee on Biological Diversity in Marine Systems[6] reports that hundreds of benthic invertebrate species co-occur within a square metre of deep-sea floor. Some even consider the sea to have a higher ecosystem diversity than the land[7,8] and to be far richer biologically than is generally appreciated.

Lack of information on biological diversity in the marine environment reflects the extent to which the world's oceans are unknown. Basic description of marine biodiversity lags behind that of the terrestrial environment, and the identification of new families, orders and even phyla of marine species continues apace.[6]

The diversity of organisms in marine environments is the product of millions of years of evolutionary history. Oceans are particularly rich in higher taxa, with representatives of 28 phyla identified so far. This includes 13 phyla endemic to oceans, with only one known phylum unrepresented. In contrast, freshwater environments harbour 14 phyla with no endemics, and terrestrial systems harbour 11 phyla, one of which is endemic.[9] This extraordinary diversity in higher taxonomic categories reflects the origin and early diversification of life in the ocean. Marine biodiversity thus represents an ancient and fascinating heritage, of which we are the privileged custodians.

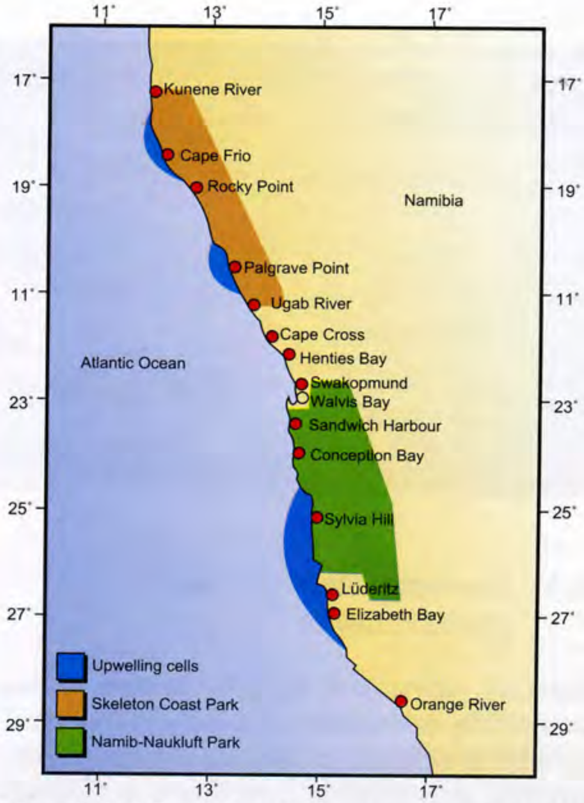
3.2 Namibia's marine environment

Influence of the Benguela system

Namibia's marine environment is dominated by the Benguela Current system, which extends along the eastern edge of the southern Atlantic between Cape Agulhas (35°S) in the south and the Angolan port of Namibe (15°S) in the north. Although the boundaries vary seasonally, the system features cool surface waters and high biological productivity. Warmer waters to the north (Angolan Current), south (retroflection zone of the Agulhas Current) and west (south-Atlantic gyre) enclose the system.[10]

The driving physical process in the Benguela system is coastal, wind-induced upwelling. Prevailing south to southwesterly winds off Namibia tend to move nearshore surface water northwards and offshore, while cool, central water from a depth of about 300 m wells up to take its place.[11] The deeper water is rich in inorganic nutrients which allow phenomenal growth of phytoplankton. As these microscopic plants form the base of the marine food chain, their enormous productivity supports some of the highest concentrations of marine life found anywhere in the world.

Off Namibia, the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns. Bottom topography and the seaward extent of the continental shelf also influence upwelling, with the most intense upwelling being found where the shelf is narrowest and wind strongest. Such conditions prevail especially off Cape Frio, Palgrave Point, Conception Bay and Lüderitz (map 3.1), although upwelling can occur along almost the entire Namibian coast. The largest and most intense upwelling in the Benguela system is near Lüderitz.



Map 3.1 ***The Namibian coast, adjacent protected areas and upwelling cells***

Upwelling is one of the few ways in which nutrients trapped in the deeper oceanic layers are brought to the surface, where they can be taken up by phytoplankton and incorporated into organic compounds. The major nutrients are various forms of inorganic phosphorus, nitrogen and silicon. When organisms die, the organic matter sinks and decays, releasing inorganic nutrients back to the sea. The region near Walvis Bay (map 3.1) is one of the most important sites of nutrient cycling in the system.[11]

The continental shelf sediments of Namibia consist of large areas of *diatomaceous* (diatom rich) muds, supporting little or no marine life but with high concentrations of organic matter and sulphur.[12] Between Cape Cross and Lüderitz the shelf sediments may contain as much as 15% organic carbon, which is exceptionally high.[11] The sulphur concentrations result in periodic, localised sulphur 'eruptions,' causing fish mortalities and giving the sea a turbid turquoise colour and pungent smell. These phenomena are caused by the sinking and decay of vast quantities of organic matter from production in the surface waters.

Decaying organic matter consumes oxygen, so that bottom waters over much of Namibia's continental shelf, extending to a depth of 100 - 150 m, are oxygen-poor. A feature of such shelf water off Namibia is that can exist in discrete pools or tongues over both the upper and lower shelf.[12] Additionally, there is a southward movement of low oxygen water (as low as 0.25 ml/l) at a depth of 300 - 400m. This anoxic water originates off Angola and is found as far south as Lüderitz. Occasionally, it wells up onto the shelf but is more common off central Namibia, where it extends as much as 50 nautical miles (nm) offshore. Such conditions are highly unfavourable for marine organisms. Further south along the Namibian coast, waters are progressively more oxygenated.

Clearly, Benguela upwellings are of great significance for marine biodiversity in Namibia. As a result of upwelling, a three-dimensional mosaic of environmental conditions occurs at any one time. These vary continuously in time and in space, under the influence of physical and biological processes associated with upwelling. This gives rise to marine habitats of variety and variability, and imparts an inherent unpredictability to the system as a whole.

Zonation

Like those elsewhere, Namibia's marine environment can be divided into several zones forming a gradient stretching west from the coast.

The **littoral zone** marks the boundary between land and sea, and extends from the splash zone down to the low tide mark. The euphotic zone extends down another 30 m. The key features of this whole zone are the shallowness of the water and the abundance of light, which may penetrate to the sea floor. Communities of bottom-dwelling organisms (*benthos*) include photosynthetic producers such as seaweeds. This is the only zone in which benthic photosynthesis occurs.

The Namibian coast runs generally in a north-south direction, with few embayments (map 3.1). It is desert along its entire length (1470 km), and most of the shore is sandy beach (54%) or mixed sand and rock (28%). Rocky shores constitute 16% of the total length, while 2% is made up of lagoonal shores.[14] Rocky outcrops may be separated by long stretches of sand, and in most localities (excluding the Walvis Bay area) the bottom sediment up to 2 km offshore consists of clean, coarse-grained sand and shells. The entire coast is exposed to heavy wave action with accompanying silting and sand scour. In general the euphotic waters are shallow, with depths increasing gradually to about 50 m at a distance of 10 - 15 km from the shore.

The **shelf zone** (also known as the epipelagic zone) comprises those areas overlying the submerged continental margins. Habitats in this zone are either *benthic* (bottom) or *pelagic* (water column), with the pelagic habitat that occurs specifically over the shelf zone known as *neritic*. Light does not usually penetrate to benthic communities in this zone, and primary production occurs in the form of floating plankton. Neritic waters are usually rich in nutrients, and are considered the most productive of all marine habitats, particularly where coastal upwelling occurs. Here, abundant nutrients are available for primary production which, in turn, supports a substantial neritic community of fish and other organisms. Many of the world's most important fish resources are harvested from this rich zone. Biological communities in this zone are divided into *planktonic* (free-floating), *nektonic* (swimming) and *benthic*.

The continental shelf of Namibia is generally fairly narrow, especially off southern Angola and Lüderitz. It is at its widest off the Orange River mouth and Walvis Bay. It extends some 90 km offshore between Cape Cross and Conception Bay, and the shelf area from the shore to a depth of 200 m is approximately 110 000 km^2. The predominant surface sediment on the Namibian shelf is *biogenic*, or formed from living matter.[12] A noteworthy feature is a belt of diatomaceous mud containing a high organic content as well as sulphur, stretching 500 km between Cape Frio and Conception Bay.[15] Decomposition of the organic matter leads to oxygen depletion, and these shelf waters are uniformly oxygen-poor. Such sediments are typical of areas of high primary production.

At the edge of the continental shelf the seabed descends rapidly to the ocean floor, marking the **shelf break** zone. The Namibian shelf is one of the world's deepest, generally thought to reach 400 m in places. A double shelf break exists off Walvis Bay, with two parallel shelves of different depths. Waters around the slope tend to be richer in oxygen than shelf waters, and specific communities of organisms are associated with this zone.

The oceanic or **abyssal zone** is the area of open sea beyond the continental shelf, cradled between the continental masses. On the whole, understanding of the biology of this zone is confined to the surface photic zone. In general, though, the waters of the open ocean are dark, cold and nutrient-poor. The Angola and Cape basins, which are the abyssal plains of the South-East Atlantic, both lie in part off the Namibian coast. The two basins are separated by an undersea mountain range, the Walvis Ridge, which extends to the south and west of the shelf edge off Walvis Bay. The Walvis Ridge acts as a barrier to the movement of deeper water.

Habitats in this zone are distinguished mainly by depth, as the physical environment is fairly uniform. The pelagic habitat thus has four regions. The *epipelagic* region (surface to about 200 m depth), includes the well lit, productive area. The *mesopelagic* region (200 - 1000 m) has many small fish species with well-developed eyes.[16] Many mesopelagic fish move up to the epipelagic region at night to feed on the abundant zooplankton in the surface water. The *bathypelagic* region (1000 - 4000 m) is fairly species-poor. Food is less abundant here and sunlight does not penetrate. The surroundings are lit only by bioluminescence of the animals that live there. Lastly, the *abyssopelagic* region (4000 m to the sea floor) is the deepest and most barren oceanic region, and its biota are poorly known.

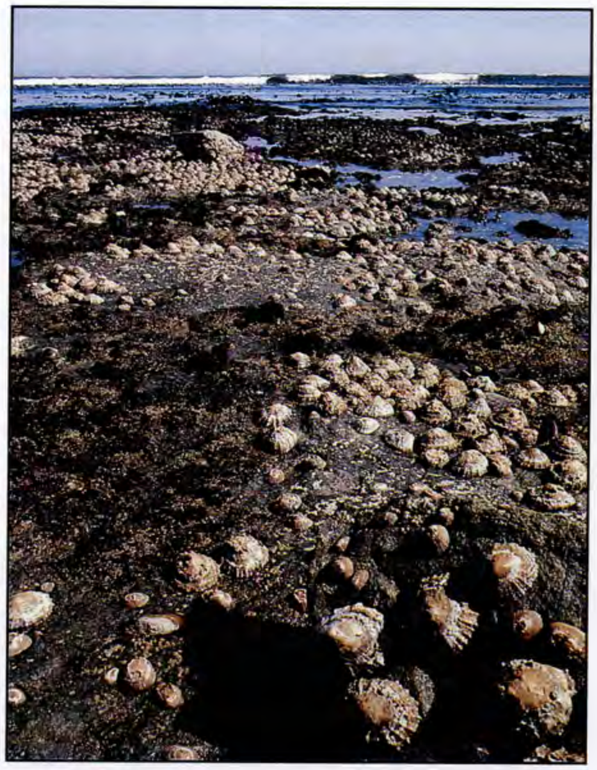


Fig. 3.1 Intertidal fauna. Courtesy K Roberts

Biogeography

Namibia's entire marine environment falls within the Benguela system. This system is continuous, and the biota are typically south-temperate. The intense upwelling cell near Lüderitz is, on average, colder and more oxygen-poor than elsewhere in the system. It is also very turbulent and has been thought to act as an environmental barrier to the movement of some marine species in the system.[11] In effect, the Benguela is divided into two parts, with Lüderitz marking the southern extent of the northern Benguela system. However, biophysical characteristics of the two areas do not differ enough to warrant distinct biogeographic regions.

The northern extent of the Benguela system coincides with the occurrence of southerly winds which drive the upwelling process. During periods of less intense wind off northern Namibia, in late summer and autumn, upwelling in this region weakens. Warm, more saline waters of the Angolan Current intrude and mix with the cooler Benguela waters, so introducing organisms normally associated with the subtropical conditions off Angola. Clearly, such events influence biodiversity in Namibian waters, the areas of interface between the two water masses having higher species richness. Usually these effects are only temporary, although warm Angolan Current waters may intrude as far south as Walvis Bay, for up to six weeks. These events, known as Benguela-Niños, have been recorded in 1934, 1949, 1963, 1973/74, 1984 and 1995. They result in both the temporary introduction of species of tropical west African origin, and adverse environmental conditions for the locally occurring species. Marked reductions in plankton production occur, associated with decreased food availability for consumers. Survival of juvenile pelagic fish is also reduced, with potentially disastrous consequences for stocks.

Namibia's littoral habitats fall within two large, temperate zoogeographic provinces. Northwards from the Orange River mouth to Lüderitz, the fauna are typical of the cool-temperate southwest (Namaqua) province, and are similar to the fauna of southern beaches in the Benguela system.[17] The region is a continuation of the Namaqua province of South Africa, and thus is not exclusive to Namibia. North of Lüderitz, to the Kunene River mouth, the littoral zone falls within the warm-temperate northwest (Namib) province.[18] Although this province extends northwards into southern Angola, the majority of Angola's coast falls within the tropical west coast province.[19,20]

3.3 Biota of the major habitats

Littoral habitat

Sandy shores

The majority of Namibia's littoral habitat consists of sandy shores in the southern Namaqua or northern Namib zoogeographic provinces. In general, intertidal and subtidal regions of Namibian sandy beaches support low species diversity, and moderate to high biomass of organisms in comparison to other west coast sandy beaches. The number of macrofaunal invertebrate species recorded on Namibian beaches is commonly about 10.[21,22] However, Tarr *et al.*[23] recorded 22 and 30 species on two beaches in the north of the country. Their analysis, however, included the terrestrial insect fauna associated with kelp (*Laminaria* sp.) washed-up from subtidal beds. In a survey of six sandy beaches between Oranjemund and Lüderitz,[24] species richness was five or less on all except a single, dissipative beach with fine sand. This last beach supported 14 species. In contrast to species richness, biomass densities of macrofauna on Namibian beaches was lowest in the south, peaked at Walvis-Cape Cross and decreased to low levels towards the Kunene River.[25]

The diversity of sandy shore invertebrates recorded for Namibian beaches (Fig. 3.2) is nowhere comparable to that found at similar latitudes on the east coast of southern Africa. This is due, in part, to a paucity of molluscan species, which are usually well represented on beaches in other areas. Another factor affecting species diversity is the moderate to strong wave action on Namibian beaches.

No endemic animals have been recorded on Namibian sandy shores, and the fauna are generally the same as recorded for shores in the southern Benguela system.[17] It is worth noting, however, that several intertidal species of tropical affinity have been recorded on northern Namibian shores. Tarr *et al.*[23] contend that shores north of Rocky Point lie within a transitional zone between temperate and tropical zoogeographical provinces, and that the presence of species such as the amphipod *Talorchestia skoogi* and the ghost crab *Ocypode cursor* reflect this.

FIg.3.2 Sandwich Harbour. Courtesy R Simmons

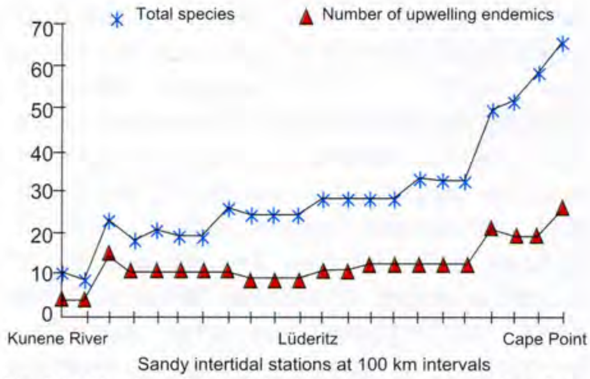


Fig. 3.3 Number of invertebrate species on sandy beaches around the west coast of Namibia and South Africa. 'Upwelling endemics' are species confined to the Benguela upwelling region. Adapted from GM Branch and RH Bustamante, unpublished

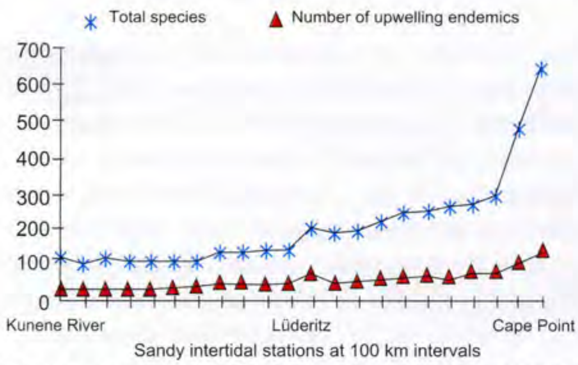


Fig. 3.4 Number of invertebrate species in rocky intertidal habitats around the west coast of Namibia and South Africa. 'Upwelling endemics' defined as above. Adapted from GM Branch & RH Bustamante, unpublished

The tropical sandy shore mussel *Donax rugosis* has been collected up to 60 km south of the Kunene River mouth. This trend is not evident in museum or historical accounts of invertebrate fauna in the area, and can be considered a relatively recent phenomenon. Branch and Bustamante (unpublished data) used these historical data as the basis for their analysis (Fig. 3.3), which therefore does not reflect the occurrence of this tropical element on Namibia's northern shores.

Rocky shores

The **intertidal** rocky shores of Namibia are among the least studied of the southern African region, and very few biological collections have been made in the area.[26,27] Bustamante *et al.*[70] recorded species diversity on rocky shores near Elizabeth Bay. In general, these studies regard the diversity of rocky intertidal species as low, in keeping with other sites in the Benguela system (Fig. 3.4, Branch & Bustamante unpublished). No endemic species have been recorded, and no species are considered rare or threatened.

Community structure of Namibia's rocky intertidal fauna clearly indicates the existence of two distinct zoogeographical regions. The fauna of the region south of Lüderitz are comparable with those of other shores in the Namaqua province, showing similar zonation and key species. In particular, the dominant intertidal mussel species are the ribbed mussel *Aulacomya ater*, the black mussel *Choromytilus meridionalis* and the alien Mediterranean mussel, *Mytilus galloprovincialis*. North of Lüderitz, the rocky intertidal communities show a different zonation, with the mussel belt extending to the infratidal fringe, and limpet-dominated low-shore zone, typical of southern shores, is absent. In this province the abovementioned mussels are completely replaced by the brown mussel *Perna perna* and the bisexual mussel *Semimytilus algosus*.

The exact position of the transition between Namaqua and Namib provinces, although given as Lüderitz,[27] could be further north. Sampling of rocky shore invertebrates by B. Currie shows the southern cool-temperate province to extend at least as far north as Sylvia Hill. The existence of the perennial upwelling cell off Lüderitz, and a large post-upwelling cell with low oxygen levels, may prevent the dispersal of larvae between the two provinces.

The far northern region of the Namib province coincides with the area of transition between temperate and tropical biota. A comparison between Namibian and Angolan intertidal molluscan fauna (Table 3.1) reveals the relatively low species richness in Namibia. A total of only 5% of the Angolan species has been recorded in Namibia, reaffirming the temperate affinities of Namibia's intertidal fauna. As is the case for sandy shore fauna, several rocky intertidal species with tropical affinities have been recorded recently on far northern shores. Approximately ten such species have been collected on shores north of Rocky Point. These include *Trochita* *trochiformis, Littorina punctata,* the whelk *Charonia nodifera,* and two species of key-hole limpets, *Diodora* sp. and *Amblychilepas* sp. These species are all abundant in southern Angola.

The presence of tropical species on rocky shores in northern Namibia is not always noted by researchers. These species seem to become established particularly during and after the intrusions of warm Angolan water associated with Benguela-Niños, or with the relaxation of upwelling in the area. This water carries the planktonic larvae of many tropical intertidal species to northern Namibian shores. The adults, once established, are not as sensitive as the larvae to water conditions, and can survive and become reproductive even after the warm water has receded. However, no reproductive products of these species have yet been recorded in Namibia.

The biodiversity in this northern area of Namibia's littoral habitat is thus dynamic and marks the presence of a shifting front between temperate and tropical zoogeographic provinces. In particular, it is the functioning of the Benguela system at its fluctuating northern boundary that gives rise to this unusual situation. Flora of the littoral zone show similar biogeographical patterns to those of the invertebrates discussed above.

A total of 205 seaweed species has been collected in Namibian waters,[28,29] representing approximately half the number of species recorded on the west coast of South Africa. The majority (80%) of Namibian species also occur on the South African west coast and there are no endemics recorded for Namibia. Only forty northern Namibian species have also been recorded in Angola, indicating a major floristic change in the region of the border between the two countries.[30]

There is a gradual decrease in species richness from the southwestern Cape of South Africa northward through Namibia to Angola. This phenomenon is apparent in all three major groups of seaweeds (Fig. 3.5). Reasons for this progressive decrease are probably related to availability of suitable habitat, as no seaweeds grow on open, sandy shores. In addition, sand inundation, competition from mussel settlement, and wave action affect seaweed diversity.[31]

Box 3.1 Seaweed farming in Namibia

There is a large and successful industry in Lüderitz Bay based on the agar-producing red alga *Gracilaria*.[32-37] *Gracilaria* farming, using rope-raft mariculture, is a considerable success story, with current and expanding production of 45 dry tons per year. There is potential to increase significantly the yield and reliability of production. However, collection of this seaweed from the shore may disrupt the ecological dynamics of seaweed-associated organisms.

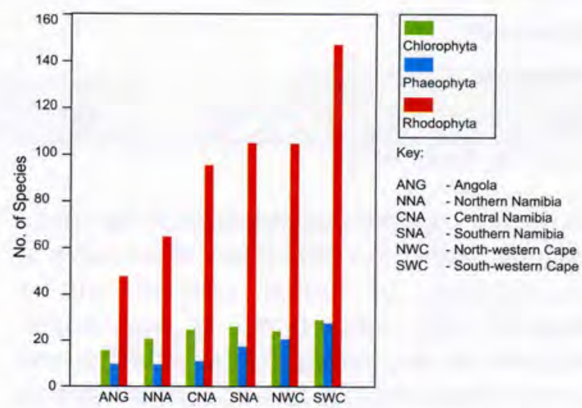


Fig. 3.5 Number of seaweed species in six regions of southwestern Africa.[30]

The seaweed communities of the Lüderitz region are similar to those on the northern shores of western South Africa, both areas falling within the Namaqua biogeographic province. Communities of central and northern Namibia are more sand-affected, low-growing, and have different dominant species. These areas fall within the Namib province.

Invertebrate fauna of the littoral zone

Research on **subtidal** organisms along the Namibian coast has also been very limited. Few scientific publications are available on the biodiversity of this particular habitat, and museum collections are not updated. The occurrence of many subtidal benthic species is under-reported, with the consequence that distribution maps for species along the southern African coastline often do not include Namibian waters, even though many of the species may be common there. Current knowledge is restricted to macro-benthic communities of rocky substrata in depths of less than 30 m, mainly in the area between Diaz Point (26°38'S, 15°05'E) and Mercury Island (25°43'S, 14°50'E).

Table 3.1 Intertidal mollusc species richness on the shores of Namibia and neighbouring Angola

Molluscan group	Namibia	Angola
Polyplacophora	8	4
Gastropoda + Prosobranchia	80	397
Bivalvia	23	150
Cephalopoda	1	6
Scaphopoda	0	2
Total	112	559

Source: B. Currie, MFMR

Generally, benthic communities of the rocky seabeds along the Namibian coast have a low richness of faunal species, but a relatively high abundance of individuals. Richness is very variable between sites, and communities within a few square meters of each another may differ significantly in terms of richness and types of species present. On a larger scale, benthic community structures differ considerably between the southern and northern coasts of Namibia. Occurrence of various groups of benthic organisms on rocky substrata between Diaz Point and Mercury Island is shown in Table 3.2. Dominant species are ribbed and black mussels, whelks (*Burnupena papyracea, Argobuccinum pustulosum, Nucella squamosa* and *N. cingulata*), urchins *Parechinus angulosus*, sea cucumbers (*Thyone aurea, Pentacta doliolum* and *Roweia frauenfeldii*), sea anemones *Anthopleura stephensoni* and various algae, including kelp *Laminaria pallida schinzii*. Spiny rock lobsters, *Jasus lalandii*, are also seasonally present in high densities. These species include predators, grazers, filter feeders and detritivores, and the trophic relationships between them are important in determining the structure and functioning of benthic communities.

Rock lobsters are dominant predators in subtidal benthic communities off southern Namibia, feeding extensively on mussels. Branch *et al.* [38] record the phenomenal impact that predatory rock lobsters can have on subtidal community structure further south in the Benguela system. Local absences of species may well be attributable to the activities of these voracious predators.

Only one known apparently endemic benthic species occurs on the Namibian coast, the disc lamp shell *Discinisca tenuis* (phylum Brachiopoda) (Fig. 3.6). These filter feeders attach to each other to form dense rafts. They occur abundantly in depths exceeding 25 m off the southern coast, and are often present in continuous layers for hundreds of meters on the seabed. They are often found washed up on the beach in large numbers, particularly in the central coastal region around Walvis Bay and Swakopmund.

The ecology of subtidal seaweeds of Namibia is almost uninvestigated. The dominant large kelp is the hollow-stiped *Laminaria pallida schinzii*,[39] which occurs at least as far north as Cape Frio, but not into Angola. *Ecklonia maxima*, which is the dominant kelp on much of the South African west coast, is a minor constituent of kelp beds in the Lüderitz area, and is absent further north.[3]

Fig. 3.6 The endemic Namibian disc lamp shell, *Discinisca tenuis*, found in benthic subtidal communities. Courtesy AL Sakko

Table 3.2 Benthic organisms common in shallow rocky subtidal communities between Diaz Point and Mercury Island*

Taxon	Subtidal benthic representatives
Porifera	Sponges generally abundant. Various species presently being identified
Cnidaria	Including sea-anemones; few soft corals, sea fans and hard corals, hydroids
Unsegmented worms	Mainly the common peanut worms
Polychaete worms	Generally abundant. Various species present
Arthropoda	Two species of sea spiders
Crustacea	Various smaller crustacea, barnacles, isopods, amphipods, mysids, one lobster species, prawns, crabs and hermit crabs
Bryozoa	A few species of moss-lace animals
Brachiopoda	Two species present, one of which is endemic
Mollusca	Various species of bivalves (2 alien species), chitons, gastropods, nudibranchs, a few cephalopods
Echinodermata	Various starfish and brittle star species; some feather star, sea cucumber and sea urchin species
Ascidiacea	A few species of sea squirts
Plantae	Local seaweeds generally have a high species diversity and abundance. Various green and red algae, codiums, kelp, coralline and encrusting algae

* *Source: K Grobler, MFMR*

Fish of the littoral habitat

About 410 species of bony fish and 83 species of cartilaginous fish are thought to occur in Namibian waters. Of these, 91 and 30 species respectively have been recorded in depths of less than 30 m.[15] These may not be exclusively littoral in distribution, and many are found over wide depth ranges. Bony fish represent 13 different orders, with the best represented order of approximately 60 species being the Perciformes or perch-like fish. Cartilaginous fish represent ten orders, with species of hagfish (1), sharks (17), skates and rays (11) and chimaeras (1) all being recorded.

The majority of littoral fish are bottom-dwelling, feeding on seaweeds, benthic invertebrates and small fish. Notable exceptions are clupeiforms such as round herring *Etrumeus whiteheadi*, pilchard *Sardinops ocellatus* and anchovy *Engraulis capensis* which are pelagic surface plankton-feeders. The mullets *Liza dumerili* and *L. richardsonii* are also common littoral species which are pelagic.

Among the littoral fish are those caught by recreational anglers from shore and ski-boats. Although the richness of angling fish is fairly low, with about ten species of bony fish and eight species of cartilaginous fish caught regularly, the Namibian coast is famous for its angling opportunities, especially in the central and northern regions (Fig. 3.7). In two months, 24 763 fish amounting to 7990 kg were caught by 8300 anglers from a 20 km stretch of coast north of Sandwich Harbour.[40] Favoured angling fish are kob *Argyrosomus inodorus*, westcoast steenbras *Lithognathus aureti* (a possible Benguela endemic), galjoen *Dichistius capensis* and blacktail *Diplodus sargus.* In the far south, kob and westcoast steenbras are caught sporadically from the shore. Hottentot *Pachymetopon blochii* and white stumpnose *Rabdosargus globiceps* are also regularly caught.

Warm-water fish occur in the north of the country, especially near the Kunene River mouth. A second kob species, *Argyrosomus coronus*, occurs here, together with angling fish such as garrick *Lichia amia*, shad *Pomatomus saltatrix* and spotted grunter *Po-*

madasys jubelini. The southernmost occurrence of these species is variable, depending mainly on the strength of upwelling and the intrusion of warm, Angolan waters. During Benguela-Niño events these species can be caught as far south as Swakopmund.

Littoral fish most commonly spawn in shallow waters, in some cases even in the surf zone. Spawning grounds are thus potentially within easy reach of anglers on the shore and on boats. The peak recreational angling season (January to March) coincides with the time at which kob enter the shallow waters in large numbers for spawning. Consequently, gravid females are often caught before release of their eggs. Historically kob spawned in large numbers in the Sandwich Harbour area, and some of this coast has been closed to anglers between January and April recently by the Ministry of Environment and Tourism to protect spawning adults. However, this is no longer a preferred spawning ground, and kob spawning in other areas, especially between the Ugab River mouth and Sandwich Harbour (map 3.1) receive no protection.

Shelf habitat

Plankton

Marine organisms which have limited powers of locomotion and drift under the influence of currents and tides are termed 'plankton.' Plankton occurs in pelagic waters (the water column from surface to just above the bottom) in littoral, shelf and oceanic habitats. Off Namibia it is particularly abundant over the continental shelf, associated with the upwelling there. Plankton range from single-celled bacteria to jellyfish of 2 m in diameter. They include phytoplankton, zooplankton, ichthyoplankton and bacterio-plankton.

Fig. 3.7 Fishing frenzy of recreational anglers in central Namibia. Courtesy AL Sakko

Box 3.2 Line-fish population concerns

Annual catches of littoral fish by commercial line-fish boats in Namibia are between 500 and 750 tons. These boats (in the region of 10 licenced boats fishing at any one time) fish at a depth of 20 - 40 m and their catches are made up mostly of larger kob (50 - 75 cm). The 1995-96 annual catch of kob by recreational anglers (excluding ski-boat anglers) was 360 tons. The current value of this recreational fishery to the Namibian economy is unknown, although it could be substantial, given its potential to attract foreign visitors. This is currently under investigation. In the past, stocks of certain angling fish, such as galjoen, have declined. Government-imposed regulations have helped aid the recovery of stocks of this species. Currently, catches of blacktail and westcoast steenbras are low, and protective regulations may be necessary.

Phytoplankton are the primary producers in the shelf habitat and the basic source of food upon which all trophic relationships in this habitat are built. Namibia's shelf waters are enriched with nutrients as a result of upwelling and this, coupled with favourable light conditions throughout the year, enables phytoplankton production to reach a mean annual level of approximately 2 g C/m^2/day,[41] representing very high marine productivity.[4,42] Namibian pelagic phytoplankton are dominated by diatoms, which are adapted to turbulent conditions.[41] They undergo rapid 'blooms' after upwelling events. At least 184 diatom species occur in Namibian waters, with dinoflagellates represented by 158 species.[43] Dinoflagellates may become dominant in blooms during more quiescent, post-upwelling conditions, since they grow efficiently at low nutrient concentrations.

Species composition of phytoplankton in Namibian waters is similar to that of the Mediterranean Sea and southwest Indian Ocean, with 73% and 72% of Namibian species found in those seas respectively.[43] Hart and Currie[44] list 44 of the most abundant or typical diatom species in the Benguela system, many of which occur in other marine regions. There is thus a low degree of endemicity, with only 4 species of diatoms (*Delphineis karstenii, Fragilaria granulata, Chaetoceros strictus* and *C. tetras*) restricted to the Benguela system. There are no exclusively Namibian endemics.

While phytoplankton are the autotrophs of pelagic waters, **zooplankton** are heterotrophic. They consume phytoplankton, sometimes as fast as it is produced.[4] Zooplankton consist of many organisms from unrelated taxa, some of which are permanently planktonic (holoplankton) while others are only planktonic as larvae (meroplankton). In Namibian waters maximum zooplankton abundance occurs in a belt parallel to the coastline, usually further offshore than the belt of maximum phytoplankton abundance.[41] Consistently higher biomass of zooplankton occurs in the area west and northwest of Walvis Bay, where there is a minor upwelling plume.

Zooplankton in Namibian waters have a relatively low species richness and high abundance, typical of the Benguela system. The most abundant and diverse group is the copepods, which are important prey for many other organisms such as juvenile fish. A total of 243 copepod species has been recorded in Nambian waters, representing roughly 12% of the world's known species.[45] The southern African distribution of 20 of these species is confined to Namibian waters, although they have been recorded in other oceanic regions.

Other important zooplanktonic groups include single-celled protozoans (*e.g.* radiolarians and foraminiferans), hydrozoans (*e.g.* *Physalia* and various jellyfish), chaetognaths (10 species), crustaceans such as euphausiids (14 species), amphipods and isopods, and chordates, including tunicates. Eggs and larvae of many of these organisms contribute substantially to the abundance of zooplankton in Namibian waters.[41,46]

Of particular interest in the zooplankton off Namibia are the eggs and larvae of several species of commercially exploited fish (**ichthyoplankton**). Preferred spawning grounds of numerous fish exist off central and northern Namibia, and Namibian stocks usually represent separate populations. Stocks of these species which occur and spawn in the southern Benguela system off South Africa are probably isolated from Namibian stocks by the presence of the major upwelling cell in the region of Lüderitz.[41] Namibian spawning grounds have been located for pilchard *Sardinops ocellatus*, anchovy *Engraulis capensis*, horse-mackerel *Trachurus capensis*, west coast sole *Austroglossus microlepis*, hake *Merluccius* spp., pelagic goby *Sufflogobius bibarbatus* and lanternfish *Lampanyctodes hectoris*.

Plankton production in Namibian pelagic waters is the foundation upon which all trophic relationships in the shelf habitat are built. The dynamics of plankton populations are complex and interrelated, and production of all components depends on the supply of nutrients and ultimately on the occurrence of wind in the region. Upwelling off Namibia is reasonably perennial, and the constant high levels of plankton provide rich feeding conditions for a wealth of marine life.

Nekton

Pelagic communities in neritic waters (those that lie over the continental shelf) usually exhibit low species richness.[47] The relatively high dispersal potential, paucity of isolating mechanisms, and large size of pelagic habitats are primarily responsible for the observed low species richness.[2] In Namibian waters, 10 species of bony fish are pelagic in shelf waters (*i.e.* have a neritic distribution), while another 14 species are pelagic in the shallow, coastal waters only. An additional 13 species are pelagic in habitats ranging from neritic to deep ocean,[15] while 21 species occur in the water column just above the sea bed in shallow, coastal waters. A further 16 species are benthopelagic in habitats ranging from shallow waters to deep ocean. No cartilaginous fish are specifically neritic, although 12 species have been recorded as pelagic in shelf as well as deep-ocean waters.

Many of the pelagic bony fish species off Namibia are either Perciformes, such as mullets, horse mackerel *Trachurus capensis*, chub mackerel *Scomber japonicus* and geelbek *Atractoscion aequidens*, or Clupeiformes. These include round herring *Etrumeus whiteheadi*, pilchard and anchovy. Clupeiform species, as well as juvenile horse mackerel, occur in the surface waters and are specialized planktivores, adapted to make use of the substantial planktonic production in the Benguela system. Both phytoplankton and zooplankton are found in the guts of these species, but it is thought that the ingestion of phytoplankton is largely incidental and that zooplankton are selectively eaten.[48]

Life history patterns of species such as pilchard, anchovy and horse mackerel involve rapid growth, short time to sexual maturity, high fecundity and short lifespan (3-4 years). These features enable populations to respond rapidly to favourable environmental conditions. High juvenile survival and recruitment into the adult population in just one favourable year can increase stocks dramatically. As a corollary, these same life history patterns give fish populations a low tolerance to more than a few years of adverse conditions. Should recruitment be low or fail completely for more than two consecutive years, the age structure of the population, and thus the reproductive potential, would be significantly altered. These small, epipelagic species thus seem to be adapted to a 'boom-or-bust' existence.[10]

The high primary productivity associated with upwelling supports massive populations of planktivorous fish in the neritic waters off Namibia. Stocks of pilchard alone were estimated to be over 11 million tons in 1964, after strong year-classes formed during the early 1960s.[48] Stocks have declined continuously since then, apart from a brief increase during the early 1970s. In addition, population 'crashes' have been recorded several times during the past few decades, the most recent in 1996 when the season's catches of 2400 tons were the lowest in the industry's history. There is evidence that population sizes of small pelagic species in the Benguela system have undergone cyclical fluctuations in the past, before the advent of commercial fisheries. Deposits of fossil pilchard and anchovy scales on the shelf off Walvis Bay show a 25 year cycle in abundance,[49,50] similar to the 30 year cycles in guano abundance of pelagic seabirds recorded off the Namibian coast.[50]

Box 3.3 Epipelagic and semipelagic fisheries

The commercial fisheries of epipelagic (pilchard and anchovy) and semipelagic (horse mackerel) species in Namibian waters are major contributors to the economy of the country. Epipelagic species are caught mainly by purse seine trawlers, and catches for all species combined reached 1.4 million tons in 1968. Horse mackerel are caught as juveniles by purse seine, and as adults by mid-water trawls. Stocks of all species have declined steadily during the 1990s, with the 1996 season producing the lowest ever pilchard and anchovy catches. Unfavourable environmental conditions during the Benguela-Niño of 1995 prevented recruitment to populations already greatly reduced by overfishing,[15] precipitating a collapse of stocks.

Small planktivorous fish are important components of pelagic habitats in other upwelling systems, for example off Peru and California. In the Benguela system there are few dominant zooplankton consumers (*e.g.* pilchard, anchovy, horse mackerel, round herring and chub mackerel), so depletion or extinction of one or more species could be expected to cause changes in ecosystem functioning. In the past, reduced catches of pilchard have sometimes been accompanied by increased catches of anchovy, indicating similar ecological requirements. However, in most instances factors leading to reduced catches affect both species simultaneously, with potentially dire consequences for their numerous predators, including man.

Reptiles

Other nektonic groups found in Namibian waters include sea turtles, seabirds, cetaceans and seals. Of the 8 species of sea turtles worldwide, 5 occur in Namibia. Most are considered endangered and are protected under the Sea Fisheries Act and international agreement. They are not exploited commercially off Namibia, although they may be caught incidentally as a result of fisheries activities. Four of the five turtles are carnivorous, while the last feeds on algae and sea grass. All are preyed upon by sharks and other marine predators, and none is known to breed on Namibian shores.

Birds

Of the 62 species of seabirds recorded in Namibian waters, 20 are only rare vagrants.[15] Twelve species breed along the Namibian coast on offshore islands and man-made platforms. These include the endangered African penguin *Spheniscus demersus* and the rare breeding endemic Damara tern *Sterna balaenarum*. The availability of offshore islands is a major determinant of the distribution of breeding seabirds, and few occur between the Namibian colonies and the major concentrations of seabirds off West Africa. Although all seabirds are protected in Namibian waters, those that produce commercially valuable guano have been subject to seasonal disturbance by the activities of guano collectors. These species, such as gannets *Morus capensis* and cormorants *Phalacrocorax carbo, P. capensis, P. neglectus* and *P. coronatus*, breed on offshore islands and platforms. Several of these species feed mainly on small epipelagic fish which school in the surface waters and are easy to catch.[52] They are thus also affected by declines in fish stocks brought about by overfishing and natural causes. Although the collection of guano was temporarily halted in 1991, the islands are currently unprotected by conservation legislation and may be subject to renewed exploitation.

Mammals

Marine mammals represented in Namibian waters include cetaceans and seals. Of the 11 species of baleen whales worldwide, eight occur off Namibia, while 23 species of dolphins and toothed whales can be found. All of the large whales were intensively exploited in the early 20th century, and are still rare off Namibia today. Shore-based and ship-based whaling factories on the coast of Namibia processed sperm whales *Physeter catodon,* humpback whales *Megaptera novaeangliae*, fin whales *Balaenoptera physalis*, blue whales *B. musculus* and others. Populations of these species were decimated before international awareness of their plight lead to the outlawing of whaling activies.[53] Today all cetaceans are fully protected in Namibian waters (Box 3.4).

Box 3.4 Namibian cetaceans

The eight species of baleen whales recorded from Namibia are probably seasonal migrants (summering in the Antarctic and wintering in west African waters), although some reside and may breed off the Namibian coast as they did over 150 years ago. Even less is known of the smaller pelagic species. A population of southern right-whale dolphins *Lissodelphis peronii* is resident off the southern Namib coast, and regular strandings document a host of other species occurring regularly or occasionally offshore. The rough-toothed dolphin *Steno bredanensis*, a north Atlantic species, was once recorded on the Skeleton Coast, and another seven species of Delphinidae probably occur as vagrants. Beaked whales (Ziphiidae) are regularly stranded, and the strap-toothed whale *Mesoplodon layardii* is one of the commonest. Another three species are recorded for Namibia, and five more are expected to occur as vagrants. Two of the three species of sperm whale are recorded, and the dwarf sperm whale *Kogia simus* is probably an occasional visitor from the South Atlantic.

-- Mike Griffin

High species richness (37 spp.) of toothed whales and dolphins occurs off the coast of South Africa.[54] Namibian waters support 32 species. Some of these are cosmopolitan in distribution, such as the killer whale *Orcinus orca* and Risso's dolphin *Grampus griseus*. Others show a preference for cool temperate conditions (*e.g.* Layard's beaked whale, *Mesoplodon layardii*, and southern right whale dolphin, *Lissodelphis peronii*) and have an African distribution that coincides with the Benguela system. The Benguela dolphin *Cephalorhynchus heavisidii* is the only cetacean endemic to southern Africa, occurring in coastal waters between Cape Point and Angola.[54] Although the smaller whales were hunted for sport in earlier years, and may still become entangled in fishermen's nets, they have never suffered the levels of exploitation of the large whales.

About 2 million seals have been culled in Namibia since the turn of the last century.[15] These successful marine predators feed on many species of fish, cephalopods and crustaceans. They breed in colonies on offshore islands, where they may compete for space with breeding seabirds, as well as on the mainland.

Box 3.5 Cape fur seal harvesting

Exploitation of Namibia's single seal species, the Cape or South African fur seal *Arctocephalus pusillus*, is the oldest fishery in the country. For two centuries these animals have been harvested for their pelts, oil, meat, carcass meal and, more recently, for the genitalia of the bulls. Due to the total lack of restrictions on seal culling before the end of the 19th century, seal populations off Namibia were reduced to the brink of extinction. Several breeding colonies on offshore islands were eradicated.[54] After sealing quotas were imposed, the populations increased steadily, and today the annual quotas of seals continues to be strictly controlled.

Demersal species on the continental shelf are typically highly mobile and include bony fish (59 spp.), sharks (18 spp.), skates and rays (12 spp.), cephalopods (6 spp.), and crustaceans (10 spp.), according to data from the database of the RV 'Dr Fridtjof Nansen.' The number of species recorded during surveys varies and is influenced by many factors, including the type of trawl net used. As many as 137 species have been recorded.[56] Since light penetration in depths greater than 50 m is severely reduced, much of this environment is dark. Distinct faunal assemblages can be identified on the Namibian continental shelf, and these tend to change along both a depth gradient and a latitudinal gradient.[57] Decreased faunal diversity is associated with the presence of pockets of low-oxygen water. The nature of the substrate does not appear to exert great influence on the biological structure of the shelf communities.[56] The sediments in this habitat are largely mud, sometimes combined with sand or gravel.

The central shelf area is dominated by the Cape hake *Merluccius capensis* and, at times, the pelagic goby. There is a low species richness in this region, due perhaps to the oxygen-deficient shelf waters. South of Lüderitz, where oxygen levels are consistently higher, fish richness is greater, and includes hake *M. capensis* and *M. paradoxis*, kingklip *Genypterus capensis*, Cape john dory *Zeus capensis*, Cape gurnard *Chelidonichthys capensis*, silver scabbardfish *Lepidopus caudatus* and Cape bonnetmouth *Emmelichthys nitidus*. Invertebrates are represented mainly by squid and cuttlefish.[15] Several species reach their northernmost distributional limits in this area, their main populations occuring south of South Africa.

The northern shelf region supports numerous species at their southernmost distribution limits. These are species typical of Angolan waters such as large-eye dentex *Dentex macrophthalmus*, thinlip splitfin *Synagrops microlepis*, longfin bonefish *Pterothrissus belloci* and the African mud shrimp *Solenocera africana*. The southernmost occurrences of these species vary depending on the strength of upwelling. During Benguela-Niño events they may occur as far south as Walvis Bay.[15] Dominant demersal species in this region include Cape hake and Cape horse mackerel *Trachurus capensis*.

Deeper parts of the shelf support Cape monk *Lopius vomerinus*, Angola flying squid *Todarodes angolensis*, blackbelly rosefish *Helicolenus dactylopterus* and several lantern-fish species, as well as hake and pelagic gobies.

Compared with the diversity of demersal species in other upwelling systems, such as off northwest Africa, Namibian shelf and slope communities are species-poor. This may be due to the more intense upwelling off Namibia.[58] The hakes are important demersal species in all regions of the Namibian shelf. Hake and monkfish are the main fish of the Namibian demersal fishery, and are caught mostly with bottom-trawls and long-lines. As hakes are numerous and important both as predators and as prey, their overexploitation could have consequences for the functioning of the marine system. Unlike the pelagic fish communities, there is no other commercially acceptable demersal species with potential to fill the void, should the hake be fished to virtual extinction.

Slope habitat

The continental slope off Namibia is characterised by waters which have in the region of 2ml/l dissolved oxygen. This is higher than for shelf waters, although the substratum is still typically muddy. Most fish in this habitat are considered benthic or demersal, although many of them undertake daily migrations to shallower waters. A small group of species is associated specifically with the slope habitat (*e.g.* members of the Chimaeridae and Rhinochimaeridae). However, the distributions of most species extend to shallower waters on the shelf, or to deeper waters on the ocean floor.

Typical slope dwellers include species of lightfish (Photichthyidae), the rough-snout grenadier *Trachyrincus scabrus*, squalid sharks *Deania calcea* and *Centrophorus squamosus*, and striped red shrimps *Aristeus varidens*. Commercially exploited species include Cape hake, deep-water hake, alfonsino *Beryx splendens* and orange roughy *Hoplostethus atlanticus*. Several lantern-fish species (Myctophidae) are common here, with their photophores and other luminescent organs glowing eerily in the dark waters.

Abyssal habitat

The open oceans and deep-sea floors are the least known of all marine habitats. The open oceans represent the world's largest single habitat, while the oceanic floors certainly fall among the most unknowable of habitats. These areas were thought to have relatively low species richness compared to terrestrial environments, and have received scant attention in the biodiversity forum. However, recent studies of deep-sea benthic habitats have revealed exceptionally rich communities, as well as a preponderance of species new to science.[61] The benthic communities of the deep ocean floors may prove to be the most biologically rich of all habitats, with estimated global totals in the order of 10^8 species.

No research has been done specifically on the biodiversity of oceanic or abyssal habitats in Namibian waters. Truly oceanic fish species are few, but are typified by the perciform families Scombridae (tunas), Xiphiidae (swordfish), and Istiophoridae (sailfish and marlins). All of these are highly mobile, epipelagic or mesopelagic species which prey on available pelagic fish both above and below the thermocline. Many species are migratory, breeding in warmer waters off Brazil and the Gulf of Guinea.

Box 3.6 Namibia's tuna fishery

Four species of tuna are caught commercially off Namibia: albacore *Thunnus alalunga*, bigeye *Thunnus obesus*, yellowfin *Thunnus albacares* and skipjack *Katsuwonus pelamis*. Catches are made mainly with long-lines, pole-and-line, and purse seines. The catches total between 2000 and 3000 metric tons annually, and the main markets are for canned tuna and sashimi.

A total of 57 species of bony fish range deeper than 1000 m.[15] In addition, seven species are exclusively *bathypelagic*, or found only below 1000 m. The majority of these deep-sea species are *benthopelagic*, found on or near the bottom. Of the cartilaginous fish, 21 species have been recorded deeper than 1000 m, the majority belonging to the Rajiformes (skates and guitarfish) or to the squaliform sharks. Species richness of fish at these depths is typically lower than in shallower habitats, and is accompanied by a decrease in biomass.[62] An estimated 500 species of demersal fish are found at depths greater than 1000 m in the Atlantic as a whole, indicating the relatively small number recorded in Namibian waters.

The deep-sea benthic communities off Namibia are largely unknown. However, in samples of macrobenthic organisms from ten deep-ocean basins in the Atlantic Ocean, species richness in sediments from the Cape Basin and the Angola Basin (off Namibia) was intermediate between the rich tropical regions and less rich higher latitude areas.[63] This trend is repeated in many groups of organisms and in many different habitats. However, the paucity of information about deep-sea biodiversity hampers comparative studies as well as the interpretation of the few existing studies.

Box 3.7 Exploitation of Namibia's deep sea

Several deep-sea species are commercially exploited in the depth range of 500-800 m. The deep-sea red crab *Chaceon maritae* is caught with bottom trawls and pots along the length of the Namibian coast. It was estimated in 1992 that the crab stocks on the fishing grounds amounted to 72 million individuals, or 17 648 metric tons.[64] Annual catches are in the region of 3 tons, although a total catch of 10 tons is allowed. Other exploited deep-sea species include orange roughy *Hoplostethus atlanticus* and alfonsino *Beryx splendens*, which are currently both caught on an experimental basis. These are slow-growing, long-lived species which take decades to reach sexual maturity. Commercial exploitation of orange roughy off New Zealand has led to the collapse of the stocks, and extreme vigilance is needed to ensure that this does not happen here.

The deep-sea red crab *Chaceon maritae* is an abundant demersal species off the shelf of Namibia. It occurs on muddy substrata up to a depth of 950 m, but most commonly between 300 and 700 m. The average crab density over the entire Namibian fishing ground was calculated to be 98.4/ha by Beyers,[64] but densities can be as high as 227.5/ha. These organisms are doubtless important prey items for numerous other deep-ocean species.

3.4 Overview of Namibian marine biodiversity

Biodiversity in the Namibian marine environment shows several pertinent trends. Most habitats support no endemic species. A few species are endemic to the Benguela system, of which the Namibian waters form a part. Species richness in most habitats is relatively low. This is evident in sandy shore, rocky shore and benthic invertebrates, littoral seaweeds, phytoplankton, fish of the littoral and pelagic habitats, and demersal fish of shelf and slope habitats. In all these cases, richness is lower than in comparable habitats in the southern Benguela system off the west coast of South Africa. In most cases, this low richness is accompanied by high biomass.

There is a well-recognised latitudinal gradient in pattens of global species richness,[2] with highest richness in equatorial regions and lowest richness towards the poles. Namibian marine biodiversity provides an anomaly in this gradient since, in general, species richness is substantially lower than recorded in the more southerly marine habitats off South Africa. In addition, there is a clear trend of decreasing marine species richness from south to north off Namibia, contrary to the expected trend. Why is this?

A given supply of food may be partitioned among many species with narrow diets (specialists) and small populations, or among few species with wider diets (generalists) and large populations. Specialisation is favoured where food availability is predictable and competition may lead to the evolution of specialised feeding behaviour. This is the case in tropical regions, where the high genetic diversity is correlated with trophic stability. In temperate regions, however, where conditions are seasonally variable, food availability is less predictable and organisms may need to feed opportunistically during times of food shortage. Specialisation is thus not as feasible, and resources tend to be partitioned between fewer species with large populations.

Upwelling systems in general are extreme cases of unstable environments, where continuous variation prevents the fine tuning of genotypes to local conditions. Food availability is variable, and generalist feeders are favoured. Such systems predictably support only low species richness, while at the same time being among the most productive habitats in the world.[4] Significantly the Namibian marine environment (particularly the northern Benguela system) is species-poor even by comparison to other upwelling systems, such as the southern Benguela and the west African upwelling systems. This may arise in part due to the intensely dynamic and perennial nature of upwelling off the Namibian coast, which creates extreme instability and unpredictability of numerous environmental factors such as temperature and water chemistry.

3.5 Potential threats to Namibian marine biodiversity

Natural threats

Fluctuations in the Benguela system

The Benguela ecosystem is characterised by continuous environmental changes on scales from hours to decades. For example, nutrient availability may vary on an hourly basis, as upwelled nutrients reach the photic zone and are rapidly used by phytoplankton. Levels of dissolved oxygen in the water may also change rapidly as patches of low-oxygen water move. Winds which induce upwelling, and thus drive the system, are perennial off the coast of Namibia, although seasonal changes in the position of the southeast Atlantic high-pressure system influence the intensity of upwelling. Nelson and Hutchings[65] refer to a three to six day pulse in upwelling strength. Seasonal changes in atmospheric 'forcing' also control the penetration of warm Angolan Current waters into the northern Benguela region,[10] with southerly movement of Angolan waters most likely in late summer and autumn. In addition, the exceptional southward incursions of warm Angolan waters as far as Walvis Bay, known as Benguela-Niños, occur on a decadal scale.
The combination of hourly, daily, seasonal and decadal patterns of change creates an inherently variable marine environment. Since biodiversity is often linked to habitat complexity, it is clear that this variety is important in maintaining biodiversity off the Namibian coast. However, it also makes the environment unpredictable, leading to mortalities of organisms that cannot cope with, or escape from, sudden changes.

Of particular interest are the intrusions of Angolan waters into the northern Benguela region. These occur seasonally, although the exact timing and extent are not predictable. At these times the front between the two systems moves southwards by up to 2°, and tongues of warm water reach into the otherwise cold waters of the Benguela.[66] The warm, saline Angolan water brings with it plant and animal species of more tropical affinity. Such species have been recorded in all the marine habitats in northern Namibia, as described in the relevant sections above. In some instances these species may become established, such as the sandy shore mussel *Donax rugosis*, but more often they retreat with the northward movement of the warm water. Conditions may become unfavourable for some temperate species during warm-water intrusions, and they tend to move away. Local mortalities are possible for less-mobile species, but these are unlikely to influence regional biodiversity.

During Benguela-Niños, warm, saline water may intrude as far south as Walvis Bay, as occurred in 1995 (Figs. 3.8 and 3.9). These intrusions may happen quickly, over a matter of days, and may last as long as six weeks. Associated with higher sea temperatures, the oxygen content of Angolan Current water can be extremely low, making conditions unsuitable for many Namibian species. During the 1995 Benguela-Niño, hake distributions off central and northern Namibia changed dramatically in response to the presence of poorly oxygenated water.[67] Several species of fish including hake, horse mackerel and pelagic goby are physiologically adapted to cope with low oxygen conditions.[67] However, Benguela-Niños represent extreme conditions and it is possible that mortalities of less-mobile species could occur.
Fluctuations in environmental conditions in the Benguela system are thus a potential short term and localised threat to marine species off Namibia. Local extinctions of fish and crayfish in response to intrusions of low-oxygen water have been recorded. However, these fluctuations are inherent in the functioning of the system, a system which has been in existence in some form off northern Namibia for about 12 million years. Even the modern Benguela system, as we know it today, is 2 million years old.[68] Clearly, species which persist have evolved mechanisms for coping with the inherent variability. Local mortalities in response to environmental fluctuations should therefore not be seen as significant threats to Namibian biodiversity on a regional or national scale.

Sulphur eruptions

Sulphurous patches in coastal and nearshore waters are a common feature off the Namibian coast, especially the central region near Walvis Bay and Swakopmund. Low oxygen water is a feature of the shelf bottom over large areas in this region. Some bottom-dwelling bacteria produce sulphur as a product of decomposition, and they may form patches of concentrated sulphur.
Such eruptions have been associated with mortalities of fish and other species. Extensive deposits of fish scales and bones found in the region of Walvis Bay may be the remains of large populations of fish that died in response to sulphur outbreaks. Like other variations, sulphur eruptions are a feature of this system and do not pose a threat to biodiversity on anything but the local level.

Anthropogenic threats

There are several ways in which humans influence biological diversity in the marine environment. Most important among them are pollution, physical encroachment by activities such as mining, overexploitation, and the introduction of exotic organisms.[5]

Underlying all these forms of disturbance are social and economic reasons which, at the time, are deemed of more importance than are detrimental ecological effects. Usually, the activities which directly or indirectly destroy marine biological diversity bring short-term profit to some group or individual. The costs of such activities, on the other hand, are incalculable and are borne by everyone.

Pollution of shore and ship origin

The coastal zone of the Namibian marine system is virtually devoid of permanent human settlement. Apart from the four medium-sized coastal towns of Lüderitz, Walvis Bay, Swakopmund and Henties Bay (map 3.1), which have permanent populations of between 4500 and 50 000, there are a number of conservation stations and fishing camps which support a few residents and a few dozen visitors at any one time. In addition, the coastal desert is not suitable for agricultural development. Consequently, the level of pollution normally associated with urban communities, shore-based industries and coastal agricultural land does not occur.

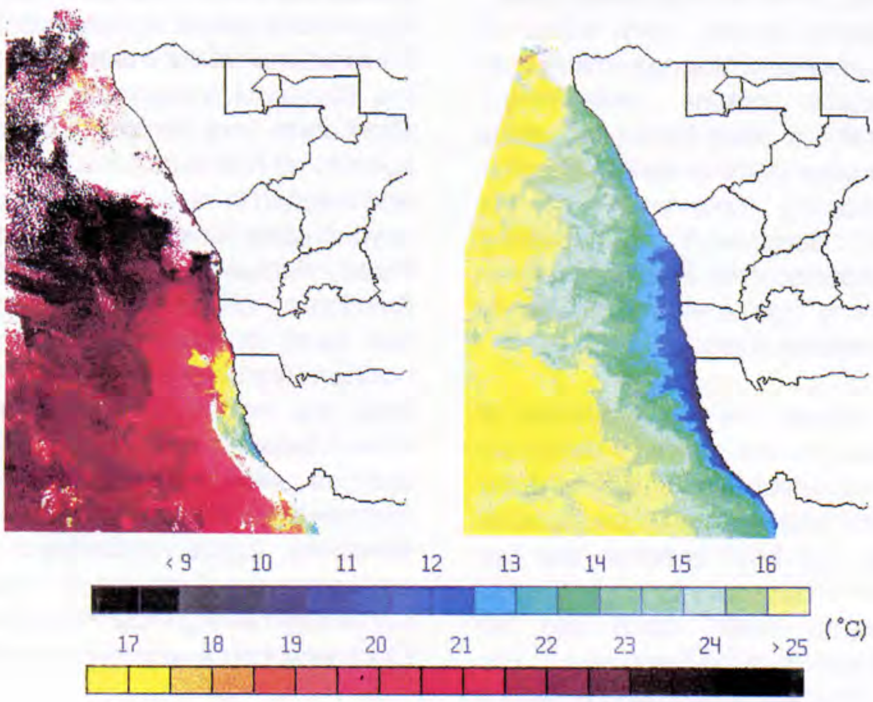


Fig. 3.8 (left) and 3.9 (right). Sea-surface temperatures recorded off the Namibian coast during Benguela Niño conditions in summer (left), and during normal upwelling conditions in winter (right). Courtesy MFMR.

Despite the lack of large-scale coastal urban development, partially enclosed lagoons at Walvis Bay and Lüderitz support cargo-handling harbour facilities. In addition, both ports are home to expanding fish-processing and related industrial factories. Organically rich effluent from fish factories has resulted in anoxic conditions in the vicinity of the outlet points of the lagoons. Spillages and disposal of inorganic pollutants, primarily hydrocarbons and anti-fouling paint, into the lagoons are additional threats. Localised shore litter, primarily plastics, originates from anchored vessels.

Monitoring of the water quality in Walvis Bay has to date not indicated pollution levels which have any more than a localised impact. In addition, species diversity of shorebirds on the mudflats of the Walvis Bay lagoon has changed little since biannual bird censuses began in 1983. However, the proximity of the harbours and fish factories at Walvis Bay and Lüderitz suggest that the lagoon communities may be vulnerable.

Much of the cargo shipped between the Far East, North America and Europe rounds the southern tip of the African continent and thus passes close to Namibian waters. Apart from the few which actually call at Namibian ports, however, these vessels remain outside the 'Exclusive Economic Zone' (EEZ). Therefore the high levels of pollutants from such vessels which occur in other major shipping lanes are not found in Namibian waters.

Coastal diamond mining

Approximately 250 km of Namibia's coastline between Lüderitz and the Orange River mouth falls in the zone known as the *Sperrgebiet* or Diamond Area 1. Access to the area is highly restricted, as this is the site of Namibia's most productive diamond mines (section 1.2). Historically, mining activities extended north to Conception Bay, but today operations are confined to the area between Oranjemund and Lüderitz.

Several forms of mining take place in this area. Sea-based operations involve the removal of gravel from intertidal and subtidal habitats, whereas land-based mining involves the removal of the sand overburden until bedrock is exposed. In some areas, such as the vicinity of Oranjemund, areas of sea are reclaimed by building a surrounding dyke and then pumping out the seawater. Sediments are then removed in order to locate the buried diamonds. On a local scale, these activities are highly destructive to biodiversity. The substrate is significantly altered and entire communities may be disturbed or totally eradicated. The mining operation at Elizabeth Bay, south of Lüderitz, is an example.

At Elizabeth Bay diamonds are mined from the land adjacent to the coast. Undersized grits, or 'fines,' resulting from the extraction processes are pumped into the sea. Discharge from the original Elizabeth Bay plant, which processed grits from nearby deposits up until 1935, resulted in a beach deposit of over 100 m along the exposed rocky shore of the peninsula. Today there is no sign of this deposit, as it was rapidly eroded away by the action of the sea, after mining ceased.

When mining operations recommenced at Elizabeth Bay in 1991, the Ministry of Fisheries and Marine Resources expressed concern at the potential impact of suspended sediments within the bay. Surveys were conducted to determine both the effect of change in beach morphology within the bay on intertidal sandy shore communities, and the impact of suspended sediments on the ecology of nearby rocky shores.[69] Unfortunately both studies were conducted after the discharge of fines was well under way and consequently no data were available prior to disturbance. Nevertheless, results of both studies suggested major changes to biological communities as a result of the beach disposal of fines. Sandy shore communities became depauperate,[24] and limpet-dominated rocky shores were replaced with lushly growing seaweeds where limpets had become dislodged.[70] In a recent survey, the Elizabeth Bay colony of Damara terns was found to have declined from 15-20 pairs before mining to two pairs. Poor foraging conditions in the bay were suggested as the reason for the decline.[71]

NAMDEB, the mining corporation, accepts responsibility for monitoring ongoing changes to the biology of the Elizabeth Bay area, and in 1992 launched an environmental programme to this end. The impacts of small-scale, surf-zone contractor operations on the intertidal and subtidal communities in the area are also monitored regularly. The monitoring programmes aim to detect and minimise long-term damage to the environment while still enabling diamond-mining to contribute to the economy of the country. It is predicted[69] that following the closure of the Elizabeth Bay mining operations, currents and winds within the bay will quickly resculpture the beach. In addition, the recovery of disturbed intertidal communities should progress rapidly once the sediment load in the water is reduced. Similar recoveries were documented after the fresh water and sediment loads in floodwaters of the Orange River caused large-scale limpet mortalities in that area.[72]

The potential for diamond-mining activities to cause biological damage is clearly great. Because of this there is an obligation to monitor changes in biological communities in areas where mining operations occur, and to restrict damage as far as possible. Since mining activity is restricted to relatively small areas, it is not considered a major threat to coastal biodiversity on a major scale. In addition, there is evidence that suggests that the physical processes occurring on the coastal zone of Namibia are of such magnitude that alterations are likely to be only temporary.

Fishing

Fisheries activities are ubiquitous across marine habitats, directly affecting virtually every habitat except the deepest ocean floors and abyssal depths. The most important impacts of fishing are the removal of large numbers of naturally-occurring organisms and the physical alteration of habitats. Both factors can have disastrous consequences for stocks of commercially exploited species and ultimately for those who derive benefit from their exploitation. All fisheries activities must therefore pursue a balanced strategy incorporating ecological considerations and socioeconomic needs to ensure the longterm sustainability of marine resource use.[6]

Physical destruction of the benthic habitat through aggressive trawling techniques, particularly beam trawling, as well as the large scale incidental catches of seabirds and marine mammals through the use of drift-nets, are legislated against in Namibian waters. In addition, the massive catch of non-target species reported to occur in other fishing nations is limited through effective implementation of strict legislation. Bottom trawling for species such as hake and monkfish most certainly has an impact on demersal habitats, although since this is out of human view it has not been considered important enough to warrant study. Habitat degradation can potentially result in a loss of species richness, as habitats are made unsuitable for certain species.

Genetic factors

The removal of large numbers of individuals from a single species reduces the genetic diversity of the remaining populations. Within each species, genetic diversity in a population (**heterozygosity**, see Box 2.12) enhances its ability to adapt to environmental change. It is the basis for natural selection, and is perhaps most important in inherently variable systems. Current levels of intraspecific variation are the result of accumulated genetic mutations over millions of years of evolution. Severe reductions in population numbers which occur when a stock is overfished, or collapses, cause a genetic bottleneck. Although populations which are subsequently protected from harvesting may recover, much genetic material has almost certainly been lost, since individuals removed from the breeding population are no longer able to pass on their genes. This phenomenon is known as 'genetic drift.' The recovered population will have a different genetic composition from the original population, as well as reduced heterozygosity and reduced ability to adapt to a changing environment.[2]

Fisheries activities can also change the genetic composition of exploited populations through the selection of specific sub-groups. Usually, larger individuals are targeted and their removal from the breeding community implies, in evolutionary terms, that there is directional selection for smaller size at maturity, smaller final size, decreased growth rate and younger age at maturity. These are the characteristics of the population left behind to continue breeding. This amounts to selection for lower productivity, and is diametrically opposed to the rationale behind genetic selection in aquaculture and agriculture in general.

Exploited fish species in Namibian marine habitats display a variety of life-history characteristics. Some species are adapted to life in stable environments where food is predictable. These include the species of the deeper shelf, slope and oceanic floor habitats, such as orange roughy and alfonsino. These species are slow-growing, long-lived, and less fecund. Overfishing of stocks of these species can lead rapidly to population collapses because of the slow rate of replacement through reproduction. It has been estimated that deep-sea orange roughy take 30 years to reach sexual maturity and approximately 100 years to grow to supermarket size.[73]

In contrast, species which inhabit the neritic waters are adapted to survive in less stable environmental conditions. They grow rapidly, reach sexual maturity early and are highly fecund. Pilchard and anchovy are among the species with such life-history patterns. These species are considered highly susceptible to the effects of genetic drift and directional selection since their generation times are short. Indeed, reduced age at maturity, and possibly increased growth rates, have been documented in Namibian pilchard[74,75] and horse mackerel stocks,[76] suggesting that directional selection has already occurred.[77,78]

The substantial reduction ('crash') of the Namibian pilchard stock several times in the past three decades has certainly reduced the genetic diversity of this species. Unfavourable environmental conditions are usually invoked as the major cause of these population crashes. It appears from historical evidence, such as records of guano yield from piscivorous seabirds on nearshore islands[51] and fish-scale deposits in the bottom sediments off central Namibia,[9,50] that populations of pelagic fish species fluctuated in the absence of exploitation. However, fisheries practices continually erode the genetic potential of populations to recover from and adapt to such conditions in the long term.

In 1995, Namibia's fisheries landed a combined total of more than half a million metric tons of marine organisms (Table 3). The value of the landings was nearly N$1500 million, representing approximately 7% of the GDP.

Healthy fish stocks are clearly essential to the continued success of the fishing industry in this country. The promotion of practices leading to sustainable use of genetic resources is an urgent priority; such practices revolve around maximising population sizes and avoiding bottlenecks. Although naturally induced population fluctuations cannot be avoided in the Benguela system, overfishing of exploited species must be prevented at all costs.

Fig.3.10 Cape fur seals are harvested in Namibia. Courtesy P Tarr

Table 3.3 Landings x 1000 metric tons[79,133] and estimated export values of catches[133,134] of certain commercially exploited species in Namibian waters. Totals refer to total catches (x 1000 metric tons) and estimated value of all fisheries, including those of species not mentioned above.

Species	1991	1992	1993	1994	1995	1996*
Pilchard	68.85	80.78	114.81	116.43	42.80	1.17
Anchovy	17.10	38.82	63.07	25.12	48.02	1.08
Red-eye		1.66	5.09	1.38	1.93	20.64
Horse mackerel	435.73	427.37	474.61	364.80	310.83	319.86
Tuna	0.22	2.24	3.55	4.09	2.61	1.59
Hake	112.26	87.59	108.10	112.21	129.82	125.71
Sole	0.28	0.07	0.53	0.66	0.46	0.34
Kingklip	0.48	0.30	0.75	1.65	3.85	3.10
Monk	4.62	8.08	9.23	12.16	10.01	6.84
Snoek	0.71	0.82	0.94	0.68	0.18	0.59
Kob (commercial)	0.05	0.23	0.56	0.59	0.04	0.46
Kob (recreational)					0.36	under study
Orange roughy	-	-	-	0.01	3.16	0.01
Alfonsino	-	-	-	-	0.48	1.01
Lobster	0.38	0.13	0.14	0.13	0.29	0.23
Crab	2.68	2.79	3.19	3.60	2.01	1.71
Total masses	591.66	654.01	789.13	647.98	564.94	497.19
Total value (million N$)	631.0	838.7	1075.3	1 279.4	1 362.8	1 242.7

** Preliminary values.*

Unfortunately Namibia's record in this regard is not good. Few, if any, commercially exploited species have not at some time shown signs of overexploitation. Rule-based fisheries management, whereby minimum spawner biomasses of exploited species are specified and exploitation is halted when biomasses are below the minimum levels, has potential to prevent the kind of overfishing that has occurred in the past.

The expectation of obtaining even, reliable catches of marine resources from year to year seems unfounded. Natural populations experience favourable and unfavourable times, the 'prosperous' years serving as a cushion against leaner years to come. This is certainly true of the variable, unpredictable Benguela system. Unfavourable events such as the Benguela-Niño of 1995 place stresses on marine populations. The tolerance of populations to these stresses is directly related to their intraspecific genetic diversity, and the practice of eroding this diversity by overfishing is an additional stress undermining long term viability of populations.

Introduced alien species

Alien species have become common in virtually all habitats occupied or modified by human activities. The single most important source of invasive aliens in the marine environment is the ballast water of ships. Ballast water, containing the larvae and spores of coastal organisms, is taken on in one biogeographical zone, transported across oceans and then discharged wherever the ship happens to be at the time. It is estimated that more than 3000 species of coastal marine animals and plants are in transit around the world, at any given moment, in the ballast of ships.[6] The effect of this is that coastal habitats all over the world are becoming dominated by alien species.

One alien species has invaded Namibia's rocky shore habitats. The Mediterranean mussel *Mytilus galloprovincialis* was introduced to South Africa in the late 1970s and has spread progressively along the west coast of that country, where it is currently the dominant intertidal mussel. By the early 1990s the species was well established in southern Namibia as far north as Sylvia Hill, where it dominates the indigenous intertidal mussels *Aulacomya ater* and *Choromytilus meridionalis*. Subtidal beds of the indigenous species appear unaffected by this invasion, since *M. galloprovincialis* is mainly found intertidally.

Further north as far as the Kunene River mouth, only isolated individuals of *M. gallo-provincialis* were found in the early 1990's. However, in 1994 in the extreme northern region, and in 1995 in the Swakopmund area, large numbers settled amongst the indigenous species of those areas (*Perna perna and Semimytilus algosus,* Fig. 3.12). The rapid growth rate and high fecundity of the alien species are matched by those of the indigenous species, and it remains to be seen which species will become dominant.

So far the presence of *M. galloprovincialis* along the Namibian coast does not appear to have had any ecosystem effects. Trophic relationships seem to remain unaltered and biodiversity on a regional scale is unaffected, although the intertidal distributions of indigenous species have been locally altered. This species appears unstoppable in its spread around the southern African coastline and no efforts are being made to control it.

Several species of alien oysters, such as the Pacific oyster *Crassostrea gigas* and European oyster *Ostrea edulis*, have been introduced to Namibian coastal waters. They are farmed commercially in sheltered, warm water conditions near Swakopmund, Walvis Bay and Lüderitz. Currently these species have not become established outside the mariculture areas, and are not considered able to survive the rigours of the local marine environment. Consequently they may not threaten the biodiversity of these areas.

The extent to which alien invasions may have occurred in the pelagic and shelf environments is largely unknown. There is a lack of base-line data on the composition of these communities, and there are no studies focused specifically on invasions. To some extent the variable and biologically harsh nature of the upwelling system that is Namibia's marine environment may inhibit invasions of species not specifically adapted to these conditions.

Fig.3.11 Alien species in marine waters are often introduced in imported bilge waters. Courtesy P Tarr

Box 3.8 African penguins: competition and exploitation

African or jackass penguins, *Spheniscus demersus*, breed at 27 coastal sites in southern Africa, almost all on islands.[80] They are endemic to southern African waters, with one of the largest colonies on Mercury Island near Lüderitz. Southern African populations were estimated at 580 000 at the turn of the century, at half that figure 50 years later, at 230 000 by the late 1970s, and at 180 000 today.[80] This is a decline of 71% over a century. If present trends continue, extinction of this species is likely by the year 2040.[80] In Namibia, some island populations of over 20 000 breeding birds have shown spectacular collapses of 96% in the 40 years since 1956.[81] Fortunately, numbers in Namibian waters appear to have stabilised recently, with about 27 000 adults in the three main strongholds of Mercury, Ichaboe and Halifax Islands. Today they are classified as *vulnerable* according to IUCN criteria.[8]

The decline of African penguins can be attributed to three main factors, all related to human greed for rich marine resources. In 1844, guano on the island of Ichaboe was first exploited. Penguins create breeding burrows in the guano to protect their nests from the depredations of seabirds such as gulls and to escape heat stress. A 22 m layer of this immensely profitable 'white gold' was entirely removed from Ichaboe in three years (see Box 1.6). Once exposed to predators and heat stress from nesting on the surface, penguin breeding success declined, and the population fell from tens of thousands in 1844 to a few hundred in 1990.[82] Breeding Cape fur seals *Arctocephalus pusillus* then moved onto some of the denuded islands, physically displacing penguins and eating fledglings.[82] Penguin eggs were also seen as a delicacy in South Africa's Cape Province, and thousands of eggs were harvested from South African colonies.[83] This practice was banned in South Africa (then including Namibia) in 1966. However, even in the mid-1970s unscrupulous conservation officials on Namibian islands were actively harvesting and pickling eggs for export to South Africa from protected islands off the Namibian coast.[84]

The third major cause of decline, after guano scraping and displacement by seals, is more recent: the population crash of the pilchard *Sardinops sagax*, a prey species, through overharvesting in the 1960s and 1970s (see below). This affects both the survival and breeding success of penguin adults. Today penguins are founding new, mainland colonies, presumably to exploit a resurgent sardine *Sardinops sagax* population off South Africa's Table Bay area.[85]

The spectacular decline of the African penguin can thus be traced directly to the overexploitation of marine resources, past and present. Penguins are excellent and sensitive indicators of the abundance of fish stocks immediately offshore.[86] Their future population trajectory will reveal the sustainable (or otherwise) use of pilchard populations off Namibia's southern coast.
-- Rob Simmons

Global climatic changes

In addition to local and regional activities that result in changes to marine biological diversity, global changes in climate should be recognized as potentially destructive. Although not directly a problem of Namibian origin, this recently recognized threat is most certainly exacerbated by human activities worldwide. In particular, the burning of fossil fuels has lead to increased levels of carbon dioxide, methane and other gases in the atmosphere. These gases trap heat radiating from the earth and have the potential to lead to **global warming**. A warmer planet will affect the sea-level, patterns of rainfall and oceanic circulation (and thus patterns of nutrient supply) and the sea temperature. Warmer waters also alter nutrient availability, and the distributions of many marine species. In addition, it would make cooler, temperate regions more susceptible to invasions by sub-tropical species.

Fig. 3.12 Dense populations of the introduced Mediterranean mussel, *Mytilus galloprovincialis* on the Namibian rocky shore. Courtesy D Louw, MFMR

Atmospheric pollution with compounds generated by human activities, such as chlorofluorocarbons, is destroying the ozone layer of the atmosphere. This layer protects the earth's atmosphere from incident ultraviolet radiation, and its destruction alters the exposure of the oceans to ultraviolet radiation. Increased UV-B (the biologically damaging UV) radiation penetrates many metres below the surface of the ocean and can cause significant biological and ecological damage.[6] Such effects have been demonstrated for phytoplankton, zooplankton, ichthyoplankton and certain benthic organisms in shallow or surface waters.

Although not a problem of exclusively Namibian origin, the effects of global climatic changes on the marine environment have the potential to supersede in importance the effects of any of the current crises, including that of resource depletion. Namibians have an international responsibility to ensure that they do not contribute unduly to the escalation of these potentially destructive processes. In addition, policy-makers have a duty to note the possible effects and to plan accordingly.

3.6 Measures to counter threats to biodiversity

The importance of research

Understanding of the mechanisms underlying the existence and maintenance of biological diversity in the sea is generally incomplete or lacking. Even the most basic data on the ecological roles of component species, or the functioning of ecosystems, are unavailable. Little funding is available for research not directed specifically at a better understanding of the biology of commercially important species. Given these factors, it is not surprising that marine scientists have been singularly unsuccessful in predicting the impacts of human activities on marine biodiversity, or protecting the marine system against these impacts.

Humans depend on the ocean in so many ways, and the use of marine resources is a fact of human life. However, with human populations increasing at ever-greater rates, stresses on the oceans are unprecedented. Long term sustained use of ocean resources is critical, and to this end it is not enough only to prevent species extinctions. The integrity and functioning of ecological patterns and processes in the ocean must be preserved in order that ocean resources can continue to fulfil human needs. Conservation of marine biodiversity is integral to this.

Understanding of marine ecosystem functioning can only be gained through research. Research at the species, community, habitat and ecosystem levels is critical in providing insight into how the marine system functions. This knowledge, once gained, should be made available to policy makers to support them in making informed judgements.

The Namibian marine environment, being part of one of four major upwelling systems in the world, has been the subject of a great amount of research in the past. Programmes aimed at investigating and monitoring ecosystem function have been extensive. Since Namibia's Independence in 1990, research programmes have intensified under the auspices of its Ministry of Fisheries and Marine Resources. Two fully equipped research vessels are at the disposal of the MFMR scientists. Assistance in this regard from NORAD, the Norwegian Agency for International Development, is invaluable. About 10 research cruises are conducted annually on the Norwegian research vessel 'Dr Fridtjof Nansen' and the Namibian RV 'Welwitschia'. Such levels of research would be considered a luxury in many developing African countries.

Most Namibian research is directed at assessing stocks and understanding the biology of commercially valuable species, not at conserving biodiversity. However, since overfishing is currently the single most significant threat to the healthy functioning of the Namibian marine system, it follows that the conservation of stocks and the conservation of biodiversity to some extent go hand in hand. Research aimed at understanding changes in marine biodiversity resulting from human activities should have, as its ultimate pupose, 'the enhanced ability for long-term, sustained use of the oceans and marine organisms for food, mineral resources, biomedical products, recreation and other aesthetic and economic gains, while conserving and preserving biodiversity and ecosystem function of life in the sea.'[6] Clearly, this incorporates the interests of the Namibian fishing industry. With the scale of Namibia's current research programmes, it would be possible at little extra cost or effort to monitor the species composition of marine habitats, and thereby initiate a database to assess future changes.

Policy and legislation initiatives

Under the Sea Fisheries Act (Act 29 of 1992), the Namibian marine environment (including open waters, tidal lagoons and sea-shore up to the high water mark) falls under the jurisdiction of the MFMR (see also Chapter 5). This Act forms the legal framework whereby the 'conservation of the marine ecology and the orderly exploitation, conservation, protection and promotion of certain marine resources' are provided for. No allusion is made in the Act to protection of biodiversity *per se*, although the conservation of 'the marine ecology' is a stated aim. This is in stark contrast to the policy of the Ministry of Environment and Tourism (MET) on terrestrial and freshwater ecosystems, which is to 'ensure adequate protection of all species and subspecies, of ecosystems and of natural life support processes'.[87]

The emphasis of the legislation and regulations of the MFMR is 'to utilize the country's fisheries resources on a sustainable basis'[88] and, to this end, to protect commercially valuable species from overexploitation. Sea Fisheries regulations are extensive, providing for the control of exploitation through total allowable catches (TACs), minimum mesh sizes on nets, minimum individual sizes, closed seasons and areas, and limited quantities. In addition, means of enforcement, and punishments for infringements, of the set regulations are detailed and potentially disuasive.

The Sea Fisheries Act makes provision for the payment of levies on all fish caught. These monies are then made available, at the discretion of the Minister of Fisheries and Marine Resources, for research on 'the utilization, conservation, protection and management of the marine resources'.[89] This is the source of funding for many of the current research programmes. Fisheries scientists, having evaluated current stocks, make recommendations to the Sea Fishery Advisory Council in connection with the annual allocation of allowable catches. The Council provides a socio-economic perspective, and also considers the industry's interpretation of the state of the stocks. The Council then makes recommendations, which are forwarded to the Minister of Fisheries and Marine Resources for consideration and amendment before submission to Cabinet where the final decision on TACs is made.

Because the recommendations of fisheries scientists, based on their research results, are not available to the public, and because of the considerable economic influence of the fishing industry in Namibia, there exists the possibility that socio-economic considerations may dominate decision-making processes while the importance of research findings becomes marginalised. The MFMR is aware of this danger[88] and makes the following statement:

> *'The history of fishery management, both international and national, shows innumerable cases where the inability to accept short-term cutbacks and losses for the industry has caused stock depletion or prevented the rebuilding of stocks to a safer and more profitable state. The Government aims to avoid this trap and cut back on allowed catches over a period for the purpose of rebuilding and strengthening the fish stock.'*

In the case of some exploited species, such as deep-sea red crab and lobster, TACs have decreased consistently since 1991. However, for the majority of fish species this has not been the case. TACs for pilchard indeed were increased between 1991 and 1994. It appears that, despite the most comprehensive fisheries legislation, there is the possibility that checks and balances at the highest levels of decision-making are not sufficient to ensure that biological considerations are given due credibility. In his cogent discussion on maintaining the world's marine biological diversity, Norse[7] states that 'governments that can limit the influence of major economic sectors and that can keep their citizens informed and actively involved in decision making are most likely to fashion enduring systems of marine biodiversity protection and management'. It is unfortunate that Namibia's fisheries policy has the potential to fall short in these two vital areas.

An additional cause for concern is the fact that several commercially exploited species, such as pilchard, anchovy and horse mackerel, occur in Angolan waters. These populations are considered to be part of the northern Benguela stocks and are important components of these species' gene pools. It is important that these populations are managed by both countries for the ultimate persistence and promotion of the stocks in the northern Benguela system. A joint management agreement between Namibian and Angolan authorities would be a worthwhile and far-sighted initiative for policy-makers to take. Initiatives for joint management of stocks are now developing in Angola, Namibia and South Africa.

Protected marine areas

Vast stretches of the Namibian coast are ostensibly protected from fishing, collection of resources and disturbance or damage in any form up to a distance of two nautical miles seawards from the high-water mark.[90] These include the area of the Skeleton Coast Park, the Namib-Naukluft Park (map 3.1), the area between Walvis Bay harbour and Pelican Point (22°53'S, 14°26'E), and the areas around offshore islands. In addition, there are two areas in the vicinity of Lüderitz where the catching of rock lobsters is prohibited.

However, 'any person may, from any fishing vessel in respect of which a licence or permit has been issued and which authorises the catching of small pelagic fish...or rock lobster ... or the use of handlines from such vessel, catch fish within two nautical miles at any place within any area,' excluding the catching of rock lobster in the closed areas to the north of Lüderitz.[91] The closed areas described above are thus effectively closed only to recreational rock-and-surf anglers, to recreational ski-boat fishermen and to commercial ski-boat fishermen. Since most of these areas are inaccessible to these groups, this legislation would seem superfluous. 'Protection' up to 2 km offshore thus does not prevent commercial linefishing, purse seining or crayfishing within the zone.

Currently there is no proclaimed marine reserve along the Namibian coast. For many years (1979 to 1993), Sandwich Harbour was the site of a protected area which extended 1.6 km seaward of the low water mark.[40] This area was proclaimed under the legislation of the then South West African Directorate of Agriculture and Nature Conservation (now incorporated into the MET). In the Sea

Fisheries Act (29 of 1992), the MFMR claimed control of the marine environment up to the high water mark, and did not make provision for the protection of any marine areas, except from unlicenced vessels, recreational anglers, and commercial ski-boat anglers as described above.[89] Commercial trawlers may thus currently operate off Sandwich Harbour. The MET's legislation concerning the 1.6 km protected area off Sandwich Harbour still stands, but this Ministry is powerless to enforce the observance of the area.

Walvis Bay lagoon is Namibia's largest coastal wetland and is used by large numbers of wetland birds. It has been recognised as a Ramsar wetland of international importance, particularly for migratory birds, which merits special protection. As a signatory of the Ramsar Convention, Namibia has an international obligation to protect this site. Although the lagoon had the status of a reserve under South African legislation, this was lost on transfer of ownership to Namibia in 1994. The 15 nearshore islands in Namibian waters were also reserves under South Africa's jurisdiction, and are also currently unprotected as a consequence of transfer of ownership to Namibia.

The proclamation of one or more true marine reserves, in which human activities, especially commercial harvesting of marine resources, are strictly prohibited, is a priority. There is a glaring imbalance between the portions of Namibian terrestrial and marine environments which are protected. Protection of even small patches of ocean can have significant effects,[92] since they can support source populations which may enable repopulation of depleted areas outside the reserve. However, the dynamic and fluctuating nature of the Namibian marine system makes the selection of sites for possible marine reserves an intimidating task. From the point of view of protecting marine biodiversity a marine reserve could prove ineffectual because so large a proportion of the marine species are migratory or highly mobile. This applies especially to those species which are commercially exploited and most in need of protection. Resident species may benefit more by such protection, although resident coastal species already enjoy protection in the vast areas which are inaccessible to anglers and to commercial line-fish boats.

The conservation of marine biodiversity might more effectively be accomplished through the protection of spawning and nursery areas of the commercially exploited species. Since the sites of spawning grounds differ for different species, no single protected site would suffice. Spawning centres exist off the Skeleton Coast Park for commercially exploited species such as hake, round herring, horse mackerel, pilchard and anchovy.[48] Protection, especially of the northern Skeleton Coast Park waters, would ensure that spawning in these species could occur. This would, however, provide no guarantee of egg or larval survival, nor of recruitment into the adult populations.

Coastal sites of special interest

Several coastal sites support unusually high biological diversity and would be particularly worthy of protected status. These are Sandwich Harbour, Walvis Bay Lagoon, Lüderitz Lagoon, the mouths of the Orange and Kunene Rivers, and the islands off the Lüderitz coast.

Sandwich Harbour is a coastal wetland situated between the high dunes of the central Namib Desert and the cold Atlantic. A sand bar projecting into the sea once protected an area of about 10 km in a north-south direction, and 3 km in an east-west direction,[93] from high energy wave action. In the late 19th century this bay was used as an anchorage for large vessels,[94] but today it is a much reduced shallow lagoon with a narrow opening to the sea. The change in topography is a natural phenomenon which continues today.[95]

The wetland consists of two parts.[96] In the north, an area of approximately 5 km x 300 m consists of saltmarsh and adjoining intertidal flats. There is a seepage of fresh water into this northern wetland, and the mixing of this with tidal waters results in variations in salinity.[97] Lush vegetation occurs in the area of the wetland, especially *Typha capensis, Sarcocornia affine, Sporobolus virginicus* and *Odyssea paucinervis.*[98] In the past 30 years the width of the vegetated belt has decreased from about 1 km to the current 300 m,[96] indicating an uncertain future for this area.

The northern wetland has been well-studied, especially its birds.[93,99] Birds are concentrated here, with at least 37 species recorded. A 1991 census revealed a total of just over 4000 birds including ducks, waders and other waterbirds. The area supports high but variable numbers, with 925 individuals of 24 species, and 5439 individuals of 27 species recorded in January of 1995 and 1996 respectively.[100,101]

The southern, less accessible area of the wetland supports an even richer avifauna. This area of about 20 km^2 is unvegetated and consists entirely of tidal mudflats.[96] Totals of 175 000 birds, comprising mainly waders, terns, pelicans and flamingos, have been recorded here. Palaearctic waders are estimated to reach densities of 7000 birds/ km^2, making Sandwich Harbour one of southern Africa's richest coastal wetlands. These wetland birds feed on intertidal invertebrates, which occur in high densities in the mudflats.[102,103] Kensley and Penrith[104] recorded the following intertidal and benthic invertebrates during a survey of the area: 27 species of molluscs, 1 species of brachiopod, 4 of echinoderms, 1 arthropod, 18 polychaetes, 11 polyzoans, 2 poriferans, 34 crustaceans and 5 coelenterans. The vertebrate fauna are represented mainly by 26 fish species.

Sandwich Harbour, particularly the northern wetland, has been the subject of intensive research. Situated in the Namib-Naukluft Park, it is a specially protected area and is rarely visited by tourists. In addition, until recently it was Namibia's only protected marine reserve and is still closed to anglers at certain times of year.[96] However, the continuous topographical changes and decreasing area of the northern wetland are having adverse effects on the quality of the site. Research in the area will continue, with emphasis on the birds, which are good indicators of the health of the invertebrate fauna and of the whole system.

Walvis Bay lagoon is the largest single area of shallow, sheltered water along the Namib coast.[105] It is a natural tidal inlet, where mudflats and sandbanks, which are exposed during low tide, provide extensive feeding grounds for resident and migratory birds. The wetland consists of the natural areas of the lagoon, the Walvis Bay saltworks with adjacent naturally flooded areas to the south, and the 'second lagoon' and eastern side of Pelican Point, its extreme northern point, including adjacent intertidally flooded areas.[105]

Regular bird censuses have been carried out at the wetland since 1977.[101,105-108] It supports up to 150 000 birds of over 40 species,[105] excluding Cape cormorants *Phalacrocorax capensis.* Of these, intra-African migrants form 50% of the total, palaearctic migrants 45%, and coastal residents 5%. The wetland supports significant numbers of Namibian red data birds (Appendix 12), including nearly 70% of the estimated world population of the rare chestnut-banded plover *Charadrius pallidus.* Walvis Bay is also a feeding site for 83% of southern Africa's lesser flamingos *Phoeniconaias minor*, 49% of its greater flamingos *Phoenicopterus ruber*, and 40% of the world's estimated population of black-necked grebes *Podiceps nigricollis.*[105,109,110]

Walvis Bay is the largest and, together with Sandwich Harbour, the most important coastal wetland in southern Africa. However, the status of the lagoon and adjacent intertidal wetlands is threatened by several factors. Encroachment by industrial and housing developments, a road and a protective dyke along the eastern and southern sides of the lagoon have all reduced the flooding area.[105,108] In addition, a gradual siltation of the lagoon's channels has occurred over recent years, altering feeding conditions for birds. Causes of the siltation may, to some extent, be natural, but have certainly been aggravated by human activity. Changes in the flooding regime of the Kuiseb

River, which formerly returned accumulated silt to the ocean, appear to be central to the lagoon's current process of siltation.

Although a Ramsar site, Walvis Bay lagoon is currently not a nature reserve and is not protected by any legislation. It is essential that every effort be made to re-proclaim this valuable and vulnerable area as a reserve.

The **Lüderitz lagoon** is a 7 km long incision into the rocky coast south of Lüderitz. It is relatively sheltered by the Lüderitz peninsula. No fresh water enters this lagoon. Small areas of intertidal wetland occur in sheltered bays, and at the southern end of the lagoon a larger mudflat occurs. The total wetland area is about 5 km^2. Saltmarsh vegetation occurs in the upper tidal areas, while mudflats with associated infauna are exposed during low tide. An area of about 0.6 km^2 at the southern end of the lagoon is only flooded during spring high tides and is devoid of vegetation.

Lüderitz lagoon is visited regularly by a significant number of wetland birds and, in addition, several sites in the nearby vicinity of the lagoon provide suitable habitat for shorebirds. In an intensive survey of the entire Lüderitz region carried out in 1982,[111] a total of 2659 birds was recorded on the mainland between Grosse Bucht (26°45'S) and Agate Beach. Most (53%) were waders of 15 species, with turnstones *Arenaria interpres*, curlew sandpipers *Calidris ferruginea* and sanderlings *C. alba* most abundant. Of the 13 non-wader species, gulls were most abundant (60%), with greater flamingos also relatively abundant (25%). Hockey's[111] counts on the rocky islands in the vicinity of Lüderitz (Shark, Seal and Penguin Islands to the north, and Halifax Island to the south) revealed 2289 birds, of which 80% were non-waders, mostly gulls. The area supports at least eight wader species, with high numbers of African black oystercatchers *Haematopus moquini* and turnstones.

The Lüderitz lagoon, its associated wetlands and nearby bird-rich areas are vulnerable to pollution from the harbour and associated industrial development around the town. Disturbance by vehicles is also a threat. The area currently has no protected status, and the lagoon itself is used as for recreation. A portion of Radford Bay on the eastern side of the lagoon has already been reclaimed for housing and sports fields. The sheltered nature of the lagoon lends itself to mariculture, and an oyster farm exists in the southern area. Commercial collection of the seaweed *Gracilaria gracilis* occurs at various sites around the lagoon and at Agate Beach. At present there is no indication of a negative effect of the mariculture on the wetlands. However, further development of mariculture could threaten the local biota through the introduction of invasive alien invertebrates. It would be desirable to declare the southern end of the lagoon, with its saltmarsh and the tidal mudflats, a local nature reserve.

The **Kunene River** is one of only two perennial rivers in Namibia which reach the Atlantic Ocean. Its mouth therefore provides a valuable habitat throughout the year for a large variety of animals. The formation of sandbars from the northern and southern shores leaves a very narrow river mouth, which is only widened after extremely high floods. The mouth is never completely closed and tidal influence is seen 4 km upstream. During high tide, the river water is dammed back and a lagoon roughly 2 km x 1 km forms inland of the sandbars.[112] The lagoon water is up to 10° C warmer than the sea, and satellite imagery reveals a plume of warm, nutrient-rich water extending 100 km^2 into the Atlantic Ocean.[113]

The very isolated nature of the area and poor security during the war years in Angola have made intensive studies of the biodiversity of the Kunene River mouth difficult. Surveys have been made mostly on reptiles and birds.[112-115] Bird counts at the mouth have identified 84 bird species, of which 72 are wetland species and 14 are red data birds. Highest numbers of birds using the wetland were recorded just as the river began to rise after the start of seasonal rains in Angola.[113] While lacking the numbers of the ecologically similar Orange River mouth, the Kunene shows a remarkably high richness of avian species. Very high numbers of Damara terns have been recorded (2000[112] to 5000[116]) in and south of the mouth. This species is a near-endemic, desert-breeding species listed as *rare.*[71,117]

The Kunene mouth is frequented by a number of reptiles and fish which depend on permanent aquatic habitats, including Nile crocodile *Crocodylus niloticus*, Nile monitor *Varanus niloticus*, and turtles *Trionyx triunguis* and *Chelonia midas.*[113,114,118,119] Little is known of the wetland's importance to fish. Hay *et al.*[120] recorded 69 freshwater fish species in the area, plus 19 marine and 5 unidentified species. Twelve of these species occur only below the Epupa Falls, and may be threatened by hydropower development.[121]

The invertebrate fauna of the Kunene River is unique in Namibia, but probably represents the southern limit of the Angolan fauna. The species richness is comparatively low.[122] Various terrestrial mammals have been recorded near the mouth, of which brown hyaena *Hyaena brunnea*, gemsbok *Oryx gazella*, and springbok *Antidorcas marsupialis* are the most common. Various small mammals also occur there.

The Kunene River coastal wetland is threatened by the proposed construction of the Epupa Dam for hydroelectricity production. The realisation of this project would likely lead to drastically reduced or zero water flow to the river mouth. This in turn would lead to reduced nutrient-rich flow into the lagoon, and greater sea-water intrusion resulting in increased salinity and lower temperatures within the lagoon. Without any conservation measures, as proposed by Simmons *et al.*,[113] the effects on the biodiversity of this important wetland would be dramatic.

The **Orange River** forms the southern border of Namibia, and is also a perennial river flowing into to Atlantic Ocean. An area of about 18 km^2 between the sea and the Ernest Oppenheimer Bridge, some 10 km upstream, comprises the Orange River coastal wetland. It is considerably larger than the wetland at the Kunene River mouth,[123] and unlike that mouth, occasionally experiences a complete blockage of river flow by sand bars.[124] At these times a brackish lagoon forms on the landward side of the bars and the environment becomes wholly estuarine. Usually, however, the river breaks through to the sea at least once a year, and then the tide influences the lower reaches of the river and intertidal mudflats occur.

Although knowledge of the biota at the Orange River mouth is limited, birds occurring in the area are well documented.[99,100,123,125,126] During summer, the Orange River mouth is the sixth richest coastal wetland in southern Africa in terms of total bird numbers.[123,127] When the river flow is low and the available feeding area is at its maximum, over 20 000 birds occur at this wetland. Thirty-two resident wetland species, 6 intra-African migrant species and 18 palaearctic migrant species are represented. Fourteen species occur on the red data lists for Namibia or South Africa.[126]

Access to the coastal wetland at the Orange River mouth is severely restricted due to strict security measures by diamond mining organisations on both the Namibian and South African sides of the river. Therefore, some animal groups in this wetland are little known, the birds being best studied. This limited access and development is certainly beneficial in terms of protection of this important coastal wetland as a whole.

Fifteen **nearshore islands** or rocks along the Namibian coast to the north and south of Lüderitz provide excellent breeding habitat for a large number of seabirds. The islands are largely devoid of vegetation, with rocky intertidal zones and no fresh water sources. Their importance to seabird populations lies in their geographical position in the highly productive Benguela upwelling system, and in their inaccessibility to mammalian predators. The abundance of fish in these waters attracts hundreds of thousands of piscivorous seabirds to the area. Nine seabird species and one wader (African black oystercatcher) breed on the island, and numerous waders and non-waders visit the islands during the summer to feed on the rocky shores. Of these, African black oystercatchers are conspicuous and the islands may support 12.5% of their estimated world population (unpublished data of A.J. Williams).

Regular censuses are conducted during November/December, the peak breeding time of most of the seabirds. In December 1995 between 140 000 and 145 000 seabirds were recorded on the islands,[128] largely Cape cormorants (55 000 to 60 000 individuals) and Cape gannets *Morus capensis* (48 000 individuals). Other endangered species include African penguins (25 200 individuals), and three other species of cormorant which have a breeding stronghold here. Red data gulls and terns comprise the bulk of the remaining species. Cormorants and gannets are all excellent indicators of fish stocks,[86] and this and their red data status makes them particularly important species to monitor.

Little is known about the other terrestrial biota of the islands. Griffin and Griffin[129] recorded in the mid-1980s two species of lizards, seventeen species of spiders, one species of tick and one alien species of domestic rabbit residing on the islands. Possession Island, the largest and most vegetated island, had the greatest richness, with 9 species of terrestrial invertebrates and one vertebrate. Although some of these species may occur naturally, most are likely to have been introduced with supplies to the islands.

Numerous Cape fur seals occur in breeding colonies on most of the islands. They are kept off the two most important seabird-breeding islands, Ichaboe and Mercury, to prevent competition for breeding space and ensure the harvest of seabird guano (Boxes 1.6 and 3.8). The largest seal populations occur on Long, Albatross and Sinclair's Islands, where they breed and have taken over major sections of the islands.

The islands had a tumultuous history from the 1840s guano rush, and were, like Walvis Bay, South African territory until March 1994. In 1987 these islands were declared nature reserves by the South African Cape Provincial Administration, but lost this status with their handover to Namibia. Although access to the islands is still controlled, there is a possibility of disturbance and exploitation while the islands are unprotected. Seabird populations have declined in the past 40 years due to food shortage and disturbance caused during guano collection (see Box 3.8). The commercial harvest of guano ceased in 1991, but may well start again within the next few years. It is hoped that the islands will be re-instated as protected areas as soon as possible, and that management regulations will be enforced to prevent unnecessary disturbance to these vulnerable sites.

3.7 The outlook for marine biodiversity

On a global scale, marine biodiversity is threatened primarily by human abuse and mismanagement of both the living resources and the ecosystems that support them.[130] The oceans are particularly likely to be abused in this way, since the degradation wreaked by human activities is largely out of view; there are no visible scars, such as are left when tropical forests are cleared, to remind us of the consequences of our activites. Humanity depends on the oceans in many ways, most significantly but subtly in terms of global environmental support. About 99% of all primary production is carried out by marine phytoplankton, which also produce half of the world's oxygen and account for one third of the annual global carbon fixation.[2] The sea governs the weather patterns and climate, stabilises temperatures and is a source of moisture for rainfall which replenishes freshwater supplies. In addition, an estimated 100 million people in the developing world alone depend upon marine fisheries activites for all or part of their livelihood.[130] Clearly, abuse and mismanagement of these precious assets is blatantly inappropriate and indefensible, and could jeopardise human survival.

It may not be necessarily to know how many species there are in the different marine habitats, or how many of these are endemic or of commercial value to mankind. What is critical is the interdependence of the different organisms, and the manner in which their ecological roles combine and support a holistic, functioning system, capable of continuing the processes upon which humankind depends. The stability and functioning of the ocean are, in turn, dependent on intact biodiversity.

In an elegant analogy, Ehrlich and Ehrlich[131] liken the act of tampering with biological diversity to that of a man removing rivets from the fuselage and wings of an aircraft. When accosted by a concerned passenger, his retort is that the airline has discovered it can sell these rivets for two dollars a piece. In any case, he is 'certain that the manufacturer made this plane much stronger than it needs to be'. Such behaviour will at some point, render the aircraft non-functional and result in the untimely demise of those aboard.

IUCN's report on biodiversity in sub-Saharan Africa,[132] states that 'Namibia's living natural resources are generally well managed and the pressures on its biodiversity are not too great at present' (p. 152). Certainly, the marine environment of Namibia is largely free of the extreme levels of pollution, oceanic dumping, disturbance and increasing human urban pressures found in the marine systems of many developed countries. In addition, there have been no recorded extinctions of known marine species on a national scale, although the caveat remains that a large proportion of species remain undescribed. Yet there is little room for complacency. Overfishing is a major threat to African marine biodiversity,[132] and there is an urgent need for protection of marine and coastal habitats.

Namibia's fish and crustacean stocks are renewable resources which generate vital income for the country. Healthy stocks are essential for a healthy economy. In the past, social and economic reasons, rather than ecological considerations, motivated management decisions concerning total allowable catches of resources. This has led to the overfishing of some stocks and a need for drastic measures to enhance their chances of recovery. As a consequence of the crash of pilchard stocks in 1996, a moratorium was placed on pilchard catches for the subsequent season. The social and economic implications of such drastic recovery measures are no more palatable than cutbacks in the TAC. Ultimately, the cost of conserving biodiversity is far less than the penalty of allowing its degradation. The era of Namibia's rivet poppers should therefore be over.

The Namibian marine environment is remarkable in many ways. It is exceptionally productive, supporting abundant marine life, and its habitats are relatively pristine, without threat of significant habitat degradation. The hyper-arid Namib Desert makes major urban and agricultural pressures unlikely in the future. And lastly, the inherently variable nature of processes within the system perhaps make its biota somewhat resilient to the vicissitudes of human activities. These features make Namibia's marine environment immeasurably precious, and worthy of protection, judicious use and careful management, both now and in the future.

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Economics of biodiversity conservation in Namibia 4

Julie Richardson

Courtesy R Simmons

4.1 Overview

What does economics have to offer biodiversity conservation? Even as international funding for conservation increases, difficult decisions still need to be made about which species, genetic resources and ecological zones must first be conserved, and how best to conserve them. How can environmental economics help in making such decisions in Namibia?

This chapter is a first step in showing how economic principles and tools (*e.g.* environmental valuation, cost benefit analysis, and policy analysis) are used to illustrate the economic values of biotic resources and biodiversity conservation, and how these values can be used to influence economic decision making. It is organised into five sections:

Introduction: This section gives a broad overview of the links between economics and biodiversity. It outlines Namibia's *economic development priorities* according to the First National Development Plan and summarises the implications of structural and economic diversification for natural resource related sectors. This section outlines the economic development context within which the National Biological Diversity Strategy must be set.

The section also introduces important economic concepts relating to biological diversity conservation. It provides a general discussion of *the economic causes of biodiversity loss* in terms of overexploitation and habitat conversion, and introduces issues relating to the *economic valuation of biodiversity* (linking ecological and economic values, environmental valuation methods, and problems in the valuation of biodiversity).

The economic benefits of biodiversity conservation in Namibia: This section develops a framework for estimating economic values of biological resources and biodiversity in Namibia. Secondary data sources are used to illustrate *economic values of genetic and species diversity* with examples from agriculture, livestock, tourism, forestry and wild plants, and *habitat and eco-system diversity* with examples from dryland and wetland ecosystems.

The costs of biodiversity conservation in Namibia: A distinction is made between different types of costs relevant to biodiversity conservation: *direct costs, external costs, and opportunity costs.* Case studies from Namibia are used to illustrate these different types of costs in the context of biological resources and biodiversity. The section concludes with an outline of the use of *cost benefit analysis* in biodiversity conservation, with examples from Namibia and other African nations.

Economic policy analysis: This section provides a general discussion of the economic roots of biodiversity loss. Examples from Namibia are used to show how market and policy failures may be at least partially responsible for the degradation of natural resources and biodiversity erosion.

Conclusions and recommendations: This section draws together numerous threads to point the way for future policy and economic analysis.

4.2 Introduction

Overview of the Namibian economy and future development plans

Namibia's political Independence in 1990 represents a significant turning point in the country's political, social and economic development. During the 1980s the political situation in Namibia stifled economic performance, and the economy stagnated with GDP per capita falling by some 20% over the decade. At Independence the Government faced the daunting task of revitalising the economy and addressing the very skewed distribution of income and assets that prevailed under the *apartheid* system. Namibia's relatively high GDP per capita hides one of the most inequitable distributions of income and productive assets in the world.

The revival of economic performance since 1990 has been encouraging. Despite prolonged drought in 1991 and 1992, and sustained world and regional recession, the Namibian economy has performed better since Independence than at any other time since 1980. Over the period 1990 to 1994, real GDP grew by 3.5% per annum. The decline in real GDP per capita has also been reversed, growing by an average of 0.4% per annum over the same period. Nonetheless, Namibia still has a long way to go before achieving a significant improvement in the economic and social well-being of the vast majority of the population. Recent economic growth has been mainly based on the mining and government sectors whose potential for future growth is extremely limited. In addition, the continued bias of the economy towards capital intensive technologies in key economic sectors, and the slow progress in land and asset reform, has not led to significant poverty alleviation,changes in income distribution, or employment creation.

Structural economic change under NDP1

The First National Development Plan (NDP1)[1] represents the medium term national development strategy for Namibia. It outlines national and sectoral objectives for the period 1995 - 2000, and provides the context for a National Biodiversity Strategy. The key economic, social and political development objectives of NDP1 are summarised in Box 4.1.

NDP1 focuses on the need to make significant *structural changes* to the economy in order to achieve economic growth and income distribution targets. There is a recognised need to *diversify the economy*, reducing dependence on the mining and government sectors, and on South Africa as a trading partner. An unhealthy dependence on South Africa still exists for almost all consumer and capital goods. The destination of exports is more varied, but remains highly dependent on primary goods and the natural resource sector. NDP1 stresses that economic growth in the short term will continue to rely on natural resource-intensive activities, but that in the medium to long term more labour- and skill-intensive activities will be the engine of growth. Fig. 4.2 shows the structural implications of this growth by comparing the sectoral breakdown of GDP between 1990, 1994 and 2000.

According to NDP1, *'the Namibian economy will have made a good start along the path of structural change and diversification by the end of the century. The most notable change is that the fisheries sector will have equalled the mining sector in contribution to GDP. Manufacturing, excluding fish and meat processing, starts from a small base so that although historically high growth rates are achieved, its contribution to GDP only increases by some 2% to about 6%. Sectors benefiting from foreign tourism, such as trade, hotels and restaurants, and transport are likely to enjoy significantly higher rates of growth than in the past. Government's share of GDP is expected to decline'.*[1]

Structural change and economic diversification has mixed messages for the natural resource sector in Namibia. It is therefore necessary to look at the proposed changes in more detail and identify any potential conflicts between national, sectoral and environmental development targets.

Sectoral development targets

Structural change and economic diversification are the means by which Government plans to achieve growth and equity targets. At the same time, Government is striving for sustainability through sound environmental policies, legislation, proper pricing of environmental resources, and the promotion of environmental education and awareness.[1]

Box 4.1 National development objectives and targets

Economic

- Formulate and carry out a vigorous and top-priority human resources development programme open to all Namibians, especially the unemployed
- Expand the role of the private sector and foreign investment in the economy
- Maintain inflation at a level not exceeding that of Namibia's main regional trading partners
- Maintain CMA membership and parity with the rand and to work with CMA partners to liberalise exchange controls
- Improve levels of household food security nationally with an ultimate aim of achieving food self sufficiency
- Diversify import sources and export markets to increase trade with other southern African countries
- Promote productive sectors with high potential for growth such as manufacturing, fisheries, tourism, agriculture and mining
- Promote national development of appropriate science and technology

Social

- Reduce the population growth rate to below 3.0% by 2010
- Reduce the total fertility rate to 4.5 children per woman by 2010
- Increase life expectancy to 63 years by 2000
- Promote the development of sport and indigenous culture
- Increase the literacy rate to 80% by the year 2000

Political

- Reduce existing regional imbalances
- Promote increased participation of women, youth and other marginalised groups in economic development activities

Source: NDP1[1]

The Government acknowledges that the promotion of economic growth in a natural resource dependent economy like Namibia can lead to unsustainable use of these resources. It is therefore important to look at natural resource sector growth targets closely, as outlined in Box 4.2.

For sustained development in Namibia, it is essential to ensure that sectoral growth targets are not met by running down environmental stocks, or at the expense of losses in productive output in other sectors. For example, short term fishing targets could be reached by depleting fish stocks, and agricultural targets can increase competition for land and water with the wildlife and tourism sector.

Under NDP1, the Ministry of Environment and Tourism has been set the task of ensuring that sectoral policies are consistent with environmental constraints and principles of sustainability (especially agriculture, food, energy and land policy). In order to do this, it is important to collect more information on potential sectoral conflicts with environmental dimensions. This means researching and compiling data on the economic value of natural resources (marketed and non-marketed) in different uses and under different development scenarios. The Directorate of Environmental Affairs has been tasked with developing databases on the Namibian environment, including on biological diversity, as well as researching the economic values of natural resources and building natural resource accounts. Progress is being made in all three spheres, with the Namibian Biodiversity Country Study an important first step in assessing the value of biological resources and biodiversity.

Fig. 4.1 National development priorities focus on the education and health sectors. Courtesy Ministry of Information and Broadcasting.

Links between economics, ecology and biodiversity

The economic causes of biodiversity erosion

Few would dispute the fact that biodiversity and human development are inextricably linked. Projections of current extinction rates indicate that over the next 50 to 100 years the earth will face a mass extinction crisis.[2] What are the implications for human development, and how have economic factors contributed to this trend? Box 4.2 shows how economists explain loss of biodiversity in terms of either overexploitation of economically valuable species, or habitat alteration threatening species with little known economic value.

A combination of these factors may *explain* the process of biodiversity loss, but what are the *underlying causes* of the global and national failure to invest in biodiversity? Swanson and Barbier[3] suggest four key reasons:

- lack of information about the economic value of biodiversity
- the relative economic rates of return to land are distorted (*e.g.* government policies that subsidise conversion of habitat at the expense of biological diversity)
- lack of mechanisms for capturing the economic value of biodiversity
- a development bias towards investing in specialised, cultivated species.

Economic specialisation at the expense of biodiversity is a global trend, lying largely outside the control of the individual nation state. Specialisation involves clearance of diverse biological communities and installation of homogeneous ones. During the twenty years 1960-1980, the whole of the developing world saw the proportions of its land area dedicated to specialised species increase by 37.5%.[3] This is a systematic trend reflecting the development of the global economy. The principle of uniformity and the law of specialisation are the basic cornerstones of modern economics. Simply, they state that uniformity can contribute significantly to productivity. Specialisation can lead to monocultural production and capital intensive methods of production which are being adopted throughout the world.[3]

This type of economic development is premised on the narrowing of 'useful' species of plants and animals, and the favouring of a few at the expense of many. If this does not change, global economic development trends will be increasingly in conflict with biodiversity conservation. Swanson & Barbier[3] believe that the way forward is to identify the economic value of biodiversity and integrate it into the economic process, so that it becomes economically attractive to specialise in diversity. Wildlife utilisation projects provide one example of how this can be achieved at the national level. This is the approach adopted here.

The economic value of biodiversity

There are a number of factors that make the economic valuation of biodiversity difficult in both theory and practice. These relate to a definition of biodiversity; problems of uncertainty and irreversibility; and limitations of the valuation methods.

What is biodiversity from an economist's perspective? The value of biodiversity depends on how it is defined. Two distinct definitions of biodiversity and its value are given below:

'Biodiversity refers to the variety and variability of all animals, plants and micro-organisms on earth, and can be considered at three levels: genetic diversity (variability within species), species diversity, and habitat diversity. The important point is that biodiversity is the degree of variety in nature. It is not nature itself.....The value of biodiversity is the difference between the current or future value of a diverse range of genes/ species/ ecosystems, and the value of a less diverse range. It is not the gross value of all naturally derived goods and services.'[4]

'Biological resources - genes, species and ecosystems that have actual or potential value to people - are the physical manifestation of the globe's biological diversity.'[5]

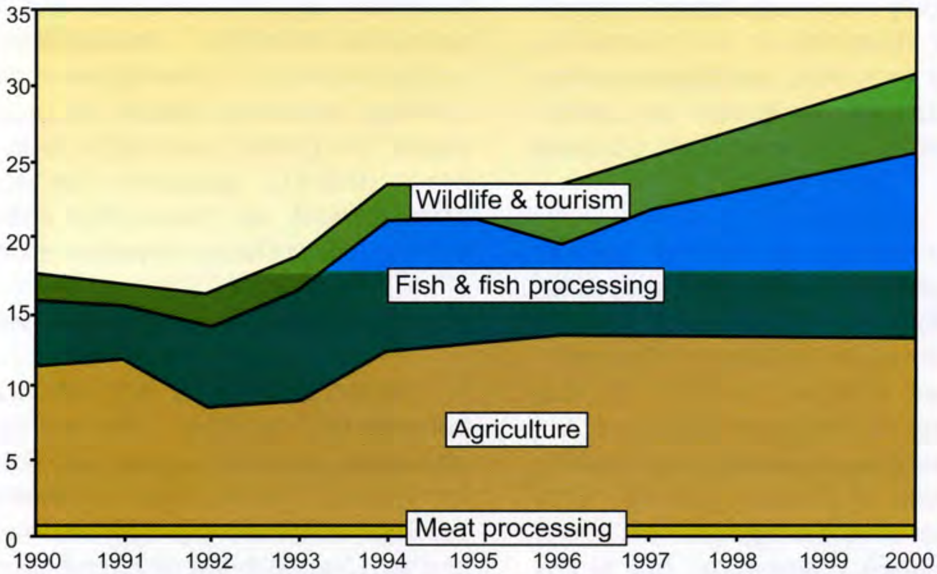

Fig 4.2 Sectoral contribution to GDP, 1990 - 2000[1]

Box 4.2 Major economic threats to biodiversity

Overexploitation arises when resources are harvested at a higher rate than the natural growth rate of the population. Species most likely to be overexploited are those with a high price relative to the harvesting costs, and low population growth rates. Species with these characteristics are elephants, rhinoceros and whales, all currently endangered.

Open access is commonly cited as a factor leading to overexploitation. Open access resources have no identified owners, and no-one can be excluded from using the resource. Open access management creates incentives not to invest in the resource, since the benefits of investment will be captured by other resource harvesters (*the free rider problem*). Why does open access management continue to exist, even though it leads to 'inefficient' management of scarce resources? Open access regimes may be 'chosen' by the state as they are the least costly option in terms of government funds.[6] *This implies that the fundamental cause of many extinctions, especially those due to overexploitation, is not the existence of open access management, but the existence of incentives not to invest in the necessary management institutions.*

Habitat conversion is the greatest threat to most land species. Wild species have to compete with humans for habitat. The main habitat displacing activity in Namibia is agriculture, both livestock and crops. One of the reasons these conversions take place is because the economic value of biodiversity is not transparent in the market place and cannot always be realised in money terms by resource owners and users. Habitat conversion means that wild resources are being *undercut* rather than overexploited.

Source: Pearce et al.[6]

These differing viewpoints highlight the important distinction between the value of *biological resources* and *biodiversity*. Although biological resources are in fact the manifestation of biodiversity, it does not follow that their economic values are synonymous. One approach is that *biological resources* are simply resources, and *biodiversity* is simply the diversity of those resources.[7] A very different approach is to estimate the total economic value of biological resources and then attribute a proportion of this value to biodiversity. For example, De Groot[8] estimated that the value of biodiversity on the Galapagos Islands was 50% of the total economic value of their biological resources.

Most economic valuations of biodiversity have adopted McNeely *et al.*'s approach,[5] in which the value of diversity is estimated by evaluating the economic contribution of the biological resources or ecosystem concerned. This is the simpler and most widely adopted approach.

This chapter makes extensive use of secondary sources of information to develop a framework for potential values of genetic, species and ecosystem diversity in Namibia. Most of these studies focused on the economic value of biological resources, but in some cases it was possible to identify economic values of diversity *per se*. This approach is therefore a pragmatic one, which uses the available information, but at the same time highlights the distinction between biological resources and biodiversity where appropriate.

Problems of uncertainty and irreversibility

The economic valuation of biodiversity is fraught with difficulties arising from both scientific and economic *uncertainty*. Scientific knowledge is deficient to the extent that there is no way of knowing whether there are 5, 10 or 30 million species on earth.[2] Currently, there is information on about 1.4 million species, so all we can say with certainty is that our ignorance is greater than our knowledge. There is also considerable uncertainty about the ecological roles of different species, and the effects of species extinction on ecological stability. There is also much uncertainty surrounding the economic values of many known species, never mind those of yet undiscovered species.

'Given that there is near total uncertainty over the future existence and values of yet undiscovered species, the future costs of genetic/species/habitat impoverishment or the preferences of future generations, the problems of valuation are considerable. The future value of biodiversity is thus in a very real sense the valuation of the unknown.'[4]

Biodiversity conservation is sometimes thought of as a way of managing this uncertainty, by adopting a precautionary or risk-averse development strategy. Viewed in this light, much of the value of biodiversity can be thought of as an insurance premium, protecting against ecological and therefore economic instability.[9] *Irreversibility* adds a further dimension to the degree of difficulty in deriving economic values for biodiversity. Again, the policy prescription is to adopt a precautionary approach to economic development, as irreversible change can severely restrict future development options.[10]

Linking ecological and economic values

In applied ecology, a distinction is made between the *structural components* and the regulatory *environmental functions* of an ecosystem.[11] In the case of a wetland ecosystem, such as the *oshana* system in northern Namibia, the structural components include biomass, abiotic matter, and plant and animal species, while environmental functions include groundwater recharge, flood control, water quality maintenance, microclimate regulation, and so forth.

In economics, a distinction is made between use and non-use values. A further distinction can be made between *direct and indirect use values* and *consumptive and non-consumptive use* (Box 4.3).

How are economic and ecological values linked? In general, *structural components* in ecology, such as fish, woody biomass, mammals, food and fibre, relate to direct use values in economics. *Ecological functions* such as nutrient retention, sediment control, maintenance of water quality relate to indirect use values. However, the relationship between ecological and socio-economic processes is not static. Changes to both ecological and economic processes will ultimately have an impact on economic values. Box 4.4 illustrates the relationship between ecological processes and economic values.

Environmental valuation methods and cost benefit analysis

A summary of the range of environmental valuation methods is given below, and examples of their applications in Namibian context are given in Box 4.5.

Box 4.3 Types of economic values

Direct use values are values derived from using the products and services of the environment. For example, direct use values of wetlands include the collection of wild plants, fuelwood, fish, water, and the benefits from recreation and tourism. Safari hunting is *consumptive use,* and photographic safaris *non-consumptive use.*

Biodiversity (as distinct from biotic resources) has a direct use value when diversity enters into consumer or producer preferences.[7] For example, a direct use value of genetic diversity is the value of maintaining a diverse range of germplasm by seed companies to improve crop breeds. Ecotourism values are closely linked to species and habitat diversity.

Indirect use values refer to economic benefits derived indirectly from protective and supportive functions of the ecosystem. For example, the groundwater recharge function of wetlands such as *oshanas* has an indirect use value through its replenishment of aquifers that supply water for agricultural, mining, industrial and domestic use. Likewise, nutrient retention and microclimate regulation support local agricultural production.

The indirect use values of biodiversity are revealed when changes in diversity affect the biological production of an economic good or service. For example, bush encroachment reduces the availability and diversity of palatable grasses in pastureland, and reduces the production of livestock in commercial areas.

Option values can be thought of as future use values. Although there may be no economic reason to use the resource today, considerable value is attached to preserving options for use sometime in the future. Option values are closely related to uncertainty and risk aversion.

Existence values are a type of non-use value. Value derives from the mere existence of a resource, by definition unrelated to current or future use by humans. As such, existence values reflect non-anthropocentric sentiments where all species have rights, independent of human preferences and consumption needs. Contributions to single-species campaigns (*e.g.* Save the Rhino Trust) are likely to have a large existence value component. A potentially very large existence value is attached to biodiversity.

Box 4.4 The dynamic relationship between ecological and socio-economic processes

Processes	Examples		
	Genetic diversity	**Species diversity**	**Ecosystem diversity**
Change in diversity	loss of genetic variation in food crop species diversity	reduction in grassland biomass and diversity	conversion of forest to agricultural cultivation
Change in ecological processes	increased success of disease and pest infestations	emergence of new dominant species	productive monocropping in place of ecotourism
Change in economic processes	attempt to maintain crop production by using other inputs	attempt to maintain livestock production by using other inputs	ecotourists travel to less aesthetically pleasing sites
Change in economic value	loss in economic value of crop production	loss in economic value of livestock production	loss in economic value from decreased aesthetic enjoyment, gain in value of agricultural production

Source: Adapted from Aylward[7]

Production Approach is the most common approach. This measures changes in the productivity of natural or man-made systems due to changes in environmental conditions. *Actual market prices* can be used to value impacts on output, but in other cases the *prices of alternative or substitute goods/ services* can be used.

Preventive Expenditure Approach values the damage caused by environmental degradation according to the costs consumers and / or producers are willing to pay to prevent this damage.

Replacement Cost Method uses increased expenditure on the replacement, restoration or maintenance of damaged environmental assets as a measure of the damage.

Damage Costs Avoided: Many of the ecological service functions that support or protect economic activity and property can be evaluated in terms of the 'damage costs avoided' if this service was degraded or lost altogether. For example, the value of watershed flood-control programmes can be assessed in terms of the avoided damage to agricultural land, buildings, infrastructure, health and safety.

Hedonic Pricing Method: The hedonic pricing method attempts to capture the additional willingness to pay for protective, recreational and aesthetic values attached to environmental systems by a detailed analysis of the land and / or property market in the local area. For example, properties in recreational areas such as attractive coastlines are more expensive than the equivalent property in areas without such amenities. This price premium reflects the extra willingness to pay for environmental amenities.

Travel Cost Method was devised to value recreation sites. Costs are incurred in travelling to a site, and these can be used as an index of willingness to pay to visit the site. The *opportunity cost of labour* is a related approach which assigns value to wild products, in terms of the labour time spent in collection.

Contingent Valuation Method seeks information on environmental preferences and value directly from the individual, using questionnaires, surveys and experimental methods. The method is useful in capturing option and existence values not revealed in market behaviour.

What do environmental valuation methods really capture?

Box 4.5 illustrates the range of approaches that can be used to estimate the value of biotic resources and diversity in monetary terms. Some approaches are more applicable than others in different circumstances. The travel cost method is good at estimating values of recreational areas, but cannot evaluate resources which are not associated with a significant travel component. The contingent valuation method can be applied most widely, but results may be seriously biased, especially if respondents are unfamiliar with the asset being evaluated (*e.g.* biodiversity).

It is also important to distinguish those environmental valuation methods based on willingness to pay (**demand side methods**) from those based on the costs of supplying or restoring environmental resources or functions (**supply side-methods**). For example, the travel cost method can be used to estimate the willingness to pay for wild products in terms of the time spent in collecting these resources. However, calculating the value of wild products in poor rural communities using the travel cost method may give low monetary estimates, even though these products may be critical for communities in terms of total household income and survival in times of drought and crop failure. This is because the travel cost method uses time spent in collection of wild products as an index of willingness to pay for these resources. In rural communities, where cash returns to labour are low and few jobs exist, time is valued at a relatively low rate. Hence the same bundle of wild plants will be valued differently depending on the income profile of the community collecting them. This disparity within countries is also reflected in the international valuation of resources using willingness to pay approaches. Therefore, environmental resources in low income countries are valued less highly in monetary terms than resources in wealthy countries. Willingness to pay approaches are based on income constrained preferences for resources. They therefore underestimate the crucial role that these resources play in poor communities, and tend to reinforce income inequalities.

On the other hand, supply side methods are based on the cost of supplying or restoring damaged environmental assets or functions, independently of a community's income profile. For example, the cost of restoring or conserving a woodland area is independent of the wealth of the community using the resource.

The choice of valuation approach will be governed by factors such as data availability, reliability, and the type of asset being evaluated. Many economists prefer willingness to pay approaches since they may be more reliable, at least in theory, whereas supply side methods may be preferred for practical reasons and do not bias results according to the incomes of resource users. Box 4.6 illustrates the importance of the choice of valuation methods with respect to harvesting of wild products in rural communities in Namibia.

Fig. 4.3 Woman gathering mangetti nuts. Courtesy LC Weaver

Cost Benefit Analysis: Values derived using methods in Box 4.5 are not very informative on their own, and must be compared to the costs of biodiversity conservation for a fuller picture. *Cost benefit analysis* is an important decisionmaking framework which involves evaluating a 'stream' of costs and benefits of a particular project or policy over a selected time period. Methods used to compare costs and benefits depend on the objectives. For example, a *financial analysis* could be performed to assess the financial profitability of a potential investment such as establishment of a tourism lodge, based on prevailing prices of inputs and outputs[13] facing the investor,taking into account government subsidies or taxes. Alternatively, a broader *economic analysis* would consider net benefits to society as a whole. This requires the adjustment of many market prices to reflect inputs and outputs in terms of their scarcity values to society as a whole. These values are sometimes referred to as *shadow prices* or *economic prices*.

An example illustrates this distinction between economic and financial prices. The Namibian Agronomic Board offers to buy all wheat and maize at fixed prices agreed annually in advance. This means that financial prices are higher than economic prices by 35% for wheat and 75 - 140% for maize.[14]

In cost benefit analysis, if the financial benefits exceed financial costs, the venture is *privately beneficial*; if economic benefits exceed economic costs, the venture is *economically beneficial*. A project or policy can be privately, but not economically benefical, such as the use of pesticides that increase private yields but cause downstream pollution. A project or policy can be economically but not privately beneficial, *e.g.* wildlife tourism may be economically beneficial but privately unprofitable due to prevailing livestock subsidies. In the first case, resources are directed towards activities which do not benefit society. The second case implies that beneficial activities are under-supplied by the private sector. Both cases highlight a role for government intervention in the economy.

Box 4.5 Applications of economic valuation methods to the Namibian environment

Types of cost	Possible valuation by production cost and replacement cost methods using:
Deforestation	
Increased time for fuelwood collection or substitute costs of commercial fuel	opportunity costs of labour and price of substitute goods
Increased time for building materials collection or substitute cost of fencing	opportunity costs of labour and price of substitute goods
Lost value of non-timber forest products	market prices and opportunity costs of labour
Wildlife	
Lost value of game meat/ animal products	price of substitute goods
Lost existence value of forests/ animals	contingent valuation
Lost recreational value of wildlife	market prices (tourism); travel cost; hedonic land values
Rangeland degradation	
Lost capital value of dead animals	market prices for restocking
Lost value of milk production	market prices or price of substitute protein
Fertility loss of arable land	
Lost value of arable production due to fertility decline	market prices of lost output; replacement costs of manure/ fertiliser; damage costs avoided
Wetland degradation	
Increased collection time of wild goods or costs of commercial substitutes	opportunity costs of labour price of substitutes
Degraded flood and flow control	damage cost method (costs avoided); preventive expenditure method (flood prevention expenditures)

Adapted from Quan et al.[12]

Fig. 4.4 Degraded lands influence people's daily costs of living. Courtesy NBRI (M Müller)

Fig. 4.5 Livestock provide multiple resources for rural people. Courtesy P Tarr

Box 4.6 Choosing valuation methods for assessing wild products harvested by rural communities

The choice of values which accurately and fairly represent our preferences is a complex process approached from many different angles by resource economists. How do we begin the task of estimating the relative value of things which people use? Without appropriate valuation methods, we cannot identify resource allocation strategies which maximise people's welfare. Each method has strengths, weaknesses, and biases. Hence, the choice of valuation methods involves a value judgement, which affects the way decision-makers perceive value, and affects their resulting decisions.

A method which accounts only for 'direct values' of wild fish consumed by households ignores the importance of fish to female-headed households which may have limited opportunities to obtain adequate protein. The value of mangetti nut oil in a local market does not reflect its value to San people in Otjozondjupa and Caprivi who depend on it for subsistence. Conversely, defining 'existence values' of game animals says nothing of their value in terms of tax revenues provided by hunters, and the welfare these revenues provide to others. Clearly, the choice and mix of valuation methods matters.

— Chris LaFranchi

A more detailed discussion of the cost benefit framework and different types of costs relating to biodiversity conservation is provided in section 4.4.

4.3 Economic benefits of biodiversity conservation in Namibia

Biodiversity is generally understood at three levels: *ecosystem, species and genetic diversity.* The ecosystem level refers to the spatial variation in habitats and ecological communities; species and genetic levels encompass the range of variation within them.[9]

This section uses the overall framework of genetic, species and ecosystem diversity to illustrate the relationship between these ecological categories and economic values in Namibia. These categories are not mutually exclusive: the value of genetic and species diversity may also be important components of ecosystem diversity. Examples focus on dryland and wetland ecosystems in Namibia. As far as possible, environmental values are given in 'net benefit' terms. This means the additional economic contribution (or value added) of the resource after subtracting the costs of managing the resource.

Genetic and species diversity

Many economic studies focus on the value attributed to particular key resources or species, rather than the diversity of species. For example, studies that relate tourism revenues to the presence of charismatic game species[15] do not attempt to attach value to the wide range of species on which these valuable species depend. In fact, no overall valuation of wildlife diversity has ever been attempted, either in Namibia or elsewhere. The following studies in Namibia illustrate the value of particular species, and in some cases genetic and species diversity, in relation to agriculture, livestock, tourism, and wild plants.

Crop agriculture

Genes transferred to domestic crop plants from their wild relatives have important economic values that can be realised through increased yields, improved quality, resistance to pests and diseases, extended growing ranges, and wide hybridisation between crop species. The value of maintaining the genetic diversity of wild plants for use in agriculture will become even more important in the future with the trend towards increasing genetic uniformity and vulnerability associated with more intensive farming systems.[4,9]

Box 4.7 Potential links between genetic diversity in wild plants and agricultural productivity in Namibia

Watermelon *Citrullus lanatus*: Watermelon is highly susceptible to *fusarium* wilt. Resistance could be present in wild species, which could be used to reduce commercial losses due to disease or used as a root stock for the crop. Wild species also have resistance to various viruses and have enhanced drought tolerance. Both genetic characteristics have commercial value.

Sweet Melon, Cucumber *Cucumis melo, Cucumis sativus*: Resistance to pests and diseases of melon and cucumber crops may be found in Namibian wild species. The most important pests and diseases are bean spider mite, white fly, nematodes, fusarium wilt, green mottle virus, watermelon mosaic virus and watermelon virus 1.

Cowpea, Bambara Nut *Vigna unguiculata, V. subterranea*: A seed protein variant present in wild beans confers resistance to bruchid beetles, a major pest in Namibia, without having a negative effect on taste or cooking traits. Wild Namibian species and landraces could contribute traits not found in more mesic traditional growing areas.

Cotton *Gossypium* spp.: Genetic traits which could be gained from wild species are cytoplasmic male sterility, short growing period, and insect and rust resistance. These could also increase fibre strength in cultivated cotton.

Tobacco *Nicotiana tabacum*: Crosses of tobacco with South American wild species have resulted in increased quality (*e.g.* lower nicotine content) and yield. The Namibian endemic *N. africana* is the only wild tobacco indigenous to Africa, and could possess unique traits.

Sorghum *Sorghum bicolor*: Wild sorghum is well adapted to an arid environment and could impart drought tolerance to commercial cultivars. It has also been used to increase the green fodder yield of cultivars, and there may be potential for resistance to *Striga,* a parasitic plant which causes very large yield losses.

Eggplant *Solanum melongena*: Eggplant is susceptible to bacterial and verticillium wilt. In Japan this problem was overcome by grafting eggplant onto a stock of *Solanum torbum.* Wild species in Namibia could possibly be used in similar ways.

Sesame *Sesamum indicum*: The diverse habitats occupied by wild *Sesamum* species in Namibia suggest that they may be genetically diverse; traits such as drought tolerance could potentially be introduced to cultivated crops.
— Herta Kolberg

Namibia's National Botanical Research Institute is currently documenting the genetic characteristics of wild plants, including those with potential commercial value. Box 4.7 shows how genetic material from wild plants could potentially be used to enhance Namibian agricultural productivity.

The move in Namibia, as elsewhere, towards specialised agro-ecosystems that focus on producing a reduced rangeof species (and a reduced range of varieties) may reap benefits in terms of increased agricultural productivity and economic growth. But what are the costs of this strategy in terms of increased risks associated with reduced genetic and species diversity? The United Nations Environment Programme[9] notes that the costs of biodiversity loss associated with modern agriculture are borne in increased management costs, such as the increased use of chemical fertilisers and pesticides needed to maintain these low-resilience systems:

'The costs of the management regime needed to maintain a system of very low natural resilience provide a measure of the benefits of ecosystem resilience. That is, where intensive management has substituted for diversity of species as the primary insurance against collapse of the agricultural system, then the cost of the management regime may be thought of as the insurance 'premium' on system resilience'.[9]

Conversely, genetically diverse traditional agricultural systems are more stable but less productive in the face of climatic, pest and disease risks. In rural communities, survival is often more important than productivity, so risk avoidance strategies could be favoured over total output. Box 4.8 illustrates the stability of some indigenous resource management systems in north-central Namibia.[16]

Box 4.8 Genetic and species diversity reduce risk in traditional agriculture

Through a process of careful rational seed selection, natural selection and experimentation, Owambo-speaking farmers over centuries have selected a series of millet cultivars which are best adapted to local conditions. Traditional cultivars were not only selected for short growing seasons and maximum grain yield, but also for resistance to droughts, poor soils, salinity, local pests and plagues, and for vegetative production. The heavily bearded millet cultivar, for example, has a natural defence against bird predators. Substituting the variety of cultivars with only one would figuratively place all a farmer's eggs in one basket. A single disaster could wipe out the entire crop, as the fate of maize monocropping elsewhere has all too often shown. The selection and use of an array of cultivars with different traits, like staggered planting and intercropping, is one of many ways to reduce the risk of overall crop failure. Given the semi-arid climate of north-central Namibia, diversified crop cultivation is the most rational choice.

Source: Kreike[16]

Livestock

Species diversity also has important economic consequences in both the commercial and pastoral livestock sectors in Namibia. Traditional pastoralists tend to manage livestock as mobile, flexible assets which can provide multiple benefits for them, including socio-cultural value, rather than for solely commercial aims such as the offtake of meat.[12] Pastoral farmers help to spread their economic risks by investing in 'livestock species diversity' where different kinds of animals have different nutritional needs and their products have multiple uses (draught power, blood, milk, eggs, dung as fertiliser and fuel, meat, skins, hair, wool, or savings/ insurance) which together provide a cushion against hardship. The Owambo agrosilvipastoral system in north-central Namibia is a good example of an integrated economic system in which economic risks are spread over a range of activities, enabling greater maintenance of species diversity (Box 4.8).

Commercial farming in Namibia is primarily focused on livestock, involving around 4400 farmers. It directly contributed an average of 10.7% to Namibia's Gross Domestic Product in the 1980s, and provides secondary inputs into the food processing and transport sectors. Commercial livestock farmers produce mainly cattle in the north and central districts, and sheep and goats in the drier south. In contrast to the pastoral sector, commercial livestock farming is geared towards maximising the returns from high quality meat production, with other products (such as pelts) being of secondary importance.

Economic decisions about stocking and offtake levels can result in significant changes in rangeland biodiversity and resilience. In ecosystems subject to heavy grazing pressure, the loss of early season palatable species has meant an increase in the relative amount of later growing species. Bush encroachment in commercial areas in Namibia illustrates the impact of changes in the quantity and diversity of grass species on livestock values. Recent research shows that grazing in the commercial livestock sector suffers from bush encroachment, incurring significant productivity losses. In the northern beef ranching areas this is estimated to affect 8-10 million ha, and to reduce beef production on the affected land by up to 30%, or 34 000 tonnes per year, worth about N$102 million.[12] These losses can be linked to changes in grassland composition and richness in grazing areas (Box 4.9).

Wild plants

Medicinal values: The consumptive and productive value of medicines derived from wild species is often cited as one measure of the current and potential future value of biodiversity. Around 20 000 plant species are believed to be used medicinally in developing countries; one quarter of all prescriptions in developed countries are based on plants.[4] The use value of medicinal plants can be estimated by the market value, or when output is unmarketed, the value of marketed substitutes can be used. The value of medicinal diversity *per se* is much more difficult to determine. The costs of reduced diversity of medicinal plants can be estimated by the costs of subsequent untreated disease, and/ or the costs of commercial alternatives.[4] These costs have not been estimated in Namibia or elsewhere.

The National Botanical Research Institute is currently collecting data on indigenous plants of economic importance, including those with medicinal properties. Box 4.10 illustrates the medicinal use value of *Harpagophytum procumbens*, known as the devil's claw or grapple plant, and its potential contribution to development in rural Namibia. This value refers to the economic value of the species, not to genetic or species diversity *per se*.

Coping with drought: Wild products are an important component of drought coping strategies in poor rural communities in Namibia. In particular, households are known to adopt survival strategies based on a wide range of different wild products as a way to spread their risks. Box 4.11 shows how the harvesting of wild products diversifies both economic and ecological risk, copes effectively with drought, and can maintain biodiversity.

Box 4.9 Links between the costs of bush encroachment and savanna diversity

In the commercial cattle farming areas of Namibia it is generally thought that overgrazing, combined with a lack of fire and a reduction in numbers of wild browsing herbivores has led to increasing bush encroachment. This process of rangeland conversion has very important links to species diversity. The selective grazing of palatable plants by livestock and the reduction in numbers of browsing game has allowed unpalatable woody bush to predominate in grazing areas. This conversion of species-rich grassland areas to grazing areas dominated by woody plants has had significant economic costs to the commercial livestock sector. Although reversal of the problem is possible, it is costly.

Using the production approach, it is estimated that the loss of grazing due to bush encroachment in the Otjiwarongo/ Grootfontein area is leading to a loss of production of around 34 000 tonnes of beef each year, worth N$102 million. Although the costs of bush encroachment are high in terms of lost production, the costs of removing it are also high. Most techniques are simply not worthwhile financially. According to recent economics research, the income generated from increased beef production over ten years is unlikely to cover the costs of treatment through either chemical or mechanical means (poisoning, burning, and/ or cutting out stems). Using removed bush for charcoal production offers a possible source of profit because of the extra income earned from charcoal sale. However, this depends on finding markets. Controlling bush through intensive grazing and/ or introduction of wildlife may also be profitable, although it is not necessarily an easy change for farmers to make.

These depressing findings underline the importance of preventing further bush encroachment through improved land management, and of developing natural methods of controlling bush. The move towards mixed game and livestock farming may help to arrest the problem.

-- Caroline Ashley and Julie Richardson, from Quan et al.[12]

Fig. 4.6 *Harpagophytum procumbens*, a valuable medicinal plant. Courtesy NBRI (B. Loutit)

Wildlife

Wildlife as an economic asset is increasing in importance in Namibia. The economic values of wildlife are many, ranging from direct use values (consumptive and non-consumptive tourism, meat, furs and so on) to existence values unrelated to current or future use. Many tourists come to Namibia rather than other safari destinations due to the diversity of species in Etosha National Park and the unique desert habitat. In Namibia, several studies show the economic use value of wildlife based tourism,[17-19] but there are so far no studies showing the value of wildlife diversity *per se*, or the value of individual species of particular economic importance.

The importance of key charismatic and vulnerable species is illustrated by Namibian Government commitment to black rhino *Diceros bicornis* conservation initiatives (Box 2.6). There is a need to carry out a contingent valuation or travel cost survey to gauge the importance of rhino conservation to tourists in Namibia (Box 4.12). Similar surveys have been carried out in other African countries[15,20] and, in some cases, have helped in revising park entry fees and other mechanisms to realise wildlife values from tourists.

Habitat and ecosystem diversity

'Ecosystem diversity relates to the diversity and health of the ecological complexes within which species occur.... Ecological processes govern primary and secondary production, mineralisation of organic matter in the soils and sediments, and storage and transport of minerals and biomass. Efforts to conserve species must therefore also conserve the ecosystem of which they are a part.' [5]

A strong case exists for focusing on conservation of habitat and ecosystem diversity rather than on species and genetic diversity *per se*. Habitat conservation is still critical even if one is only interested in the gene pool or in conservation of a particular species, for several important reasons.

Box 4.10 Devil's claw: the value of wild plants for rural development

Devil's claw or grapple plant (*Harpagophytum*) used to be seen as a problem plant by livestock farmers in Namibia. Now it is regarded as a plant with significant economic value due to its medicinal properties.

Medicinal properties: It is commonly used to treat arthritis, gastrointestinal problems, arteriosclerosis, diabetes, and hepatitis. There is also evidence that it may reduce spasmodic blood pressure.

Contribution to exports: In 1994-95, Namibia exported 5.43 tonnes of dried tubers with an estimated value of N$10.9 million. This is a conservative estimate based on an export price of N$20 per kg. High quality tubers can fetch up to N$30 per kg on the export market, with the final product retailing at N$50-70 per kg.

Contribution to rural incomes: Collectors in rural areas can potentially earn up to N$300 per day in the autumn if the material is of good quality. This assumes that one person can harvest up to 150 kg (fresh weight) or 30 kg (dry weight) of tubers per day. This potential is yet to be realised. Harvesting in communal areas is opportunistic and limited by how much a person can carry.

Future development potential:

- Processing the dried material into powder, tablets and capsules in Namibia would increase the value of the resource and provide employment.
- Moving towards sustainable harvesting: Although the plant is protected under schedule 9 of Ordinance 4, there are currently no annual harvesting quotas. Some collectors believe the resource is decreasing due to over-exploitation. Sustainable methods would require that only secondary tubers be collected to ensure plant survival.
- Improving collection, drying and sorting methods: Significantly higher export prices can be obtained for material that has been correctly dried and sorted.

Source: Marianne Strohbach-Fricke, National Botanical Research Institute

Box 4.11 Economic diversification and drought-coping strategies depend on biological diversity

Namibia is the driest country in sub-Saharan Africa. Very few people in the country can escape the consequences of droughts and the variable distribution of rainfall over time and space. Such variability makes primary production unpredictable. Hence, livestock and cropping enterprises upon which rural Namibians depend for their livelihood are fraught with uncertainty. Farming systems in Namibia are generally marginal even when normal rainfall occurs. Moderate decreases in rainfall can increase livestock mortality rates and result in crop failures.

Strategies involving a variety of activities are used by rural Namibians to increase economic and food security. Indigenous, renewable resources yielding food supplies and sources of income balance uncertainties associated with subsistence agriculture. Freshwater fish are caught and eaten. Fruits and nuts from indigenous trees and shrubs supplement diets and/ or serve as subsistence foods. Local trees, grasses, and termite mounds are used as dwelling construction materials. The value of these resources imputed by their use is, at least traditionally, a natural force which acts to preserve the base of biodiversity on which they depend.

Diversification and versatility may be the keys to stable food supplies and increased income for rural people.

— Chris LaFranchi

First, given the number and diversity of species in habitats such as wetlands, there are often economies of scale in protecting several species at the same time.[9]

Second, there is a great deal of uncertainty about which species are likely to turn out to be the most valuable.[9]

Third, the complexity of interactions and mutual interdependence among species normally makes it necessary to protect many species to ensure the protection of one.[9]

Fourth, there are other benefits from habitat preservation, such as watershed protection, harvesting of non-timber forest products and attraction of recreational and scientific tourism.

This section provides a framework to indicate the range of economic values associated with wildlife habitats in dryland and wetland ecosystems in Namibia.[21] The many *use* and *non-use values* of wildlife and wildlife habitats which can be applied in the context of drylands and wetlands are outlined in Tables 4.1 and 4.2 respectively.

Using official statistics and several important empirical studies, it is possible to capture some of the economic values outlined in Tables 4.1 and 4.2, particularly use values relating to tourism and the wild products in dryland and wetland areas. Unfortunately, there are few economic studies of the value of ecological services and functions (indirect use values), on non-use values, or on the value of ecosystem diversity *per se*. Nonetheless, a recent study on the costs of desertification in Namibia provides important estimates of the economic value of ecological services and functions in semi-arid areas. For wetlands it is possible to identify direct and indirect values in qualitative terms from a recent study of the *oshana* wetland system in northern Namibia.

Direct use values

Tables 4.1 and 4.2 list a range of direct use values relating to dryland-wetland habitats in Namibia. Economic values are available for some of the most important categories, such as *tourism values*, *wildlife products* (sale of live animals, game meat and wildlife products), and *harvesting of other wild products* (medicines, foods, building materials, fuels and so on).

Box 4.12 The costs and benefits of rhino conservation in Namibia

Rhinos are important 'flagships' for conservation, with immense potential to generate funds. To what extent do black rhinos *Diceros bicornis* and white rhinos *Ceratotherium simum* bring costs and benefits to the Namibian economy? Government expenditure on rhino management in three state protected areas (Etosha National Park, Waterberg Plateau Park, Hardap Recreation Resort) and a communal area (the former Damaraland in Erongo and Kunene Regions) was used to estimate the financial costs of rhino conservation. Benefits were not calculated, but can be estimated as below.

The only costs directly attributable to rhino management are the costs of capture and dehorning, a controversial anti-poaching tactic pioneered by Namibia and Zimbabwe in the early 1990s. These amount to about N$1000 per rhino, a small amount compared to the larger fixed costs of rhino conservation. The main fixed cost is the Wildlife Protection Service (WPS), an anti-poaching patrol unit which covers areas used by rhinos and elephants *Loxodonta africana*. WPS staff spend approximately 60% of their time on rhino protection, and National Park ranger staff spend about 20%, amounting to N$1.4 million in the 1994-95 tax year. This figure does not, however, take into account fixed costs of administering the Ministry of Environment and Tourism.

Revenues from rhino conservation were not calculated, but this can be done using two methods. The best approach would be a survey to determine tourists' reasons for visiting Namibia, which would allow an estimate of how much tourism revenue is attributable to rhinos. There is also a small amount of trophy hunting of white rhinos on private land in Namibia, which generates foreign exchange earnings. The global benefits from rhino conservation include consumer surplus to foreign tourists and existence values. Because prices in the National Parks are so low, there is probably a large amount of consumer surplus currently not captured by the Namibian Government. Existence values accruing to people outside Namibia are quite large, as people indicate pleasure just in knowing that rhinos are alive in Africa. Cambridge and London University researchers are estimating these values among potential tourists from the United Kingdom.

Benefits also accrue from direct conservation revenues. There are two Namibian non-governmental organisations which spend considerable energies monitoring and protecting rhinos in the communal areas of the northwest. As virtually all of their funding is from foreign sources and is spent in Namibia, their budgets (which are in excess of N$500 000 for Save the Rhino Trust alone in 1993-94) can also be seen as revenue. All of these values are financial and do not reflect the real resource costs and benefits to Namibia. In order to calculate the economic value of rhinos, financial prices have to be converted to economic prices.

— *Nigel Patching*

Wildlife values: *Direct use values* were introduced in Box 4.4, and in this context refer to the resources and services provided by directly exploiting wildlife. These may include both consumptive (trophy, sport and subsistence hunting, culling, live game dealing) and non-consumptive activities (ecotourism, photo safaris, and education). In Namibia, national tourism statistics and a number of economic studies on wildlife use provide some estimates of these values in different regions of the country.[22-27] Wildlife species may also have important *indirect use values* through key ecological roles. For example, elephants have important ecological roles in African savannas and forests through diversifying ecosystems,dispersing seeds, reducing bushlands, expanding grasslands, and reducing tsetse fly, which is of value to livestock grazing.[28] So far, there are no economic studies of the ecological role of different wildlife species in Namibia.

Finally, there are important *non-use,* or existence values reflecting valuation of these resources as unique assets in themselves, unrelated to their use. There are no studies of the existence value of wildlife in Namibia, although work has been done elsewhere of relevance to this country, such as a study of the use and non-use values of rhinos currently undertaken by the Centre for Social and Economic Research into Global Environments (see Box 4.12).

In the following sections, data from national statistics and regional studies are compiled to provide an overview of the use values of wildlife relating to tourism and wildlife products.

Table 4.1 Economic values of wildlife and wildlands in typical African dryland areas*

Use values			Non-use values
Direct value	Indirect value	Option value	
Harvested products (meat, skins, furs, fish, timber, fruits, fuelwood, grasses, medicines, other products)	Using drylands sustainably can yield a variety of 'ecological' benefits:	Future uses with direct and indirect value	Existence values Cultural heritage
	Retention of soil and prevention of erosion		
Tourism (safari hunting, angling, non-consumptive & aesthetic values)	Shelter and crop protection		
	Land stability		
Genetic materials	Control of water run-off and sedimentation downstream		
Education			
	Climatic regulation (local and regional)		
Human habitat			
	Habitat for wildlife and pollinators (pest control)		

**Adapted from Winpenny[29] and Swanson & Barbier[3]*

***Tourism values*:** Some recent published statistics on tourist arrivals and receipts are shown in Table 4.3. The National Tourism Development Study[25] applies a 32% 'across the board' increase in the 1991 figures to provide an estimate of 282 000 international tourist arrivals in 1992, spending a total of N$394 million in foreign exchange. Of this, about 65% represents holiday expenditures largely on wildlife based tourism. Using these national figures, it was estimated[30] that wildlife based tourism contributed *c.* N$200 million value added to Gross Domestic Product in 1992. The potential is also growing. Tourist numbers are expected to grow at an average rate of 8.5% per annum over the next ten years. This will mean a doubling of tourist numbers by 2002 from about 300 000 per annum to over 600 000, with high spending European tourists increasing five-fold.[25]

Empirical studies at the regional level provide a more detailed picture of actual and potential returns to wildlife based tourism, relative to other land uses in private and communal lands as well as in protected areas. More than 90% of large mammal wildlife is found outside formal conservation areas, largely in agricultural land. About 80% of the larger game species are found on privately owned commercial farms, which comprise around 44% of the total land area in Namibia. Communal areas comprise around 41% of the country, supporting around 9% of the larger game species.[24]

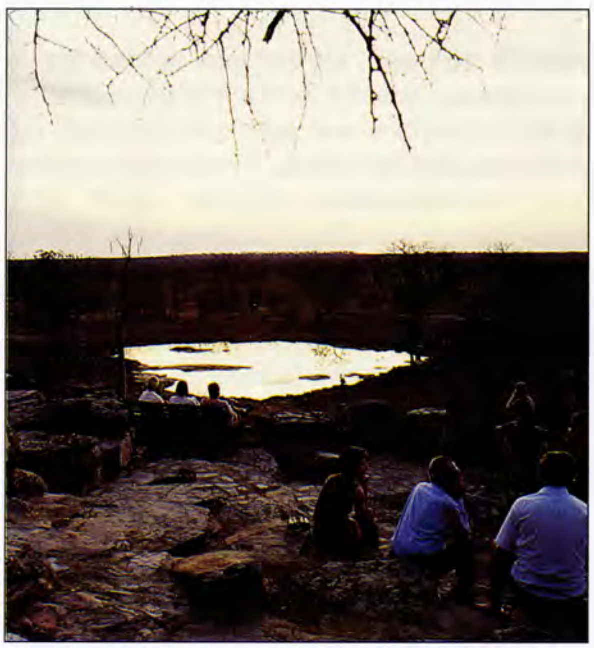

Fig. 4.7 Wildlife-centred tourism is one of Namibia's fastest growing economic sectors. Courtesy P. Tarr

Table 4.2 *Economic values relating to wetlands*

Use values			Non-use values
Direct value	Indirect value	Option value	
Fisheries	Groundwater recharge	Future uses with direct and indirect value	Existence values Cultural heritage
Forest resources (timber, fuelwood)	Flood and flow control		
Widlife products	Shoreline stabilisation/erosion control		
Forage resources	Nutrient retention		
Wild plants (food, medicinal, crafts)	Sediment retention		
Water supply and transport	Water quality maintenance		
	Storm protection/windbreak		
Recreation and tourism (incl. aesthetic values)	Microclimate stabilisation		

Adapted from Winpenny[29] and Swanson & Barbier[3]

Table 4.3 *Estimated tourist receipts by market area, 1991 (1992 prices)**

Market area	Estimated no. of tourist arrivals	Weighted average per head expenditure (N$)	Total tourist receipts (N$ million)	Tourist arrivals %	Tourist receipts %
South Africa	134 000	791	106	62.9	34.3
Other Africa	17 300	1279	22.1	8.1	7.2
Germany	29 600	3331	98.6	13.9	31.9
UK	10 200	1714	17.5	4.8	5.7
Other Europe	16 100	3466	55.8	7.6	18.0
Other countries	5 800	1610	9.3	2.7	3.0
Total	213 000	1452	309.3	100	100

**Source: Ministry of Environment and Tourism (1994)*

Tourism values on commercial land: Aggregate estimates for wildlife populations and species diversity on private lands indicate that the number of animals and biomass has increased by 80% over the period 1972 to 1992. The number of game species has increased by some 44% over the same period. On commercial lands, the overall trend has been towards conversion of land from livestock to wildlife, which has been enhanced by the development of conservancies enabling growth in diversity of species, as well as in overall stocks. The greatest diversity of species is found in the northern savanna private lands.[31] This trend supports both economic theory and empirical evidence in other African countries that secure property rights (to land and wildlife) are essential in any strategy to conserve and encourage long term investment in wildlife habitat.[32-37]

The main economic activities dependent on wildlife in commercial areas include game meat, sale of live animals, selling of recreational hunting opportunities for biltong and trophies and non-consumptive tourism. The results of economic modelling exercises[31] using a conservancy land use system indicate that the economic contributions of pure wildlife ranching for upmarket wildlife viewing can contribute more to the economy than do livestock and wildlife production for consumptive use.[38] These returns can be further enhanced by the move towards larger scale conservancy systems that enable cost sharing across individual ranches.

The study considers the returns to wildlife[39] under three scenarios involving game and livestock related activities. Model 1 refers to a southern mixed sheep and game ranch system involving dorper sheep breeding for lamb production, combined with the consumptive use of three game species for culling, trophy hunting, biltong hunting and own use. Model 2 refers to a typical northern mixed cattle and game ranch system involving beef cattle, combined with the consumptive use of four game species for culling, trophy hunting, biltong hunting and own use. Model 3 refers to northern savanna lands specialising in the production of a diverse community of game for non-consumptive tourism. In models 1 and 2, wildlife supplements livestock production, whereas in model 3, wildlife completely replaces livestock as the primary land use. Estimated net economic returns for these three types of land and wildlife use are given below (Table 4.4).

Table 4.4 shows that the total net value added due to wildlife use on private lands is estimated to be in the region of N$56 million, or N$157 per km^2 in 1992. It also indicates that there is a move towards conversion of land from livestock to wildlife use, motivated not by government policy initiatives nor by conservation concerns, but by the forces of relative economic returns and the chance to diversify farm income in a highly variable, drought-prone environment. As a rough guide to the relative contributions of non-consumptive tourism, consumptive tourism, and other consumptive uses, it is estimated that around 30% of net income (i.e. N$15-20 million or $N47 per sq. km) accrues to non consumptive tourism; a further 10-15% (i.e. N$5-8 million or around N$20 per sq. km) to consumptive tourism, and the remaining 55-60% to other consumptive uses.

These results are optimistic for the much sought after partnership between economic profitability and biodiversity conservation.[40] However, there are three important caveats.

First, to boost tourism revenues some farmers have started to invest not only in wildlife stocks but also in species diversity, including the introduction of species alien to Namibia. It is not yet known what the consequences of this practice might be for the stock levels and diversity of indigenous species. Further research is needed on alien species and genetic pollution.[31]

Second, the figures and analysis presented in this section are based on *economic* and not actual *financial* prices. Economic values will differ from financial values in the presence of price distortions such as sales taxes, livestock subsidies, and foreign exchange distortions. Wildlife viewing may well have an economic advantage over mixed livestock/ game production. However, whether this economic opportunity can be exploited by commercial farmers will depend on the financial incentives facing individual farmers, which in Namibia are distorted by government livestock subsidies and drought aid.

Table 4.4 Estimation of the annual net contribution to the Namibian economy of wildlife use on private lands in 1972 and 1992 (N$, 1994 prices)

Year	1972	1992
Northern, predominantly cattle lands*		
Total net value added due to wildlife use	22 096 600	41 194 060
Net value added by wildlife (per sq. km)	115	214
Southern, predominantly sheep lands**		
Total net value added due to wildlife use	8 552 500	14 922 875
Net value added by wildlife (per sq. km)	52	91
Total private land		
Total net value added due to wildlife use	30 649 100	56 116 935
Net value added by wildlife (per sq. km)	85	157

* Land in the following districts: Tsumeb, Grootfontein, Outjo, Otjiwarongo, Omaruru, Karibib, Okahandja, Windhoek and Gobabis

** Land in the following districts: Mariental, Maltahöhe, Lüderitz, Bethanie, Keetmanshoop and Karasburg

Source: Barnes & de Jager[31]

In the current policy context, this leaves Barnes & de Jager[31] to conclude that there is little financial incentive for farmers with mixed livestock and game production to convert to pure game production, despite the probable economic advantages over mixed production.

Third, overstocking or overutilisation to increase short term income at the expense of land resource losses is perfectly possible in wildlife use, as in livestock ranching, and is already anecdotally reported.

The importance of government policy and other factors in influencing the economic decisions of individual natural resource owners, users and managers will be discussed in more detail in section 4.5.

Tourism values on communal land: According to one economic study,[24] the distribution of wildlife in communal areas represents a share of 40% of species and 10% of the wildlife population in Namibia. Across regions, eastern Caprivi shows the highest number of mammals from relatively diverse and rare species (section 2.9). Okavango has the greatest richness of rare and common species, with relatively good numbers. The former Namaland (Karas Region) has the lowest species richness. The former Owambo (Omusati, Oshana, Oshikoto and Ohangwena Regions) has high mammal richness, but the poorest numbers of all the communal areas.

Wildlife tourism can often supplement livestock farming in communal areas, but the scope for outright substitution is generally limited. Livestock, and cattle in particular, provide not only multiple economic services and products (meat, eggs, skins and furs, milk, blood, dung for fertiliser and fuel, wool, draught power, store of wealth), but have important social and cultural meaning in Namibia. In many respects, the question of whether to farm wildlife in place of livestock means little in societies where 'a man without cattle is not a man.'[24] For this reason, many of the regional studies evaluate wildlife tourism (and other wildlife utilisation activities) in the context of the *net additional benefits* that can be earned from moving towards a mixed game-livestock environment. In a mixed system, there is considerable potential to develop wildlife tourism in communal areas and to distribute these benefits to local communities through the 'conservancy' system which is currently developing.[41] Until now, the benefits of tourism for people in communal areas have been largely restricted to craft sales and employment in lodges and parks.

Table 4.5 shows estimates of the current contribution to national income of tourism activities in four areas of communal land in Namibia. Results show that the total estimated net contribution[42] to Net National Income from wildlife and tourism in the study area is some N$7.6 million per annum, ranging from N$4 to $221 per sq. km.[43] Not surprisingly, results are greatest in areas adjacent to protected areas and prime wildlife viewing areas such as Caprivi.

Table 4.5 shows that the bulk of economic benefits of wildlife tourism accrue to private enterprises and the government, with people in of communal areas largely excluded. As long as the economic benefits of tourism for people in communal areas remain restricted to craft sales and employment in private lodges and parks, tourism cannot be an economic alternative to subsistence farming or a significant option for the unemployed.[27]

What is the future of tourism development in communal areas? Assuming that wildlife stocks and returns to existing activities remain constant,[45] there is potential for the net benefits of wildlife and tourism in the combined study area to more than double.[19] There is also potential for earnings of local residents (from wages, self-employment, community enterprises, joint ventures and concession fees) to more than triple.[18] This assumes that tourism development in Namibia is fully exploited and that community based resource use initiatives are successfully implemented.[46] Only if local benefits increase to provide incentives for wildlife conservation and investment in tourism as a land use, is its economic potential likely to be realised.

Of the growth in wildlife enterprises, non-consumptive tourism is likely to take the lion's share, especially in high potential areas. The potential for further development of consumptive style tourism in these areas is constrained by existing hunting and fishing quotas which may already reflect annual sustainable yields. Non-consumptive tourism, on the other hand, is not quite as dependent on these ecological constraints and is more dependent on scenery and habitat or species diversity, rather than stock levels of species *per se*. Box 4.13 shows how the promotion of community based wildlife tourism can contribute to both diversifying economic and ecological risks in communal areas.

Tourism values in protected areas: Data on wildlife numbers in protected areas are incomplete, but suggest steady or slightly increasing numbers.[27] Namibian conservation areas have traditionally been known for the diversity of species rather than absolute numbers. Although changes are afoot, until now the conservation ethic in protected areas has been an elitist one, in which wildlife and their habitats were protected for the benefit of foreign tourists, with the vast majority of Namibians being excluded from related benefits. This ethic is now rapidly changing with the establishment of buffer zones adjacent to conservation areas, the development of wildlife conservancies, and community based wildlife utilisation projects in communal areas.[47]

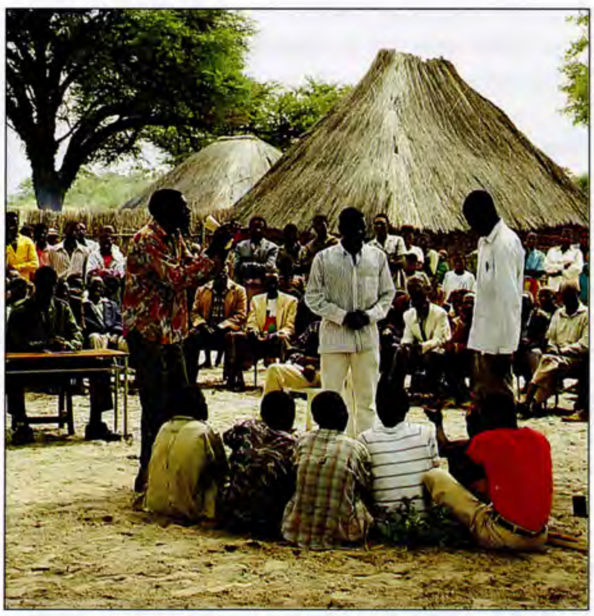

Fig. 4.8 Communities can negotiate partnerships with private sector and government wildlife and tourism interests. Courtesy P Tarr

Table 4.5 Current contribution to national income from tourism and related activities in four areas of communal land, 1994 (in N$)

Area	Caprivi	Bushmanland*	Opuwo**	Damaraland***
Extent (sq. km)	18 800	17 877	61 585	58 105
Non-consumptive tourism:				
• Community run	32 700	17 400	20 100	41 775
• Private sector run	1 897 600	0	1 312 850	1 071 300
• Government run	78 850	0	63 500	303 750
Consumptive tourism:				
• Safari hunting	1 548 120	0	0	333 680
• Angling	420 900	0	0	105 225
Crafts	171 901	59 589	70 331	48 987
Total	4 150 071	76 989	1 466 781	1 904 717
Total per sq. km	221	4	24	33

* *former Bushmanland (Tsumkwe District, eastern Otjozondjupa Region north of 22°S)*

** *Opuwo District in former Kaokoland, now northern Kunene Region*

*** *former Damaraland (all of Khorixas District in Kunene Region, western communal land in Erongo Region, and the West Coast Recreation Area)*

Box 4.13 Promoting tourism to conserve biodiversity and diversify risks

Tourism cannot provide maize, meat and milk to rural people, but it can complement agricultural livelihoods by providing cash income and diluting economic risk. Tourism is relatively independent of drought. Tourism revenues are certainly subject to risk and fluctuation, but this is due more to international markets than to rainfall. In this way, tourism can diversify economic risk in rural communities by acting as a drought buffer. Combining game and livestock further increases the land's carrying capacity and can reduce degradation, due to the different habits of livestock and game.

Tourism depends on the maintenance of species and habitat diversity. This suggests that a strategy of promoting community-based non-consumptive tourism is best able to achieve both community development and biodiversity conservation goals. However, for a specific region, leasing or exploiting hunting rights could be the most profitable option, and one most compatible with continued livestock grazing. This may encourage conservation of wildlife habitats *per se*, but not necessarily their diversity. Non-consumptive tourism is likely to expand internationally and in Namibia, whereas consumptive use may eventually be constrained by pressures from northern environmentalists.[22] The combination of options most likely to give people long-term incentives to regard wildlife as viable complementary land uses should be promoted.

—Based on Ashley[18] and Ashley et al.[27]

There is very little information on the economic contribution and development potential of state controlled protected areas. In 1991, the government derived N$20.3 million in revenue from the operation of public accommodation facilities in national parks, and N$2.3 million from park entrance fees.[25]

The fees for entrance and public tourism facilities are set at a low level and bear no relation to the real economic value of the services. The Government actually runs accommodation facilities in national parks and protected areas at a loss, representing a significant annual subsidy to protected areas. The underpricing of public tourism services is likely to undercut tourism initiatives in the communal and private sectors. However, the parks are the main attraction for international tourists who sustain an industry worth over N$200 million per year to the national economy. In addition to the direct economic benefits of tourism, protected areas clearly generate a wide range of other benefits: education, research, maintenance of rare and endangered species and so on.

In spite of the institutional constraints, there still exists significant potential to increase the value added from tourism by additional government investment within the sector. The rate of return on state investment in the environment and tourism sector is estimated at about 42% over a 12-year period.[30] Many of these benefits will accrue to the private tourism sector and not directly to the Ministry of Environment and Tourism. This makes it difficult for the MET to increase its investment rate, particularly under current budgetary arrangements which return all environment related revenues to central government, rather than directly to MET.

The available information on national parks provides little real insight into the net economic benefits of these areas. One way to estimate the economic value of national parks would be to calculate the opportunity costs of the land in alternative uses, such as private or community tourism or agriculture. This method has been used to estimate the economic value of Kruger National Park in South Africa[48] and of biodiversity in Kenya.[49] To do this in Namibia, we need further research on the economic value of land in alternative uses.

Wildlife products: Other wildlife uses (unrelated to tourism) include live capture and sale, consumption for own use and wages in kind, game meat, and wildlife products such as furs, skins, and bones. Permits governing consumptive use of wildlife in Namibia are issued with reference to estimates of sustainable yields of wildlife stocks. This regulation of wildlife consumption seems effective in commercial lands, but less so in communal areas. Table 4.6 summarises recent studies which estimate the value of consumptive use (excluding tourism) of wildlife in Namibia.

The best estimates[50] of the economic contribution of wildlife consumption (excluding tourism) in Namibia are those of Barnes[19] and Barnes & de Jager.[31] Using these estimates, the net economic contribution of consumptive use of wildlife (excluding tourism) in commercial areas is in the range of N$85 to N$95 per km^2 representing *c.* N$30-34 million per year.

Harvesting wild products

Wildlife habitats in Namibia provide a rich source of wild products which are harvested either for sale or own use. There is a growing body of information relating to the economic value of this resource in different areas in Namibia. At the **national level**, the first Household Income and Expenditure Survey (HIES) of 1993-94[51] provides relatively detailed information about household consumption of a range of marketed and non-marketed goods in different regions in Namibia. Subsistence consumption in Namibia, as in other African countries, is relatively important. Approximately 29% of household consumption at a national level comes from products produced by the household, or received in kind with no cash transaction.[51] Of this 29%, 8% is for food, 19% for rent in kind,[52] and 2% for other subsistence goods. In rural areas, the importance of subsistence consumption is much higher, representing approximately 38% of total consumption in these areas. The monetary values of subsistence or non-traded products were estimated with reference to the market values of similar or substitute products in the local area.[51]

Many of these subsistence products are cultivated foods such as crops and livestock. However, the harvesting of wild products also represents a significant proportion of subsistence consumption. Cultivated foods (bread and cereals, meat, vegetables) represent approximately 67% of total subsistence food consumption, whereas wild foods (fish, fruit and nuts, other) represent 33%. Therefore, 33% of total household consumption comes from wild foods.[51]

Although the majority of wild products are non-marketed, some products are traded for cash. Table 4.7 gives more detailed information on the estimated monetary value of selected wild products (marketed and non-marketed[53]) of special importance to Namibian households. According to the HIES estimates, the most valuable wild products are fish, game, home-made drinks and baskets. There is great variation in the relative importance of wild products to households across regions: Omusati, Ohangwena, Oshikoto, and Okavango are the most dependent regions, and Hardap, Erongo and Karas are the least.

A note of caution must be added when intepreting these figures. The data and results are preliminary; although the survey was the most complete analysis of household income and expenditure so far in Namibia, it did not collect data on all wild products of value to householders.[54] For this level of analysis, it is necessary to undertake more detailed and targeted surveys at the local level. The Directorate of Environmental Affairs and WWF/ LIFE Programme recently undertook two studies in communal areas of Namibia to assess the economic value of wild products.[19,55]

Fig. 4.9 Wild foods are extremely important to rural households in northern Namibia.
Courtesy HH Kolberg

Table 4.6 Value of consumptive use of wildlife (excluding tourism) in N$ million per annum

National		
Gross income from wildlife consumption (excl. tourism)		10.74[a]
Private lands		
Net value added from wildlife consumption (excl. tourism)		30-34[b]
Communal lands		
Kunene	: Net revenue from live capture and cropping	0.83[c]
Caprivi	: Net revenue from live capture and cropping	0.47[c]
Caprivi, Kunene, Damaraland & Bushmanland		
	Net value added from community hunting	0.10[d]

Sources: [a] Du Plessis[56] using 1991 values; [b] Barnes & de Jager[31] estimated economic potential; [c] Yaron et al.[24] [d] Barnes[19]

Direct and indirect use values of ecosystem functions and services

The costs of desertification

A well functioning dryland ecosystem provides a range of ecosystem services and functions which support economic activity. Some of these functions and services, and the direct products they support, are regarded as the values or benefits of these ecosystems, and are listed in Table 4.8. Once the ecosystem is degraded, these services and functions are undermined. The subsequent loss in economic value can be regarded as the economic losses or costs of degradation of biological resources and erosion of biodiversity. These 'economic costs' can be thought of as the values lost or foregone, and must be distinguished from the actual costs of biodiversity conservation discussed in the next section.

Table 4.7 Total annual consumption of selected wild products (cash and in kind) by region, 1993-94 (in N$ thousands)

ITEM/REGION	Caprivi	Erongo	Hardap	Karas	Khomas	Kunene	Ohang	Okava	Omahe	Omus	Oshana	Oshik	Otjozo	NAMIBIA	RURAL	URBAN
FOOD																
Game	122.98	490.24	557.01	2773.5	439.40	30.98	14.49	317.44	555.08	10.54	9.53	17.62	1443.77	6783	6242	541
Mopane worms	76.75	7.52	16.60	30.16	138.48	3.71	87.01	18.93	0	79.45	70.21	3.08	0	532	299	233
Fresh fish	2050.70	950.66	336.35	348.25	1514.47	43.88	804.67	2660.52	14.15	2040.3	2562.13	206.67	189.26	13722	8609	5113
Dried fish	153.53	0	34.79	0	49.45											
Omaze ongombe*	0	0.35	0.02	0	0.34	3.46	0.20	0.13	0.44	0.31	0.04	0.24	2.16	8	7	1
Eengeshu**	0	0	0	0	0	0	2.93	1.34	0	2.27	1.38	0	0	8	8	0
Oombe***	1032.44	1.40	0	0	0.67	12.34	176.96	47.36	0.51	163.78	107.28	401.69	0	1994	1887	58
Omahutu****	137.42	2.10	0	0	2.87	0	159.62	529.49	0	151.35	89.16	16.88	0	1089	1042	46
Beverages	630.80	103.96	13.96	8.76	695.91	187.75	3190.68	3102.53	59.86	3531.2	1681.18	1808.18	408.76	15423	13749	1675
CLOTHING																
Traditional wear	15.68	0	0	0	0	0	9.20	0	0	105.90	0.50	0	1.47	133	32	1
ENERGY																
Fuelwood	6.43	19.87	2.63	1.83	3.44	6.06	0.41	34.42	2.60	4.24	11.61	12.68	11.70	118	93	25
HOME TOOLS																
Baskets	193.36	130.28	71.04	95.05	724.69	540.98	357.17	184.37	43.47	654.39	640.11	92.63	296.89	4024	2828	1196
Pounding sticks	21.15	26.01	0	0	154.24	0	162.62	8.44	0	86.29	160.04	23.97	0	643	418	224
Brushes	3.26	112.06	85.31	61.99	289.25	37.47	24.35	35.91	38.74	39.47	23.66	12.44	70.40	834	214	620

**Omaze ongombe* is a rich brownish butterfat, to be cooked together with porridge or other foods. ***Eengeshu* is the berry of the bush *Grewia flava*. ****Oombe* is a berry (probably *Berchemia discolor*, also called *ovume*). *****Omahutu* is the husk of millet (*omahangu*), added as bran to porridge.

Source: The 1993-94 Namibia Household Income and Expenditure Survey (Central Statistics Office, 1995)

What component of the returns to crops, livestock and other economic activities is due to ecological services provided by the sustainable functioning of dryland ecosystems? A recent study in Namibia[12] attempts to capture some of these values, by estimating the economic costs incurred when these ecological services and functions are degraded. The avoided costs (*damage costs avoided* or *replacement cost* valuation methods) of desertification can be used as an index of the direct and indirect use values of sustainably managed dryland ecosystems.

Economic costs of desertification in communal areas: Case studies were carried out in two communal areas, Uukwaluudhi in the north and Gibeon in the south. Box 4.14 indicates the types of costs suffered by a typical household in Uukwaluudhi from desertification, including costs of deforestation and rangeland and pasture degradation. The study used a range of environmental valuation approaches including 'prices of commercial substitutes' and the 'replacement cost' approaches.

Based on the estimates in Uukwaluudhi, an aggregate figure for the total costs of desertification in northern communal areas was estimated. This aggregate figure indicates that total subsistence losses in terms of reduced output and resource availability due to long term degradation are over N$110 million per annum in northern communal areas.[12]

Economic costs of desertification in commercial areas: Case studies were carried out in two commercial farming areas: Otjiwarango/ Grootfontein in the north, and Keetmanshoop in the south. The analysis in the commercial areas was more straightforward, with the primary economic costs being reductions in livestock productivity due to bush encroachment in the northern beef ranching areas. Box 4.9 indicated that this phenomenon can be at least partly explained in terms of losses in grassland diversity. The estimated costs are substantial:

'...the primary economic cost imposed by desertification results from bush encroachment in the northern beef ranching areas. This is estimated to affect 8-10 million ha, and to reduce production by up to 30%, or 34 000 tonnes of beef per year. This in turn is estimated to have resulted in annual losses worth approximately N$100 million, over the past 40-50 years; the annual loss is considerably higher at today's prices.'[12]

Direct and indirect use values of wetlands

The *oshanas* are a system of shallow seasonal rivers and pans in southern Angola and northern Namibia (Omusati, Oshana, Oshikoto and Ohangwena Regions). Floodwaters start several hundred kilometres north of the international border in Angola and flow south into Namibia to end in Etosha Pan. The *oshanas* are a major ecological unit with great economic value, supporting one of the most densely populated areas in Namibia.

Economic data on the use and non-use values of the *oshana* system are sparse. Although the use value of various products hasbeen estimated, no valuation has been done of the use and non-use values of this important system as a whole. In the absence of monetary values, it is helpful to identify some of the direct and indirect use values of the *oshana* system and indicate the types of valuation methods that could capture these values in economic terms. Box 4.15 illustrates how this could be done.

Fig. 4.10 Wetlands are critical resources for people in arid Namibia. Courtesy S. Bethune

Box 4.14 *Some indicative monetised costs of desertification for an Uukwaluudhi household*

	N$ per year
Lost fuelwood supply Cost of commercially purchased fuelwood 1 bundle/day @ N$2 per bundle	720
Lost fencing materials Cost of purchasing wire and poles for replacing 1/5 of fence around mahango field	400 -640
Lost livestock due to lack of access to grazing, exacerbation of drought. Replacement cost of 2 cattle, 3 goats	480
Lost milk output due to lost cattle 50% of loss of 6 months output of small milking herd Costs of purchasing substitute protein plus loss of income from sale of surplus	300 -600
Reduced millet production due to shortage of cattle dung. Purchase of commercial substitute food for 1.5 months	165
Total notional monetisable costs per annum	$ 2 065 - 2 565

Notes:
1. Non-monetisable economic costs are excluded.
2. Building and house/ fence maintenance costs have not been calculated and are excluded, although in principle are monetisable.
3. This assumes that 3 months' millet requirements and 6 months' milk output is lost, of which 50% is attributable to long-term degradation rather than drought. In practice, these two sets of losses are inseparable and the costs faced by households would be higher.
4. These are indicators of the *values* of lost resources, rather than estimates of *actual expenditures* by people, most of whom could never afford to purchase commercial substitutes on this scale. In practice, people cope by working harder, switching to alternative resources, or more often, making do with less.

Source: Quan et al.[1]

Box 4.15 Economic values relating to the oshanas

Direct use values:

Wild plants are collected for many uses, including food (marula, *embe*, spinach, water lilies, aloe, palm tree fruits), medicine (*Diospyros lycioides, Albizia anthelmintica, Harpagophytum*), building and household materials (palm leaves, roots, bark). **Building materials** in the *oshana* area come from wood, palm leaves, grasses and soil. **Fish** are an important part of the diet in the *oshana* area. There are a few permanent waterbodies that provide fish all year, but the greatest volumes to be had are during large *efundja* seasonal floods. It is estimated that 250 tons of fish can be caught along the road between Oshakati and Ondangwa in an *efundja* lasting two months. Fuelwood is the main source of **energy**, with about 90% of households using wood for cooking, lighting and heating. Other biological fuels include dry *omahangu* (millet) plants, palm leaf stems and palm fruits. And of course, the *oshanas* also supply **water for household use and water transport.** As all these products become increasingly scarce, the people dependent on them have two options. They can either travel greater distances to collect these products, or they can purchase substitutes in the marketplace (*e.g.* paraffin for fuelwood; wire and poles for collected fencing materials). The economic value of these products can thus be estimated using the price of *marketed substitutes*, or the value of labour time spent in collection — *the travel cost approach* or *opportunity cost of labour.*

Indirect use values:

These relate to the important ecological functions that support economic activities. Two of the most essential ecological functions of the *oshana* system are **groundwater recharge and flood control.** Degradation of wetland ecosystems undermines these functions, causing damage to infrastructure, livestock and crops through flooding, and reducing the quality and quantity of groundwater. Various valuation methods could be used, including *estimating the damage costs of flooding avoided,* and *flood prevention expenditures.* These functions are already being threatened by infrastructural developments in the area. Construction of a canal and tarred road between Ruacana and Oshakati has blocked the natural water flow in the *oshanas.* South of the canal, there is now less water available for groundwater recharge and vegetation growth.

The *oshana* system provides an important service by filtering toxins and sediments. This **water quality maintenance** function is crucial to the health of the people, livestock, and wildlife that rely on it. It may be possible to estimate the *health damage costs avoided.* Alternatively, the value of water quality maintenance can be estimated by the *costs of replacing this function* with water treatment facilities.

Finally, the overall hydrological, nutrient, and energy cycles of the *oshana* system may help stabilise local climatic conditions, particularly rainfall and temperature, with resulting positive effects on agricultural or resource based activities. It is generally difficult to identify these complex ecological and economic relationships. Yet if agricultural productivity can be linked to changes in local climatic conditions due to watershed degradation, then the *productivity approach* could be used.

Adapted from Barbier[57] *based on information from Desert Research Foundation of Namibia*[58]

Summary of the economic benefits of biodiversity conservation in Namibia

Genetic and species diversity

There are many examples of how genetic and species diversity can affect economic values in Namibia, but few studies have put monetary estimates on these values. Economic values of genetic and species diversity largely reflect the value of reducing ecological and economic uncertainty.

The costs of uncertainty can be particularly catastrophic in ecologically fragile environments, and in poor rural communities in which a single crop failure could threaten survival. In these types of environments, socio-economic systems and technologies have evolved to diversify risk in accordance with local environmental conditions. For example, many pastoral farmers spread economic risks by investing in 'livestock species diversity,' where different kinds of animals have different nutritional needs and their products provide multiple uses. On the other hand, commercial farmers in Namibia focus on maximising productivity through specialisation. Nonetheless, commercial sectors are affected by genetic and species diversity, as reflected in their higher management costs and lower natural resilience. The National Botanical Research Institute is gathering data to show how genetic material from wild plants can enhance Namibian agricultural productivity.

Ecosystem diversity

This report compiles the economic data currently available on the value of biological resources and biodiversity in semi-arid lands and wetlands in Namibia. The most important results are in Table 4.8.

Interpreting the values: Great care should be exercised in interpreting the values in Table 4.8. First, the values cannot be aggregated to derive an estimate of the total economic value of biological resources and biodiversity in Namibia. This is because there are inevitable trade-offs between the different components of total economic value. Also, some estimates relate to financial and others to economic values. Second, values in Table 4.8 tell us nothing about *opportunity costs.* For example, promotion of wildlife based tourism will reap economic returns, but these need to be compared to the economic benefits which could have been realised had the land and resources been directed to other activities such as livestock or arable farming. Third, economic information has been compiled largely by district or region. In most cases, these boundaries do not correspond to ecological zones, so there is a mismatch between economic and ecological information. Finally, values are far from complete. There are large gaps in our knowledge of the value of biological resources and biodiversity which are not revealed in Table 4.8. Lacking a more complete picture, we might focus on those values which have been estimated and ignore those which have not, even though the latter may be more significant.

Gaps in our knowledge: This section has revealed that there is relatively detailed information on use values of dryland-wetland ecosystems (including estimates of the use value of wildlife based tourism, wildlife products, and wild foods), but a large gap in our knowlege of the economic value of ecosystem functions. Nonetheless, the study by Quan *et al.*[12] shows the indirect value derived from protective and supportive ecosystem functions, in terms of costs to livestock, woodlands and arable farming when these functions are degraded. In addition, there were no data on non-use values, such as existence values or the international value attributed to Namibian biodiversity. The global nature of the value of biodiversity means that many benefits of biodiversity conservation in Namibia will accrue to other nations. Global values may be very significant, but are at present unknown. Finally, studies tend to focus on the use values of ecosystem products, and not on the value of diversity *per se.*

Table 4.8 Some summary estimates of economic values of dryland - wetland ecosystems in Namibia

Economic value	Period	Benefit estimate	National value (N$ million)	Value per sq. km. (N$)	Source
Direct use values					
Tourism:					
Commercial	1994	Net economic	56	157	(1)
Communal	1996	value added	6.33	4-221 (actual)	(2)
				56-375 (potential)	(2)
Wildlife products					
Commercial	1994	Net economic	30-34	85-95	(1)
Communal	1996	value added	3.26	16	(2)
Other wild products					
Wild foods	1993-94	Net financial	41		(3)
Freshwater fish	1996	value added	1.58		
Woodland /forest products	1996		336.08	480	
Values of diversity, *e.g.* insurance		not estimated			
Indirect use values					
Commercial (livestock)	1994	Damaged costs avoided of	110		(4)
Communal (wood, livestock, crops)	1994	desertification*	100		(4)
Other ecol. functions, *e.g.* water cycles		not estimated			

* A sustainably managed dryland ecosystem can support a range of economically valuable products including wood, livestock, and crops.

Sources: (1) Barnes & de Jager[31] (2) Barnes[19] (3) CSO[51] (4) Quan et al.[12]

Courtesy HH Kolberg

Future directions: maintaining diversity through wildlife use

This chapter shows that there are significant values attached to wildlife use strategies such as consumptive and non-consumptive tourism and wildlife related products. Tourism has also been targeted as a key growth sector in future national economic development. Box 4.16 considers to what extent the various uses of wildlife are consistent with conservation of species and habitat diversity.

Valuable to whom?

The estimation of the economic values of biological resources and biodiversity is an important component in the development of a national biodiversity conservation strategy. Yet these values do not tell us *who benefits and who loses out from biodiversity conservation.* Developing policies towards biodiversity conservation need to consider the different stakeholders in existing and proposed management systems. In many cases there will be a difference between those who reap the benefits of conservation and those who bear the costs. For example, the existence values attributed to species conservation may largely accrue to developed nations, whereas the costs of species conservation (in terms of foregone agricultural output) will accrue to the national economy. Unless the benefits of biodiversity conservation can be realised in monetary terms and directed towards those who currently bear the costs, there will be little scope for changing environmentally damaging activities.

Which groups hold stakes in the benefits of biodiversity and biological resources? This section distinguishes stakeholders at the household, national and global levels.

Benefits to the household

Householders in Namibia, particularly in rural areas, receive a wide range of monetary and non-monetary benefits from biological resources and biodiversity. For example, Oshiwambo-speaking farmers have developed a diverse cropping system to reduce economic and ecological risk (Box 4.8). In other examples, biological resources themselves provide important income generating opportunities, for example from community based tourism ventures and the collection of wild products. Even within the household, different environmental resources will have different value to different members of the household. Box 4.17 indicates how the value of wild products to rural communities is distributed between men, women and children.

A National Biodiversity Strategy in Namibia must take into account the monetary and non-monetary values of biological resources and biodiversity. It must also reflect the critical role that these can play in income generation and risk aversion strategies, both within and between households. As seen from studies in northern Namibia, it is not enough to demonstrate the economic value of conservation to communities: it is necessary to establish a link between those who bear the costs of conservation and those who reap its benefits. This may mean changing resource rights, such as access to wildlife in communal areas, and developing innovative means of returning revenues and management control to communities. It also requires publicising the link between local incomes and conservation.[18]

Fig. 4.11 Rural communities can develop mechanisms to distribute direct benefits from wildlife conservation, via tourism and hunting. Courtesy P Tarr

Box 4.16 Wildlife utilisation and biodiversity conservation: a partnership in heaven or hell? Some thoughts for Namibia

Wildlife utilisation has been promoted as a way to marry biodiversity conservation and economic development objectives. Is this a long term partnership, or are these aims mutually incompatible? In Namibia there are encouraging signs, but also important caveats and reservations. Wildlife utilisation requires making wildlife 'pay its way' to prevent the conversion of habitat to other activities. In the past, although wildlife had a perceived value, there were few mechanisms for individuals to realise this value in hard financial terms. The development of wildlife utilisation strategies has expanded the range ofwildlife-associated activities that can yield real financial returns. In Namibia, these include photo-tourism, safari hunting, and the sale of game meats and products. Some of the returns from these activities have been presented in this chapter. But are these various activities consistent with the conservation of species and habitat diversity?

Wildlife use strategies have increased the land allocated to wildlife habitat in Namibia. This is especially true of commercial agricultural lands, where the stocks and diversity of wildlife have increased significantly over the last 20 years.[31] Nonetheless, among these different wildlife uses, some are more compatible with biodiversity conservation than others. At the top of the list must come non-consumptive tourism such as ecotourism and photo-safaris. These activities are economically lucrative and a growing sector, but are also founded on maintaining diversity in species and habitats. Consumptive uses may also be economically attractive in some areas in Namibia, and will discourage further conversion of wildlife habitats to alternative uses. However, in these areas the emphasis will be on encouraging stock levels of popularly hunted species. Specialisation in a few species can potentially disrupt the functioning of dryland ecosystems and cause conflict between consumptive wildlife use and biodiversity conservation. Such conflict may be exacerbated by introducing alien wildlife species into Namibia for consumptive and non-consumptive use. Further study is needed to establish the implications for the population levels and diversity of indigenous species.

In communal areas, wildlife habitat has been under considerable theat. Recent legislation that focuses on community-based wildlife utilisation, in order to devolve wildlife use rights and responsibilities, should do much to reverse this trend.

Community-based wildlife use initiatives provide an important link between those who bear the costs of wildlife and those who receive the benefits. Under previous legislation, this link had been severed. Many people in communal areas bear significant costs of sharing wildlife habitat in terms of damage to crops, livestock, infrastructure, and threats to personal security. At the same time, they have largely been excluded from enjoying the benefits. The move towards community-based resource use will encourage long term vested interests in maintaining wildlife and wildlife habitats for current and future use.

Finally, wildlife utilisation, as the term suggests, is about making economic use of wildlife. But there are limitations of this approach for biodiversity conservation:

> *'The most important limitation is its inapplicability to the facets of wildlands that are not appropriable: ecosystem services, genetic information, even the existence rights of other species.'[3]*

This chapter has tried to show how some indirect use and non-use values may be appropriated. Yet in many cases, these intangible benefits may remain under threat, even under a well-designed wildlife utilisation policy.

Benefits to the national economy

The economies of most developing countries depend heavily on natural resources, and Namibia is no exception. Natural resources contribute to the national economy by generating employment, foreign exchange, and overall government revenue.

It is now widely accepted that the current way of calculating national income and Gross Domestic Product (GDP) is flawed. It fails to include the value of many environmental goods and services, as well as the value of natural resource stocks such as woodlands and wildlife. Directorate of Environmental Affairs (DEA) economists are developing a system of Natural Resource Accounts (Box 1.5) which will better reflect the real status of the Namibian economy, including monetary and non-monetary contributions of environment-related sectors to GDP.

Until this is done, the only Namibian data on the contribution of natural resource related sectors to the national economy come from sectoral estimates of GDP (Fig. 4.2). Table 4.9 shows the contribution of different sectors in Namibia to GDP in 1995, and the expected annual growth in each to 2000.

Table 4.9 shows that the main natural resource related sectors are agriculture, fishing, and hotels and restaurants (as an index of wildlife based tourism), contributing 12.6%, 3.4% and 2.1% to GDP respectively. These sectors — fishing and hotels and restaurants in particular — are targeted for future growth in excess of the annual average of 5% per annum.

Box 4.17 The value of wild products to men and women in rural Namibian households

How are wild resources distributed within households? Understanding how men and women access and use the resources is the key to answering this question. The following example from Nabane[59] highlights typical gender conflict, complementarity, and control involved with using resources from mopane trees, *Colophospermum mopane.*

Joint interviews in eastern Caprivi, supplemented by interviews with women only, show that the same resource can be used by men and women for different reasons. Findings indicate which mopane resources are controlled by men and which by women, and which gender works to harvest them. The mopane tree is a prime example because it provides resources important to traditional roles of both men and women.

Mopane caterpillars, firewood, roots containing a diarrhoea medicine, fibre, and a flu medicine contained in leaves were identified as resources predominantly harvested and allocated by women. Carving wood and construction poles are generally under the control of men. Potential and actual conflict over mopane use rights between men and women was revealed when participants were asked to sketch the tree identifying those portions of it they use. The exercise clearly demonstrated that when resource allocation decisions are made, it is critical to involve both women and men.

— Chris LaFranchi

Table 4.9 and NDP 1 demonstrate that natural resource sectors will be the engine of economic growth in Namibia. It is therefore absolutely critical that the natural resource stocks on which this growth depends are not eroded in the process.

Natural resource-based activities contribute heavily to national income, yet resource degradation leads to a range of costs and trends which jeopardise the stability of the economy. For example, Box 4.18 summarises the key economic implications of desertification in Namibia.

Employment generation

There is no good information on the actual or potential contribution of natural resource related sectors in generating employment. Yet many of these sectors, including the wildlife tourism industry, are labour intensive.

Recent estimates suggest that 20 000 jobs are generated either directly or indirectly by the tourism industry,[25] accounting for an estimated 15% of private sector employment.

Foreign exchange generation

Returns from the mining industry still dominate foreign exchange receipts in Namibia, but wildlife related goods and services are recognised as an export sector with considerable growth potential. Table 4.10 shows the 1995 contribution of wildlife related products to exports of goods and services.

According to Table 4.10, the export of game and related products, fish and travel services[60] currently accounts for 1.7%, 4.0% and 14.7 % of total exports respectively. The export value of the foreign tourism sector is of particular importance, and exceeds the export value of either agricultural products or of meat and meat products.

Table 4.9 Gross domestic product (GDP) by sector

Sector	Contribution to GDP in 1995 (%)	Projected annual average real growth (%)
Agriculture:		
Commercial	9.4	4
Subsistence	3.2	9
Fishing	3.4	12
Diamond mining	8.0	2
Other mining	3.1	5
Fish processing	2.8	21
Meat processing	1.2	5
Other manufacturing	3.5	14
Electricity & water	1.8	4
Construction	3.1	7
Trade	8.6	5
Hotels & restaurants	2.1	14
Transport & communications	4.7	5
Finance & business	12.3	4
Social services	1.4	4
General government	28.6	1
Other producers	2.8	4
Total GDP growth		5

Source: NDP1[1] and National Accounts

Box 4.18 Some probable macroeconomic implications of desertification in Namibia

Losses in commercial beef production worth N$102 million per year plus additional losses for small stock production.

Losses in subsistence production and livestock capital worth N$110 million per year in communal areas.

Declining food security and greater dependence on food imports, with reduced agricultural marketing opportunities.

Depletion of timber stocks and increasing fuelwood scarcity: Annual losses of timber stands may be worth up to N$720 million.

Increasing unemployment due to declining profitability in the commercial agricultural sector, and shrinking size of secondary sectors such as meat processing.

Loss in export earnings from beef over the last 30 years may be up to N$500 million.

Declining government revenues: Losses in income tax revenues due to declining livestock productivity are estimated to be in the region of N$12.7 million per annum.

Increased government expenditure on subsidies, drought relief support, employment and welfare programmes.

Source: Quan et al.[12]

Table 4.10 Exports of goods and services, 1995 (percent contribution to total exports)

Product group	% contribution
Live animals and products	9.8
Cattle	4.9
Sheep and goats	3.2
Game, ostriches and products	0.4
Karakul wool and pelts	0.2
Other hides and skins	1.1
Fish and other aquatic products	4.0
Ores and minerals, electricity	44.2
Manufactured products	26.1
Travel	14.7
Other services	1.3

Source: National Accounts, 1995

Contribution to government revenue

One effective way to convince national and local governments to divert more resources to conservation is to show how these investments generate real returns in the form of government revenues. This exercise has not been attempted for the economy as a whole, but initial estimates have been made for the wildlife sector.[30] In 1993, tourism alone generated an estimated N$160 million in government revenue, representing over 5% of total government revenue. This figure was in the order of three times the total budget of the Ministry of Environment and Tourism. Investment by the Government of Namibia in wildlife and tourism sectors could easily generate an increase in revenue to pay back the initial investment after a start period of about five years, according to recent estimates of the potential value added of government investment in environmental capital.[30]

Benefits to the global economy

Recent surveys of the distribution of species wealth, in terms of stocks and diversity, reveal important patterns. One of the most striking features is the extent to which species wealth is located in developing countries, whereas much of the value of biodiversity flows to the developed world.[61] Benefits from genetically engineered products accrue mainly to developed countries, for example, though most of these genes originate in the developing world.[3]

The simple message is that if the international community wishes to preserve biological diversity, it must begin to pay for previously freely-exploited component resources. Development efforts in the South will continue to put intense pressure on a dwindling global supply of wildlife habitats and biodiversity. This will mean developing mechanisms for global compensation and transfer.

4.4 Costs of conserving biological resources and biodiversity

Section 4.3 outlined some of the economic values attached to genetic, species and ecosystem diversity in Namibia, and the potential economic losses due to biodiversity erosion. These values are not very informative on their own: they must be compared to the costs of biodiversity conservation. A range of different types of costs needs to be considered:

- **direct costs** include all private, NGO and government expenditures on conservation activities. Wildlife tourism, for example, incurs capital costs (buildings, vehicles, roads, waterholes) and running costs (labour, electricity, water, petrol). In section 4.3, economic values were shown mainly in terms of 'net benefits' or 'net value added.' This means that the private costs have already been deducted where this information was available. The section below outlines government and NGO contributions to conservation expenditures.

- **opportunity costs** are the value of net benefits foregone as a result of the decision to conserve biological resources and biodiversity. They may include net economic benefits which could be achieved from converting a national park to an alternative use, or the benefits foregone from harvesting of species.

- **external costs** are the value of adverse impacts on third parties, attributable to conservation activity. The cost of damage to property or person caused by elephants in communal areas is an example of an external cost of conservation.

Direct costs: government expenditure

Table 4.11 shows data extracted from government records including the 1993-94 budget for the MET. It shows the costs incurred during that year, which represent the government's investment within in the wildlife sector. Also shown are those parts of the costs estimated to be specific to the protected areas (parks and reserves) of Namibia. These figures are not a complete measure of the government's investment in biodiversity, which is also reflected in varying proportions of the expenditures of other ministries, such as the Ministry of Agriculture, Water and Rural Development.

Table 4.11 also shows some of the revenues from the sector, mainly those of the tourism resorts within the protected areas. The net subsidy to protected areas can be seen to be N$28.7 million. Below, a section on 'Costs and benefits of increased investment in the environment and tourism' puts these figures into perspective.

Fig. 4.12 Government investment in park management is substantial in Namibia. Courtesy P Tarr

Table 4.11 Costs of state protected areas and revenues from game (N$)

	Total 1993-94 budget	Protected areas
Revenue from parks:		
Shops, restaurants, entry fees and accommodation *		27 163 536
Game auction**	1 290 000	967 500
Total revenue		**28 131 036**
Cost of running parks:		
Office of the Minister***	924 021	696 313
Administration***	2 965 789	2 234 925
Conservation management	21 886 393	16 414 795
Research	3 999 258	2 399 555
Resorts management	12 621 641	12 621 641
Tourism promotion	5 518 310	1 821 042
Information	1 001 004	750 753
Utilities****	39 884 000	19 942 000
Total costs		**56 881 024**
Subsidy		28 749 988

*Assumptions: * This figure refers to the 1993 calendar year. The Directorate of Tourism keeps their accounts in calendar, not financial, years. ** Some auctioned game is captured on communal land, but approximately 75% is taken from reserves. *** These overhead costs were calculated by taking the amount spent on parks as a proportion of the Ministry's total budget. **** Utility costs are paid by the Ministry of Works, which could not estimate the amount spent inside parks, so the figure is a guess.*

Opportunity costs, external costs, and cost benefit analysis

Resources used in biodiversity conservation, such as land, capital, labour, and water, could in theory have been directed to alternative uses for more immediate profit, such as commercial livestock farming. Consider the choice of whether to allocate land to non-consumptive tourism in a northern communal area, or to expand arable farming in the same area. The decision to invest in non-consumptive tourism will mean diminished economic benefits from agriculture. The foregone net benefits are known in economics as *opportunity costs.* Some land use options can coexist with wildlife conservation, in which case the opportunity costs will be relatively small. A major advantage of tourism as a land use option is that it can coexist with wildlife conservation. In contrast, large scale or intensive agricultural uses are inconsistent with conservation and tourism based on game viewing. Consequently, the opportunity costs will be much higher.

The concept of opportunity cost is the foundation of cost benefit analysis. Cost benefit analysis provides a decision making framework to compare the net benefits of a range of different resource use options. For example, suppose the government was considering whether to invest in wildlife conservation through development of tourism (project A) or to convert the land to commercial livestock farming (project B). The net benefits from project A would be compared to the net benefits of B to determine which land use option had the highest economic return. Of course, economic return is certainly not the only criterion. Yet if project A had the highest net benefits, the opportunity costs would be the net benefits foregone from not undertaking project B. When comparing net benefits from Projects A and B, it is very important to take external costs into account. Box 4.19 outlines the decision making framework of cost benefit analysis in the context of a protected wildlife area.

In biodiversity conservation, it is important to identify projects which are socially but not privately beneficial. In these cases, the projects will not be undertaken without some intervention by the government to improve their commercial viability. In other cases, commercially viable projects may be socially undesirable because of the large external costs borne by third parties. In both cases, the divergence between private and social benefits indicates that there is some 'distortion' in the economy that needs intervention and correction. For example, livestock subsides will distort the returns to livestock relative to other land uses such as wildlife or arable agriculture. Exchange rates and trade controls will distort the price of locally produced goods relative to foreign goods. Lack of user rights to wildlife in communal areas means that these communities bear the external costs of wildlife, but are largely excluded from the benefits.

The following case studies illustrate some of these important economic concepts, relating to the costs of biological resource and diversity conservation in Namibia.

Case studies of opportunity cost and cost benefit analysis

Opportunity costs of wildlife in commercial areas

The foregone returns from the farming of domestic livestock will have a far greater opportunity cost than will agronomy in commercial areas. The use of wildlife on private farms has generally developed as a supplement to livestock production. Yet a small and increasing number of ranches is devoted purely to wildlife production.[31] The potential costs to livestock from investing in wildlife may include competition for grazing land and water, disease transfer from game to domestic livestock,and loss or damage to domestic stock from wild predators.[24] Unfortunately, no economic estimates have been made of these potential costs (Box 4.20). However, Barnes and de Jager[31] have estimated the relative returns (financial and economic) to three different types of commercial ranch in Namibia. Table 4.12 compares financial and economic rates of return in the three different models: southern mixed sheep and game farming; northern mixed cattle and game farming; northern ranch based on the production of game for non-consumptive wildlife viewing.

Table 4.12 shows two very interesting trends. First, the greatest *economic* returns are attributed to non-consumptive wildlife tourism, but this same activity reveals the lowest *financial* returns. Therefore, if government subsidies to commercial livestock farming were removed, farmers would increasingly move to wildlife based activities. Removal of this support would both boost cash returns to wildlife based activities and enhance biodiversity goals. Second, it indicates that the opportunity cost (in terms of economic returns over ten years) of wildlife tourism in northern commercial areas is a return of 8.5% per annum in respect of cattle/ game farming.[62]

Opportunity costs of wildlife in communal areas

How do the returns to wildlife utilisation in communal areas compare to the returns to livestock grazing? Table 4.13 compares the financial returns from livestock with returns from utilising wildlife in Caprivi.

Table 4.13 clearly indicates that the financial returns to wildlife are higher than to livestock. The net financial return to wildlife is N$1.83/ ha, or N$498 per household, compared to returns to livestock of N$1.41/ha (N$384 per household). In addition, the wildlife option enhances environmental goals by reducing pressures on pasture and water resources. The removal of government livestock subsidies would further enhance the relative returns to the wildlife utilisation option.

Fig. 4.13 Government subsidies supporting commercial livestock production remove financial incentives for wildlife-based activities. Courtesy P Tarr

Table 4.12 ***Comparison of economic and financial rates of return in different commercial ranch management models in Namibia (in N$, 1994)***

Rate of return	Southern sheep/ game	Northern cattle/ game	Northern game lodge
Financial:			
FRR[1]	5.8%	3.9%	4.2%
NPV per ha[2]	-16.0	-40.0	-50.0
Economic:			
ERR[3]	10.8%	8.5%	13.6%
NPV per ha	19.0	5.0	67.0

[1]Financial rate of return; [2] Net present value/ hectare (at 8%); [3] Economic rate of return

Source: Barnes & de Jager[31]

Box 4.19 Comparing protected area benefits and costs

Comparing costs and benefits can guide decisions of whether to (1) establish a protected area, (2) add visitor facilities (such as a tourist lodge) to an existing protected area, or (3) convert a protected area to an alternative development use. There are several ways of comparing benefits and costs when evaluating such alternatives. If estimates of both costs and benefits are available, some form of benefit-cost analysis (BCA) can be carried out. This requires evaluating a stream of benefits and costs over a selected time period. The BCA can involve the calculation of a net present value (NPV) figure, a benefit/cost ratio (B/C ratio) and an internal rate of return (IRR) for each alternative. Comparing all of the benefits and costs allows one to categorise a venture in one of three ways:[63]

Privately Beneficial: The economic benefits directly obtainable by individuals, communities, or firms are larger than the costs. In this case, there is an incentive for the venture to be undertaken without any government intervention.

Privately Beneficial: $PB > PC$ *

Socially Beneficial (but not privately beneficial): The net computed benefits (benefits minus costs) to society as a whole are positive. But individuals, communities or firms could not easily capture all of the benefits and therefore would not be willing to undertake the venture on a commercial basis without an additional incentive.

Socially Beneficial: $PB < PC$ and $SB > SC$

In some cases, projects may be privately beneficial but not socially beneficial. This will occur when private individuals do not take all the costs of their activity into account, and *external costs* are conferred onto third parties. This can be written as:

$$PC + EC > PB < PC \text{ and } SB < SC$$

Undetermined Benefits: The net computed benefits (benefits minus costs) to society as a whole are negative, but the benefits may be diffuse or hard to measure. If a park is being compared to a development alternative (the benefits of which can usually be estimated with reasonable accuracy), an *'opportunity cost analysis'* may be useful. The net monetary benefits of the development alternative are first compared with the quantifiable benefits minus costs of the park. If the former are larger, the difference will indicate how large the park's unquantified benefits would need to be in order to outweigh the net benefits of development. If it can be argued that the qualitative (unquantified) benefits are at least this large, then conservation and/ or tourism would be the preferred option.

Undetermined benefits: $SB_{computed} < SC$

The methods used to compare costs and benefits depend on the aims of the analysis. A financial analysis should be performed to assess the profitability of a potential investment, whereas a social welfare analysis should be used to assess the net benefits to society as a whole. A social welfare analysis is broader in scope and often more difficult. While a financial analysis usually can be based on prevailing prices, social welfare analysis requires many prices to be adjusted so as to reflect inputs and outputs in terms of their scarcity values.

* PB = Private benefits; PC = Private costs; SB = Social benefits;
SC = Social costs; EC = External costs

Adapted from: Wells [64]

Table 4.13 Comparative estimated returns to wildlife and livestock utilisation enterprises on communal land in Caprivi, 1993

Financial return ($ per annum)	Livestock[1]	Wildlife[2]
Net revenue	2 753 486	3 568 545
Net revenue		
per hectare[3]	1.41	1.83
per kg	0.10	0.41
per household	384	498
Net revenue		
excl. subsidies[4]	556 369	3 111 795

[1] *Returns from slaughter for meat sale, and hiring of draught power;* [2] *Returns from a combination of photo-tourism, trophy hunting, cropping and live sale;* [3] *Based on 1.9 million hectares in western and eastern Caprivi;* [4] *Subsidies include government provision of water points and veterinary services received by the sector, but not specific to individual farmers. Sources: Yaron et al.*[24] *and Ashley et al.*[27]

So why isn't wildlife utilisation more popular with communal farmers? Ashley *et al.*[27] identify two main reasons, and a third is put forward by Yaron *et al.*[24] First, farming game rather than livestock requires different management skills and additional infrastructure. Second, the returns to tourism-based wildlife uses do not accrue exclusively to the community, as private companies will be involved in some of the enterprises, and the state is involved in park management and issuing of hunting licences. Third, even if households were willing and able to switch to the economic activity with the highest return, they are likely to stick with livestock farming as long as the state continues to bear a significant proportion of the cost. All three factors indicate a divergence between private and social benefits requiring government policy intervention.

Box 4.20 shows the financial costs and benefits of wildlife to households in Caprivi. Once again, there is a role for government to intervene to make a socially beneficial activity also privately beneficial.

International estimates of the opportunity costs of conservation

An example from Kenya: Recent research estimated the opportunity costs of biodiversity conservation in Kenya from the potential net returns of crop and livestock production, and compared them with net returns from tourism, forestry and other conservation activities.[49] Nationally, agricultural and livestock production in Kenyan parks, reserves and forests could support 4.2 million people, and generate gross annual revenues of US $565 million and net returns of US $203 million. These foregone net returns of $203 million, some 2.8% of GDP, represent the crude opportunity cost to Kenya of biodiversity conservation. The current combined net revenues of $42 million from wildlife tourism and forestry are currently quite inadequate to cover these costs.[49]

An example from South Africa: Box 4.21 outlines the opportunity costs of the Kruger National Park in terms of foregone benefits from agriculture. The same approach could be used in Namibia to derive an estimate of the economic potential of protected areas to support agriculture and livestock.

This could be part of a broader study to evaluate the net benefits (not just economic considerations, but also essential environmental values) and opportunity costs of land under various uses. Important research in Namibia was initiated in 1997 to address some of these issues.

Stakeholders and external costs in resource use

When considering development options, it is important to consider different stakeholders involved. The benefits to one group may confer costs to another group, as the example in Box 4.22 illustrates.

Costs and benefits of increased investment in the environment and tourism sector

One way to assess the value of government investment in a sector is to compare the investment cost against that sector's increased contribution to GDP.[30] This has been done based on an economic analysis of the tourism industry[25] and financial and economic enterprise models constructed at the DEA. The model compares the costs of increasing the MET's budget with the increase in value added, or GDP, that would occur due to expansion of tourism and consumptive use of wildlife. Other benefits of Ministry investment in the resource base and in promoting sustainable resource management are not included.

Box 4.20 Can the financial benefits of wildlife outweigh the costs for Caprivi households?

Research in east Caprivi on four years of elephant damage to crops shows that some of the worst affected villages, around Mudumu National Park on the east bank of the Kwando River, lose about N$1000 worth of crops per year. Losses of cattle and goats to hyenas, lions and crocodiles cost another N$2000 or so per village per year. In the four villages on the northern border of Mamili National Park, where lion attacks are more frequent, livestock losses ranged from N$1300 to N$23 000 per village in 1994, calculated at the market price of cattle of N$800 per head. These losses are catastrophic in a subsistence economy. Although crop losses have a lower cash value, they are significant since the poorest households depend on crops rather than cattle.

However, these villages along the Kwando are in prime tourism areas. Total losses per village, averaging N$3000 per year for most and N$12 000 for a few, are still less than what could be earned by local people from tourism. A community enterprise, such as a traditional village or campsite, can earn a community anything from a few thousand to more than N$20 000 per year. A bed-night levy from a nearby lodge, such as Lianshulu Lodge, can bring in about N$15 000 a year plus local staff wages of over N$50 000 a year. If communities establish conservancies with tourism rights, they could lease out tourism concessions for tens of thousands of dollars per year.

If the households that lose crops and stock can also receive the benefits of tourism, the costs of wildlife can be outweighed by the benefits. Much depends on who earns the wages and shares the community profits, or whether a share of profits is used by the community to cover compensation claims.

Along the Kwando River, local losses from wildlife damage have been estimated at approximately N$70 000 per year since 1991. By comparison, total annual earnings of local individuals selling crafts and working in lodges and camps are probably already around N$300 000. This could double if tourism and wildlife develop to their sustainable potential (for example, community guided walks and mokoros, one or two more lodges), and increase further through joint ventures. Cash alone won't offset the costs of lost livelihood and disruption — especially if the benefits are earned by a few individuals and not whole communities — but with appropriate rights and institutions, it can be worthwhile for communities to develop wildlife as a complement to farming.

— Caroline Ashley and Caitlin O'Connell, drawing on research by Jon Barnes and monitoring data by IRDNC Community Game Guards in east Caprivi

Box 4.21 Potential benefits from turning South Africa's Kruger National Park over to agriculture

Dryland cropping in Kruger National Park would require annual average rainfall of at least 600 mm, a condition met only in 25% of the park's 2 million ha. Even here, rainfall is extremely variable. Adverse soil conditions, topography and other constraints would eliminate 95% of this area, leaving only 25 000 ha suitable for maize cultivation. Yields would be unlikely to exceed 500 kg/ ha. Sales less production costs were estimated at R80/ ha, yielding a total gross margin to farmers' households of R2 million from 25 000 ha. This ignores the one-time cost of clearing the bush for agriculture, estimated to be R600-800/ ha or R15 million. Using a 10% discount rate, this is equivalent to R1.5 million/ year, reducing the total gain to R0.5 million/ year.

Livestock could be sustained up to about 12 ha/ large stock unit (LSU), with an estimated gross margin of R8/ ha. Applied to the whole park, this would yield R16 million. Improvements such as fencing, reservoirs, costs, troughs, boreholes, quarantine camps and spray dips could increase carrying capacity to 8-10 ha/ LSU, but only if sufficient groundwater could be found. If 8 ha/ LSU could be achieved, the annual gross margin would be around R27/ ha, or R54 million in total. Infrastructure costs were estimated at about R190/ ha, or R380 million in total. Again using a 10% discount rate, this is equivalent to R38 million/ year, reducing the total gain to R18 million. If the cost of establishing an extension service to support farmers is taken into account, the R2 million gain from infrastructure investments would be virtually wiped out.

Total benefit: The gross income from unimproved farming of R 2 million from maize plus R16 million from livestock was estimated adequate to support about 1200 six-person families at slightly better than minimum subsistence levels in 1993.

Source: Engelbrecht & van der Walt[48] in Wells[64]

Table 4.14 shows the costs and benefits of increased government investment, and the internal rate on return of capital invested over a 12-year period. It shows that if the MET increased its budget by 15% per annum in real terms between 1994 and 1997, and then by 3% per year thereafter until 2002, then the total benefits (value added from wildlife) far outweigh the additional costs. The total additional investment in 1994 prices amounts to less than N$ 100 million, whereas the total additional value added amounts to N$ 1840 million.

The net benefit to the economy (benefits minus costs) increases year by year. The value to Namibia today of this stream of income is N$ 380 million (assuming costs and benefits are discounted at 8% per year).

The rate of return on investment (the internal rate of return) over the 12-year period is 42%, which is an excellent investment by any standard. These important findings indicate that even in terms of direct use values alone, the government investment in the wildlife sector has a positive economics return.

Therefore, there is strong economic justification for a significant expansion in government investment in the environment sector. Barnes and Ashley[30] conclude that the MET needs a budget increase in real terms of at least 15% per year, particularly through direct capital expenditure on the resource base and tourism facilities, and through research and policy expenditure to set a strategic framework for the industry as a whole.

Box 4.22 Trade-offs and stakeholders in water point development in Namibia

The benefits of exploitation and of resource protection cannot both be maximised simultaneously for a given resource, although we can try to achieve a balance in the uses to which resources are put. A prime case for Namibia is the trade-off between water point development and the quality of pasture resources in the immediate vicinity. We cannot have a water supply and expect no degradation to occur on the surrounding land; this is the price to be paid for watering cattle in the dry season. In most cases this is considered an acceptable price to pay, if grazing is otherwise plentiful.

In considering these trade-offs we should also consider the different *stakeholders* in natural resources: the users who benefit in different ways from different uses or allocations of resources. Stakeholders (commercial farmers, the owners of large cattle herds, government institutions, and communal farmers) often have different degrees of power, influence and access to resources. In the water point example, trade-offs may need to be reconsidered if large herd owners monopolise water and degrade the surrounding pasture. Poorer local farmers, whose water demands are more limited, may gain no benefits from the water supply, while losing access to seasonal grazing they formerly used. The supply of water points can confer considerable *external costs* on small-scale farmers, who need to be taken into account in the project analysis.

Extracted from Quan et al.[12]

Table 4.14 Costs and benefits of increased investment in the environment and tourism sector (N$ million)

Item/ year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Government investment costs	46.2	50.9	58.0	61.6	70.9	81.5	93.7	96.6	99.5	102.4	105.5	108.7
Benefits (value added)												
Tourism uses	0.0	46.0	55.3	65.0	85.4	107.8	132.5	166.4	204.6	247.5	295.8	350.2
Consumptive use	0.0	1.1	2.3	3.4	4.7	5.9	7.3	8.7	10.2	11.8	13.4	15.1
	0.0	47.1	57.5	68.4	90.0	113.7	139.8	175.1	214.8	259.3	309.2	365.3
Total value added												
Net benefit/ cost	-46.2	-3.8	-0.5	6.8	19.1	32.2	46.0	78.6	115.3	156.9	203.7	256.6
IRR (@ 12 years)	42.44%											
NPV (@ 12 years)	380.9											

Source: Adapted from Barnes & Ashley[30]

4.5 Economic factors affecting natural resource use and biodiversity conservation

Economic roots of biodiversity erosion

There is an extensive and growing literature on the reasons why current economic systems have led to overexploitation of biological resources and biodiversity.[65-70] The bare bones of the economic arguments are summarised here in six key points, as adapted from McNeely 1988.[67]

1. Biological resources are not given appropriate prices in the marketplace

Many biological resources are not traded in formal markets. Even when they are, they may have associated values not reflected in their price. In economic terms, there is a divergence between financial prices (prices that producers and consumers actually face, which guide their resource use behaviour) and economic prices (the true value of the resource to society, taking into account its scarcity and non-marketed values).

In addition, the benefits of the existence of biological diversity are conferred on all who value them, and the diversity enjoyed by one person does not reduce the amount available to others. Biological diversity is thus a public good, and individuals and industries can often gain its benefits without paying for them (the 'free rider problem').

2. The benefits of protecting natural areas are seldom represented in economic decision making

This is because the benefits of conservation are often intangible, widely spread, not reflected or undervalued in market prices, and difficult to evaluate. As a result, developments go ahead with incomplete economic information. In Namibia, this is true of roads and canals which have blocked water flow in the Oshana Region, affecting groundwater recharge and the growth of vegetation. Essential ecological services were not sufficiently taken into account in the initial development decision.

3. Those who reap the benefits of resource exploitation are often not those who bear the costs

For example, people in communal areas in Namibia have often suffered from wildlife damage to crops, livestock, and infrastructure, and threats to personal safety. Yet they have been largely been excluded from the financial benefits of wildlife, which have largely accrued to tourism companies and wildlife licence holders (Box 4.23). In economic terms, the costs accruing to communities are known as external costs, or externalities, which are often accidental side-effects of other economic activities — in this case wildlife tourism and hunting.

Some would argue that externalities are not so much the 'accidental costs' of economic activity, but are characteristic of market based economic systems, in which producers and consumers seek opportunities to shift the cost burden of their activities onto third parties.[71] The issue of external costs and cost shifting is often regarded as one of the outcomes of ill-defined property rights systems.

4. Failure in property right systems

In many African societies there has been a gradual breakdown of traditional systems of common property, in which resource use was regulated by community structures. The species, ecosystems and ecosystem services which are most overexploited or abused tend to be the ones with the weakest system of property rights, where use rights are ill-defined or poorly enforced. A total breakdown or absence of defined, enforceable and exclusive property rights leads to open access resources, which are most at threat from overexploitation.

5. Discount rates and the interests of present and future generations

Costs and benefits that occur at different points in time are said to have different values in economics. Economic analysis discounts future benefits and costs, because society tends to value benefits sooner rather than later, and tends to consider future costs as being less important than costs today. The higher the discount rate (the greater the value attached to today vs. tomorrow), the greater the risk that a biological resource will be mined or exploited to extinction. Some would argue for adjustments to the discount rate on environmental grounds and to help safeguard the interests of future generations. Others would say that it is better to make more targeted adjustments to the individual costs and benefits.[72]

6. Economic growth built on natural resource depletion

Conventional measures of economic wellbeing, such as per capita GNP, do not recognise the drawing down of the stock of natural capital, and instead consider the depletion of resources (the loss of natural wealth) as net income. As a result, the total assets of the economy are declining, even if per capita GNP is growing. Economic growth built on resource depletion and degradation is short sighted and cannot be sustained.

These factors outline some of the particular characteristics of natural resources and biodiversity that tend to work towards overexploitation, conversion, or degradation of wildlife habitats and wildness areas. In the context of development and growth in market based economies, the features of environmental resources that lead to their overexploitation and undersupply are termed 'market failures.' Some argue that these undesirable traits are so fundamental to the workings of the market economy that their solution calls for a radical overhaul in the economic system itself and a redefining of the development goals of society.[69,71,73,74]

More mainstream economists argue that adjustments and interventions can be made to correct for the undesirable environmental consequences of economic activity. In other words, government intervention is required to correct for market failures. This can take the form of legislation that works towards more secure, well-defined, enforceable property rights governing the use of natural resources, or environmental taxes to ensure that the real value of environmental resources are reflected in market prices. Unfortunately, in many cases adjustments and interventions are not actually made, and environmental degradation and biodiversity loss continues unabated.

Government policies often exacerbate the underlying tendency for environmental resources to be overexploited. In most cases, these are unintended side effects of other government policies. They arise because government tries to achieve many different development objectives simultaneously (economic growth, full employment, balance of payments, stability, national security, social equity and environmental conservation). Policies that inadvertently exacerbate underlying market failures are known as policy failures, such as government subsidy of chemical fertilisers and pesticides to encourage intensified farming. The resultant low price and increased use of these substances does not take into account the environmental damage associated with their use. In this case, government policy has exacerbated the failure of the price mechanism to reflect external costs.

Fig. 4.14 Government subsidies of intensive agriculture are potentially highly destructive to biological diversity. Courtesy P Tarr

Market and policy failures in Namibia

This section outlines some market and policy failures that are at least partly responsible for the degradation of natural resources and erosion of biodiversity in Namibia. The review is not exhaustive, but does indicate the types of policies in Namibia which require more detailed analysis and reform. It is important to note that reform in this context does not necessarily mean changing the original policy objectives, but only finding better targeted instruments to achieve policy objectives that simultaneously eliminate undesirable environmental effects.

Policy failures in Namibia which negatively affect natural resource use must be identified and corrected especially urgently. Not only does the Namibian Constitution prohibit the unsustainable use of resources, but ultimately and more importantly, Namibians today and in the future can not afford to suffer the consequences of poor management and overexploitation. Without reform, Namibia could very easily go the route of some other arid African countries with small, natural resource based economies and histories of overexploitation.

Livestock subsidies

Livestock in communal areas is subsidised through veterinary services, quarantine and abattoir provisions, income tax and land rental waivers. In the commercial sector, subsidies have been gradually dismantled, with the largest remaining subsidy being on loans taken out before Independence.[14] Livestock subsidies can be seen as policy failures if they accelerate the conversion of natural habitats to agricultural use and erode biodiversity, in order to achieve a quite different goal of raising rural living standards.

Drought relief

This policy provides for state support to farmers during drought periods and to encourage destocking. However, according to many sources,[12,14,24] it may also have unintended detrimental effects on range management. The present system of drought aid provides fodder, transport and grazing subsidies to commercial and communal farmers. Farmers report that the provision of feed for livestock during the drought actually encourages retention of animals rather than destocking. Further, the payment of N$20 for each breeding ewe that the farmer sells can have the effect of encouraging farmers to retain their stock until they can receive payment.[12] This is an example of a well-intentioned policy which fails due to perverse incentives which reward poor land management and overstocking.

Price support for commercial maize and wheat producers

The Namibian Agronomic Board offers to buy all wheat and maize produced by farmers at a fixed price agreed annually in advance. This policy indirectly provides effective rates of protection at around 35% for wheat and 75% to 140% for maize.[14] This government policy distorts the relative economic returns of agriculture and natural habitats, artificially enhancing the former at the expense of the latter.

Water pricing

Water is one of the scarcest and most valuable resources in Namibia. Yet it has long been supplied to the domestic and commercial sectors at highly subsidised prices. For example, the use of heavily subsidised water for irrigation results in a high cost of water for relatively low economic benefit (value added). Dramatic negative effects downstream on the water table and flow of perennial and ephemeral rivers are of ecological and development concern.[75] Opportunity costs are neither reflected in prices nor taken into account.[14] Water pricing is being addressed under the 1993 Water Supply and Sanitation Policy, which allows for differential pricing for rural, urban and irrigation uses. This policy has yet to be fully implemented, and even so, still carries a significant subsidy for water use in Namibia.

Breakdown of common property management in communal areas

According to Dewdney,[14] traditional community systems of common property management and transhumance in rangeland areas are being undermined by two factors. First, the practice by wealthy individual farmers of fencing off grazing areas is reducing the pasture available to the rest of the community. This creates grazing pressure and intensifies competition between livestock and wildlife. Second, expanding human populations in communal lands adds pressure to the traditional systems of common property management. The issue of land reform is currently under review by the Government, and the introduction of the Agricultural (Communal) Land Reform Bill is a high priority in NDP1.

Access rights to wildlife in communal areas

Under the colonial administration, people on communal lands were denied the rights to use and benefit from wildlife on these lands. As a result, wildlife was regarded as an expensive nuisance, conferring costs on the local population by disrupting farming and other livelihoods. This is a good example of a policy failure that has discouraged the management and protection of wildlife in communal lands. Its effects are evident in the diminishing wildlife stocks in many of these areas. Since Independence, the government has adopted a new approach to community wildlife management. Focusing on the conservancy approach, communities will be granted rights to utilise and benefit from wildlife within its boundaries. Cabinet approved this policy in March 1995,[47] and legislative amendments were approved by the National Assembly in March 1996.

Other policy related issues with possible environmental repercussions include current *uncertainty about land reform*,[14] which may have the effect of encouraging farmers to take unduly short term views of natural resources; the *historical absence of effective rural development policies in communal areas*,[12] the *financial disincentive for the MET to increase conservation expenditures* due to the accrual of all state revenue generated by wildlife and tourism to central government coffers,[27] and *inadequate mechanisms to appropriate the value of biodiversity* that accrues to other nations.

4.6 Conclusions and recommendations

1. Traditional production technologies are based on risk spreading and economic diversity. These diverse and adaptive economic systems depend on, and indeed help conserve, biological diversity. More specialised technologies, although more productive in conventional terms, can be riskier, and require increased management inputs to compensate for higher degrees of economic and ecological vulnerability.

2. Biodiversity can be threatened either by overexploitation of valuable resources or by habitat conversion due to competition for land resources. In Namibia, terrestrial species and ecosystems are most at threat from habitat conversion for agricultural use. Marine species are threatened more by exploitation above sustainable yields.

3. Most economic valuation studies refer to biological resources and not biodiversity. Even in the valuation of biological resources, there is very little known about non-use values and indirect use values which relate to environmental functions. In many cases, it was difficult to tie up economic and ecological data, as the former were compiled by region/ district and the latter by ecological zones. In addition, the global values of biodiversity remain unknown.

4. More information is needed on variability and adjustment in ecological and economic systems, and on the interrelationships between these systems. Consequently, environmental values are not static and there may be significant differences between short and long term values.

5. Environmental values based on 'willingness to pay' approaches tend to assign low values in areas (and countries) where incomes are low. In so doing, they underestimate the crucial role that these resources play in poor communities, and tend to reinforce income inequalities.

6. As an example of the value of biological diversity, the economic contribution of wildlife, through tourism, was estimated. Recent research indicates that wildlife based tourism contributed in the region of N$218 million value added to GDP in 1993-94. Some wildlife strategies are more compatible with biodiversity conservation than others. Non-consumptive tourism, in particular, is not only economically lucrative and a growing sector, but is also based on diversity in wildlife species and habitats.

In commercial lands, the development of game utilisation and conservancies has contributed to the conversion from livestock to wildlife, and increases in species diversity and population sizes. This trend is motivated not by government policy initiatives or (necessarily) by environmental conservation concerns, but by incentives to diversify and increase farm income.

In communal areas, lack of legal rights to wildlife has restricted the economic benefits of tourism to craft sales and employment in reserves and lodges. Once communities have use rights over wildlife, there is considerable potential for tourism to complement farming livelihoods by providing cash income and diversifying economic risk. The move towards a mixed game and livestock system reduces the risk of environmental degradation and helps maintain species and habitat diversity.

For protected areas, there are no economic valuations, but in 1991 government revenue from public accommodation facilities and park entrance fees was about N$ 23 million. The charges and park entrance fees are set at a low level and bear no relationship to the real economic value of these services.

Future research needs to be undertaken to estimate the economic value of protected wildlife areas; to consider revision of the fee structures and budget allocations to the MET to achieve conservation and economic objectives; and to develop a comprehensive tourism strategy that integrates the public and private sectors.

7. In selecting projects for biodiversity conservation, it is important to identify projects which are socially but not privately beneficial, or projects which are commercially viable but socially undesirable because of large external costs. For example, in Namibia non-consumptive tourism may be socially beneficial in some areas but not commercially attractive in the context of direct and indirect subsidies to the livestock sector.

8. There is a need for research into the biodiversity and broader environmental implications of different land use options in Namibia. This would serve two important purposes: first, to provide urgently needed information to the land reform process, and second, to highlight the strengths and weaknesses of different valuation methods.

9. Further research is needed on the genetic effects of introducing alien wildlife species into Namibia. Will this enhance genetic diversity, or threaten the genetic integrity of indigenous species?

10. This report indicates the types of policies that may have perverse, unintended effects on the conservation of biological resources and biodiversity (livestock subsidies, drought aid, agricultural price support, water pricing policies, property rights in communal areas). There is a need for a comprehensive review of all policy and institutional factors that may affect biodiversity conservation.

Fig. 4.15 Specialised habitats on private land may be degraded through inappropriate policies and incentives. Courtesy R Simmons

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39 These returns are based on actual market prices, adjusted for economic distortions.

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41 Conservancies currently occur on private land, where farmers group together to manage and use wildlife. The new policy extends this concept to communal land, giving defined communities custodial rights and responsibilities over their land. Numerous communal conservancies are currently developing (Chapter 1).

42 Net economic contribution was derived by subtracting economic costs (including costs of capital) from economic benefits, and converting financial values to economic values using the shadow pricing criteria of Barnes (ref. 44).

43 An earlier study estimated the returns to wildlife tourism in the Kunene and Caprivi Regions (ref. 24). The results showed returns in the same range as in Barnes (ref. 44), but overall were less optimistic given the high potential for tourism in these areas.

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45 Existing economic activities in the communal areas include livestock and crop production for cash and subsistence consumption. The model assumes the development of a mixed tourism-agricultural system, and that future development of the tourism sector will not reduce net returns from these traditional activities.

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62 Mixed sheep and game farming appears to be the next best land use, with an economic rate of return of about 11%. However, the characteristics of the land and its tourism potential differ between north and south. When estimating the opportunity costs of land use, it is important to compare the economic returns of different land uses in the *same* area.

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Legal approaches to protecting biodiversity in Namibia 5

Jan Glazewski, Napoleon Kangueehi and Michaela Figueira

Courtesy M Griffin

It has been globally acknowledged that urgent action must be taken to conserve species and ecosystems to curb the increasing rate of loss of biological diversity.[1] Namibia has taken up this challenge in a number of ways.

Its constitution, which came into effect at the country's Independence in 1990, explicitly refers to biodiversity, providing that in the interests of the welfare of the people, the State shall adopt policies aimed at maintaining ecosystems, ecological processes and biodiversity for the benefit of present and future generations (Article 95: l). More specifically, Namibia has launched a project to review and revise its environmental legislation, incorporating the Convention on Biological Diversity (CBD) as outlined below. Namibia's National Biodiversity Programme, and indeed this book, demonstrate Namibia's commitment to biodiversity conservation.

In general, legal approaches to conserving biodiversity in Namibia must be seen in terms of its developing country status, its relatively recent Independence and colonial legacy, its unique and fragile ecosystems, and the diversity of its people.

5.1 The Convention on Biological Diversity (CBD) and Namibia

Status, overall objectives and definition

Namibia signed the Convention on Biological Diversity on 12 June 1992 in Rio de Janeiro, at the United Nations Conference on Environment and Development, and ratified it on 18 March 1997. Namibia is accordingly now obliged under international law to ensure that its domestic legislation conforms with the CBD's objectives and obligations.

The Convention's overall objectives are set out in its Article 1:

- the conservation of biodiversity;
- the sustainable use of its components;
- the fair and equitable sharing of benefits arising from the use of genetic resources.

Article 1 outlines the framework within which action must be taken, and demands that implementation and further development of the CBD conform to these objectives. It will thus help ensure that balanced decisions are taken, and that where interpretations diverge, conflicts are resolved amicably.

Article 2 of the CBD defines biodiversity to mean the variability among living organisms from all sources, including terrestrial, marine and freshwater ecosystems. This includes diversity within species, between species, and of habitats or ecosystems.

General features of the CBD

Two of the Convention's general features should be noted at the outset. First, it is **broad ranging**, covering conventional legal methods of habitat and species protection, as well as innovative instruments, ranging from the use of intellectual property rights to the regulation of biotechnology. Traditional legal approaches to general conservation in Namibia are outlined in section 5.3 below, while innovative methods which are still new to the country are discussed in section 5.4.

A second feature of the CBD is that it does not lay down substantive rules. Instead, it lays down overall principles, objectives and goals, leaving it up to contracting states to develop and adopt detailed means to achieve these. It is **facilitative rather than substantive**. With this framework in mind, the CBD leaves it up to individual countries to determine exactly how to implement most of its provisions. Therefore, major decisionmaking is placed at a national level.

Unlike other treaties related to the conservation of biodiversity, the CBD lays down no lists of accepted sites or species to be protected. These are left to individual countries to determine.

Fig. 5.1 Courtesy P Tarr

5.2 Threats to biodiversity in Namibia

The Convention recognises that the conservation of global biodiversity is a common concern of humankind, and a common and shared responsibility exists based on its paramount importance to the global community. While recognising that biodiversity knows no national borders and that international legal instruments must thus be adopted, the CBD respects national sovereignty.

Any programme to conserve biodiversity must recognise underlying reasons for biodiversity loss. The root causes of diversity loss recognised globally[2] also apply to Namibia:

- population growth and increasing resource consumption;
- ignorance about the roles of species and ecosystems;
- poorly conceived policies;
- effects of global trading systems;
- inequal resource distribution;
- failure to account for the value of biodiversity.

It is evident from this that human actions, economies and policies are the cause of most biodiversity loss. Legal efforts to address this loss must urgently consider these and other factors, and not only focus on the species and habitats which require direct priority action.

5.3 Environmental law in the context of Namibia's political and legal system

Namibia is a young country, having only attained Independence in March, 1990. It then inherited Roman Dutch common law from South Africa, and took over laws put in place by that country. Many of its environmental laws are accordingly outdated and inappropriate for the newly independent country, still reflecting vestiges of its colonial *apartheid* past.

For these reasons, Namibia is undertaking a four year donor-funded programme to review and revise its environmental legislation, and has appointed an environmental lawyer to manage the project.

The Namibian Constitution stipulates that both common law (its Roman Dutch legal heritage) and customary law shall remain valid to the extent that they do not conflict with the Constitution or statutes (Article 66). When considering current and new laws for conservation, both western and customary legal models must be kept in mind.

5.4 Pertinent obligations under the CBD

Biodiversity must be conserved for continued human survival, as well as for its own sake. This is why the CBD's preamble affirms that biodiversity is humankind's common concern. Although national sovereignty is recognised, States are also obliged to conserve biodiversity and regulate the sustainable use of its component resources.

In situ conservation (Box 5.1) first requires contracting States to establish a system of protected areas or areas where special measures are needed, including guidelines for their selection and management. Second, it requires the conservation of biodiversity and maintenance of viable populations in these areas.[2]

Box 5.1 In situ and ex situ conservation

To comprehend the obligations created by the CBD, especially those requiring international co-operation, one must understand the distinction between *in situ* and *ex situ* conservation. The CBD defines *in situ* conservation as where the maintenance and recovery of habitats, species and populations occur in their natural surroundings or, for domesticated or cultivated species, in the place where they developed their distinctive properties (Article 2). *In situ* species conservation cannot occur without also conserving species habitats. *Ex situ* conservation, on the other hand, is the conservation of components of biodiversity outside their natural habitats, for example in zoos and aquaria. It is complementary to *in situ* conservation. *Ex situ* conservation also refers to species domesticated in a place where they have not developed their distinctive features, for example on farms.

The CBD involves several general obligations:

a. Contracting parties must cooperate with each other regarding areas beyond national jurisdiction and other matters of mutual interest.

This will be done directly or, where appropriate, through competent international organisations (Article 5). The jurisdictional scope of a contracting party includes the land within its internationally recognised borders, its territorial waters, and maritime zones adjacent to them. A State may make rules for areas in its national jurisdiction and the biological resources found there. It can also regulate all processes and activities occurring there, whether by nationals or foreigners. These powers are derived from a State's sovereignty over its territory.

The situation is, however, different for areas beyond the limits of national jurisdiction. These areas are outside the sovereignty of any State, and are often referred to as global commons. They include, for example, the high seas and the upper atmosphere. In these areas, States may only regulate the activities of their nationals in order to achieve the CBD's objectives.

The need for cooperation can not be overemphasised, since transfrontier impacts by one State, for example via pollution, may profoundly affect another State's biodiversity. Second, species migration takes place between States and many species range over several national boundaries.[3] Namibia's Caprivi Strip, which is closely ecologically linked to Angola, Zambia and Botswana, illustrates this vividly.

Two other obligations of every contracting party are (Article 6:a,b):

b. Countries must develop and adapt national biodiversity strategies, plans or programmes;

and

c. Countries must integrate the conservation of biodiversity and the sustainable use of its components into relevant sectoral or cross-sectoral plans, programmes and policies.

Fig. 5.2 Poor agricultural land management can be a major cause of biodiversity loss. Courtesy MAWRD

This creates an obligation for national planning institutions to prepare a blueprint which, at the minimum, reflects how the obligations of the Convention will be fulfilled and how its specific objectives will be achieved. This report partly fulfills these objectives. National biodiversity strategies recommend specific steps to conserve biodiversity and use its components sustainably. National biodiversity action plans are supposed to answer the "how" and "when" of implementing the national strategies. Through national programmes, these strategies and action plans can be implemented.

It should be borne in mind, however, that this process is a continuous one. Reassessment, adjustment and improvement are needed if the conservation of biodiversity is to be achieved. This is a complex process involving the government and other components of society which may be most affected, such as communities, NGOs, and representatives of both capital and labour (Box 5.2).

The requirement of Article 6b, that biodiversity conservation objectives be incorporated into sectoral planning, creates obligations on nations to treat biodiversity conservation and sustainable resource use holistically, not just sectorally. Plans and policies of other sectors such as health, fisheries or agriculture, may lead directly to biodiversity loss (Fig. 5.2).

Box 5.2 NGOs and the CBD

Many solutions to biodiversity loss can be found at national and local levels. At these levels, the expertise of non-government organisations (NGOs) is important for contracting States to make use of. Because of their place in society, NGOs can bridge the gap between the citizenry and policy-makers. They can also act as watchdogs to monitor biodiversity conservation at local, national and other levels. Namibia does not have as many active environmental NGOs as are found in many other countries, and the few that exist do not have a particularly strong lobby. It is to Namibia's advantage to strengthen these NGOs and involve them fully in the implementation of the CBD.

Conservation of biodiversity and the sustainable use of biotic resources can thus not be promoted by natural resource agencies alone. Integration must take place between biodiversity conservation and related programmes. Planners in sectors such as health care, trade, agriculture and economic planning must be encouraged to consider the needs of biodiversity conservation in their national plans, programmes and policies.

d. Countries must, as far as possible, identify and monitor the components of biodiversity and identify processes and activities which may significantly jeopardise the conservation and sustainable use of biodiversity (Article 7).

As mentioned, the CBD does not contain a list of species and habitats that should be protected. This is left to individual States. The CBD does, however, require identification and monitoring activities to follow broad guidelines set out in its Annex 1. These include a focus on ecosystems and habitats with high diversity; with large numbers of endemic or threatened species; and with species, communities or genomes of ecological, scientific, social, medical or economic importance.

These three categories reflect the three conceptual levels of biodiversity: ecosystem, species, and genetic diversity.[3] Annex 1 of the CBD is a guide to those components which need to be identified and monitored.

It classifies them as distinctive, rich, representative of key species, or of economic, cultural or research importance -- apart from the extent to which they are threatened.

For a country like Namibia, with limited technical and financial resources, it is essential to prioritise action (Chapters 2 and 6), for example by identifying important ecosystems and habitats. Thereafter, and more specifically, threatened communities, species and genomes would be identified. National lists are essential in this context to set national priorities, as the Convention does not lay down such lists itself.

Identification of priorities alone, however, is far from sufficient. The components of biodiversity also need to be monitored, especially those that require urgent conservation measures and those that offer the greatest potential for sustainable use (Article 7:b). But monitoring is typically time-consuming and costly, and long-term funding is not always easy to secure. In Namibia, lack of skilled personnel is also a limiting factor (Chapter 6).

Finally, the success of legal efforts to address biodiversity conservation depends on identifying and influencing the root causes of biodiversity loss. Pollution, deforestation, and the spread of invasive alien species are some of the harmful processes that a country should identify and aim to control. Namibia has tried to control these activities through legislation, but improvements can be made, as set out below.

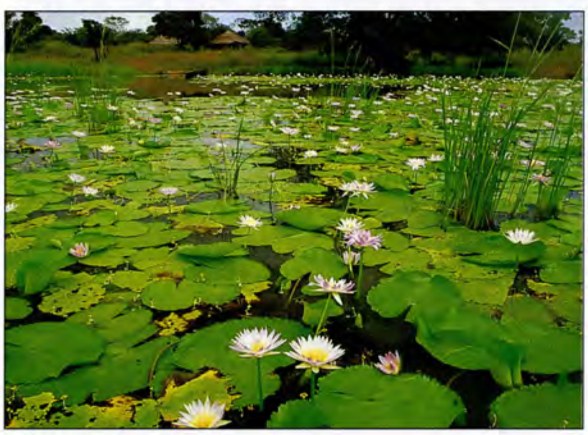

Fig. 5.3 Wetlands need priority protection in Namibia. Courtesy S Bethune

Fig. 5.4 Commercial harvesting needs careful regulation in Namibia. Courtesy P Tarr

5.5 Traditional legal methods of conserving biodiversity in Namibia

Traditional regulatory means of conserving biodiversity include (modifed from Sands[2]):

- establishing protected areas;
- regulating harvesting with quotas or with scientific criteria, *e.g.* maximum sustainable yield;
- prohibiting harvesting of designated species;
- regulating harvesting methods;
- establishing harvesting seasons and prohibited periods;
- prohibiting or regulating cross-border trade in certain species;
- managing habitats and ecosystems;
- prohibiting the introduction of new, alien or invasive species.

Indirect regulatory means of conserving biodiversity include those related to pollution control or hazardous substances management, for example industrial planning laws and control of agricultural pesticides.

Since a national biodiversity strategy must address all sectors relevant to conserving diversity and the sustainable use of biotic resources, it must also identify existing sectoral legislation and recommend areas where this needs implementation or improvement. Namibia has considerable legislation in place to conserve biodiversity, most of which preceded its ratification of the CBD.

Species and habitats

Key laws concerning species and habitats are the Nature Conservation Ordinance (4 of 1975) and the Forest Act (72 of 1968), both administered by the Ministry of Environment and Tourism (MET), and the Sea Fisheries Act (29 of 1992), administered by the Ministry of Fisheries and Marine Resources (MFMR). These and related laws are discussed below.

Wildlife (animals, plants and others)

The Nature Conservation Ordinance, hereafter 'the Ordinance,' deals with *in situ* and *ex situ* conservation by providing for the declaration of protected habitats as national parks and reserves, and for the protection of scheduled species wherever they occur. It regulates hunting and harvesting, possession of, and trade in listed species as described below.

Habitat protection

Habitats are protected in three broad ways. First, the Ordinance itself proclaims Etosha National Park as a "game park for the propagation, protection, study and preservation therein of wild animal life, wild plant life and objects of geological, ethnological, archaeological, historical and other scientific interest and for the benefit and enjoyment of the inhabitants of [Namibia] and other persons."

Second, the Ordinance provides for the proclamation of "other game parks or nature reserves" for identical purposes as well as for the protection of fisheries. As of 1997, 21 protected areas have been proclaimed under this section (Table 1.9).

Fig. 5.5 Etosha National Park was formally proclaimed as a 'game park'. Courtesy P Tarr

Curiously, there is no legal difference between a "national park" and other "game parks and nature reserves". There is a clear need for legal provision for a spectrum of protected area types, perhaps modelled on those of the World Conservation Union, IUCN (see 5.8, below).

Generally, persons are prohibited by the Ordinance from hunting, removing animals or plants, and introducing domestic animals within the confines of game parks or reserves, except by permission of Cabinet. Special permits are granted to landowners and land tenants.

Third, the Ordinance provides for the declaration of private game parks and nature reserves on application of the landowner. The effect of this is that the owner has greater rights over species in such areas, with the exception of "specially protected" and "protected" game and protected plants. An empowering provision is needed for the State to impose some kind of protected status over private land in appropriate circumstances, subject to agreement with or compensation to the owner (see 5.8, below).

Veld fires and the removal or destruction of any plants from parks or reserves are prohibited. This applies regardless of whether the game park or nature reserve is public or private. In the case of a private park or reserve, however, an owner may hunt any game or any other wild animal, except for protected and specially protected game. These regulations also apply to the picking of any indigenous plant.

Species protection

In situ species protection is provided for in the Ordinance by general prohibitions and permit requirements for scheduled species. It provides for categories known as Specially Protected Game, Protected Game, Huntable Game, Huntable Game Birds (Schedules 3-6) and Protected Plants (Schedule 9).

The Cabinet has powers to determine hunting seasons and times, hunting methods, the number and sex or species of game to be hunted in a season (bag limits), controls over capture and transportation, and so on.

An apparent contradiction is that the Ordinance permits a landowner, lessee or other authorised person to hunt game, excluding elephant, hippo and rhinoceros, in order to protect grazing, cultivated lands and gardens. Furthermore, an owner or authorised agent may hunt scheduled "problem animals," such as the black-backed jackal. If in the opinion of Cabinet these animals pose a threat or are a nuisance, Cabinet may order the owner to exterminate them or reduce their numbers.

Control of trade in endangered species

The Ordinance provides that import and export of raw skins and raw meat are allowed only by permit, but needs updating to make reference to the Convention on Trade in Endangered Species of Fauna and Flora (CITES), to which Namibia acceded in 1991. The Wildlife and Parks Management Bill, now in draft form, will replace the Ordinance and will incorporate Namibia's obligations under that convention.

Trees and forests

Although plants are regulated by the Nature Conservation Ordinance, trees and forests are controlled under two separate laws, the Forest Act (72 of 1968) and the Preservation of Trees and Forests Ordinance (37 of 1952). Both are administered by the MET's Directorate of Forestry.

Fig. 5.6 A Caprivi clearing. Courtesy S Bethune

The Forest Act aims to protect forests, prevent fires, and regulate trade in and removal of useful forest products. This Act allows the Minister of Forestry (now Environment & Tourism) to declare protected forest areas in the public interest. The Minister may declare any area as a nature reserve for the preservation of forests, natural scenery and forest products, for the protection of water supplies, or for the prevention of sand drift. In terms of these provisions, the Minister also has powers to declare wilderness areas.

The Act prohibits anyone from cutting, injuring, destroying or removing protected trees or other forest products, except with the Minister's consent. However, the Ministry can take measures, in the public interest, to eradicate noxious weeds and pests. The Minister may pass regulations prohibiting trade (import/export) in forest products other than fruits and fruit trees. A Forestry Council is established to promote development of the forest and timber industries. The Minister may also declare any forest products in State Forests to be specially reserved. This means that no person may fell, remove, or injure such products until that notice is withdrawn.

The Minister may make such regulations as he/she deems fit for the prevention of veld fires and the clearing of firebreaks. The specified fine of not more than N$1000 is not stringent enough to deter offenders; an increase is needed if forests and their products are to be adequately protected.

The Preservation of Trees and Forests Ordinance provides for the protection and use of trees and forest products in several ways. It allows for land to be reserved on which to preserve, propagate or manage trees, timber or forest products. It also makes it illegal for anyone to cut, injure, take, remove or destroy any reserved tree growing on land except by agreement, permit or contract. Where such authority is granted, the Ordinance gives precise logging guidelines. However, a lawful owner or occupier of land may destroy or remove a reserved tree for "bona fide domestic purposes," *e.g.* for fuelwood or construction.

This Ordinance also allows any officer to clear or have cleared a firebreak on common boundaries to curtail fires. Anyone may extinguish any open air fire if he/she thinks that it constitutes a danger to person or property. This Ordinance also states that possession of forest products without a valid licence or other authority is unlawful and punishable.

Forestry legislation needs

The Forest Act was put in place by South Africa in 1968 for that country's needs and circumstances, rather than Namibia's. South Africa replaced their own act in 1984, but this rather archaic and inappropriate instrument still remains in Namibia's statute book.

The Directorate of Forestry has undertaken a revision of legislation with the assistance of the Food & Agriculture Organization (FAO), and has drafted a new Forest Bill. It makes provision for various categories of protected forests, and precludes the cutting, burning, uprooting, damaging, destruction, collection or removal of any forest product. It also prevents the clearing of any land, the building of any road or structure, the removal or disturbance of any soil, the cultivation of any crops, or the grazing of any animal in such areas, except with authority under the Bill.

Section 8 of the draft Forest Bill provides that the forest resources of Namibia shall be managed and developed in order to conserve soil and water resources, to maintain biological diversity, and to supply the greatest amount of forest products compatible with the Directorate of Forestry's primary role as protector and enhancer of the environment.

Fisheries

- Sea Fisheries Act (29 of 1992)

The Sea Fisheries Act provides for marine environmental conservation as well as the orderly exploitation, conservation and promotion of certain marine resources to the benefit of all Namibians, present and future.

It regulates the commercial exploitation of fisheries and other marine resources by providing that anyone wishing to gain rights to exploit and utilise living marine resources for commercial purposes must apply to the Minister of Fisheries and Marine Resources for a permit. A permit is in essence a quota, and is subject to annual review and renewal. The Act provides for total allowable catches of given fish species to be determined for a specified period. Quotas are then allocated accordingly. The Minister of Fisheries and Marine Resources has powers to regulate the species, number, and biomass of fish to be caught, as well as trade in (import and export) and transportation of fish.

Regarding conservation of biodiversity and the overall marine environment, the Minister may declare marine reserves to protect or regenerate fish stocks and any other marine life. He or she may also regulate which species may or may not be caught or collected within that marine reserve.

Room for improvement exists, however. The Act could provide for the declaration of threatened species or stocks, as well as special measures for their protection. Unlike other resource management acts, it does not lay down lists of fish or other marine species which can be regarded as threatened. It consequently fails to identify protected areas and leaves too much to the Minister's discretion. The Act must be reviewed to establish whether it provides adequately for the protection of marine diversity in Namibia.

- Territorial Sea and Exclusive Economic Zone of Namibia Act (3 of 1990, amended by Act 30 of 1991).

This Act determines Namibia's territorial sea, internal waters, contiguous zone, exclusive economic zone (EEZ) and continental shelf in conformity with international law.

It defines Namibia's territorial sea as the sea within a distance of 12 nautical miles from baseline (the low water mark). It establishes Namibia's internal waters as waters landward of its low water line or any other baseline.

The contiguous zone is established as the sea outside the territorial sea but within a distance of 24 nautical miles. In this zone Namibia may exercise any powers deemed necessary to prevent the contravention of any laws, for example on immigration.

In the 200 nautical mile EEZ established under the Act, Namibia may exercise powers to control the use and conservation of living marine resources. When it comes to exploiting non-living resources, such as precious stones, the continental shelf is regarded as State land.

Water

Water is probably Namibia's most critical and scarce natural resource, and provides habitats for species. Therefore, a key environmental act is the Water Act (54 of 1956), currently being reviewed. This is essentially the old South African Water Act, of which certain articles have been made applicable to Namibia. It is under review, as it is inadequate for the needs of a modern industrial society. It also focuses almost exclusively on water supply, rather than on water as a habitat needing protection. We outline below those features of the Act most relevant to biodiversity conservation.[4]

Fig. 5.7 Old water legislation focused on water supply without regard for water as a habitat. Courtesy P Tarr

Administration and water supply

The Water Act is administered by the Department of Water Affairs, Ministry of Agriculture, Water and Rural Development (MAWRD). It gives the Minister the power to take all steps he or she deems necessary for the development, control, and use of water. It also provides for the control of freshwater and marine pollution from sources on land. The Act seeks to achieve its aims in several general ways.

It distinguishes between 'public' and 'private' waters. According to Namibia's Constitution (Art. 100), all water belongs to the State. This implies that the State must regulate the ownership and allocation of water for different uses to different users. *Public water* is found on public land, whether visible above ground or not, and its use is regulated by the Act. *Private water* occurs naturally on privately owned land, and may be used exclusively for any purpose by the owner. The Act separates these categories so as to define who has rights to use water, and how. It also allows utilisation by people on communal land, who do not own the land on which they live.

The Act places important restrictions on the use of private water. For example, water may only be taken by permit across the boundaries of the land on which it is found. Groundwater use may be brought under State control to regulate its abstraction.

The construction of dams in public streams is controlled by the Water Act. The Namibian interior has no perennial streams with normal surface flow. 'Surplus' water is defined as all public water which is not normal flow, for example floodwater. Surplus water can be used by riparian landowners, regardless of the needs of downstream users. However, the water must be impounded to be used. In Namibia, the Minister of Agriculture, Water and Rural Development regulates dam construction in public streams in order to protect the rights of downstream users. Only those with a permit and sufficient capital to build a dam may use floodwater in a public stream.

The Minister is granted the right to construct and control State Water Schemes to conserve or utilise water, to drain land, to store water, or to control the abstraction of underground water. This water may then be supplied at the Minister's discretion to any person, for any use, on any land. This applies to private individuals, local authorities, or any person granted rights to supply public water to consumers.

Water quality, conservation and enforcement

The Water Act prohibits pollution of public or private water, either by negligence or intent. It contains many provisions to control the purification and disposal of effluent and industrial water. The disposal of any effluent is prohibited, except by permit.

The Minister can regulate the protection of the quality and supply of subterranean water, found naturally underground or existing in any area declared as a subterranean water control area. This includes limiting the landowner's use of subterranean water.

The Act provides for the establishment of Water Courts both in South Africa and Namibia. These were never established in Namibia. Instead, an Advisory Water Board was instituted (Regulation R1277) to advise the Minister on the allocation of water, including the granting of permits to use surface runoff or groundwater in subterranean water control areas. The Water Board therefore functions in an advisory capacity to avoid disputes over water allocation and use, rather than as a forum to arbitrate disputes.

The Act provides for the levy of periodically revised tariffs for water supplied by the State, and for penalties for contravention of the Act.

Although the existing Water Act does not explicitly strike a balance between water resource development and the health of aquatic environments, this is one of the major implied responsibilities of the Department of Water Affairs. Powers vested in the Minister allow for regulations to be passed in this respect, but the protection of aquatic ecosystems in rivers, lakes, dams, wetlands, estuaries, caves, and subterranean water is not adequately regulated in terms of Ministerial powers accorded by the existing Act.

In 1995, the Ministry engaged consultants to review the Water Act. The Act must be urgently rationalised, improved and simplified to bring it in line with the Constitution, technological advances and the socio-economic and environmental demands facing Namibia. This will help to ensure the sustainable management of a scarce and variable natural resource, in an arid country with increasing demand for water.

Human populations are dependent on healthy aquatic ecosystems. People are part of the environment, and need to modify their activities and impacts to ensure the long term health of aquatic ecosystems, which support biodiversity in the broadest sense. These are some of the important aspects concerning the maintenance of biodiversity which will be addressed in the new water legislation for Namibia.

Agriculture

Namibian agricultural legislation is still largely of South African origin. There is, however, no central agricultural conservation act along the lines of the South African Conservation of Agricultural Resources Act

(43 of 1983). The four main acts in Namibia are the Soil Conservation Act (76 of 1969), a South African-imposed act since repealed in that country; the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (36 of 1947) which governs agricultural substances; the Animal Diseases and Parasites Act (13 of 1956) and regulations made under it (GN 114, Government Gazette 1103 of 30 June 1995); and the Agricultural Pests Act (3 of 1973). The latter will probably be replaced by a Namibian act of the same name, currently in draft form.

The Agricultural Pests Act provides for the issue of phytosanitary certificates for the export of plant products. The act covers possible health risks, but not broader environmental consequences of the export of alien disease or pest organisms. Environmental consequences would fall not under the purview of the MAWRD, but under legislation administered by the MET, especially the Nature Conservation Ordinance (which regulates the import and export of plants) and the Forest Act (which governs the use of plant products). The importation of plant products such as maize bran is governed by both the MAWRD (Agricultural Pests Act) and the Ministry of Trade and Industry (Import and Export Control Act, 30 of 1994). The broader environmental risks of importing alien plant pests or disease organisms are inadequately covered.

Agricultural legislation and the CBD

Namibia's agricultural legislation needs urgent review in terms of its effects on biodiversity and the overall environment. As in many developing countries, the focus of a biodiversity strategy in the agricultural sector in Namibia must be on food crops and livestock breeds: issues equally relevant to commercial and communal farmers.

The wide array of instruments referred to in the CBD generally apply to the agricultural sector. Sections 5.6 and 5.7 below explicitly link access to genetic resources, biotechnology, and indigenous knowledge issues to their agricultural context.

Fig. 5.8 The environmental risks of importation of alien agricultural pests and diseases are not covered by existing laws. Courtesy E Marais

5.6 Innovative methods to conserve biodiversity

Apart from the traditional methods outlined above, the Convention on Biological Diversity also refers to more innovative regulatory techniques or policies to conserve biodiversity. In general, these focus on three areas which have not previously been given attention in international law.

Access to genetic resources

Genetic resources are tissue samples of plant, animal or other species containing functional units of heredity such as DNA. In the context of the CBD, this refers to biotic resources used or needed for the extraction of genetic material.[3]

Traditionally, in the case of plant genetic resources, such resources were held to be the common heritage of humankind and should thus be freely available.[5] However, the last few decades have seen pressure to modify this situation, via calls for plant breeders' rights, farmers' rights, and intellectual property rights. Each of these has generated international debate, but no consensus has been reached. However, there has been global agreement that a formal mechanism must be developed to return at least some of the benefits from what was traditionally free access to genetic resources back to their country of origin.

The Convention reflects this move away from a 'common heritage of humankind' view:

"Recognising the sovereign rights of States over their natural resources, the authority to determine access to genetic resources rests with the national governments and is subject to national legislation..." (Article 15:1)

and more specifically provides that

"Each Contracting Party shall take legislative, administrative, or policy measures, as appropriate ... with the aim of sharing in a fair and equitable way the results of research and development and the benefits arising from the commercial and other utilisation of genetic resources with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms." (Article 15:7)

Thus the Convention emphasises a need for contracting parties to facilitate access to genetic resources by other parties for environmentally sound uses. It attempts to minimise restrictions contrary to the CBD's objectives. At the same time, however, it recognises the authority of individual States to determine access to genetic resources. The intention is not to prohibit access to resources, but to facilitate and control access for the benefit of both the state of origin and the state or party granted access.

Article 15 of the CBD also refers to financial mechanisms, provided for in Articles 20 and 21, for sharing in a fair and equitable way the results of research and other benefits arising from the use of genetic resources.

Namibia has to date not undertaken any formal survey to determine whether controls should be imposed for any genetic resource. We hope that scientists in this field will identify resources for which some form of control needs to be considered. As a wide array of potentially valuable genetic material is found in Namibia, this survey should be conducted urgently. Legal mechanisms which could be explored in this regard include Intellectual Property Rights agreements (Article 16), bilateral agreements, and regulatory controls.

It should nonetheless be noted that 'genetic resources' referred to here are only those (a) provided by a party that is the country of origin; or (b) provided by a party that has acquired resources in accordance with the CBD.

Biotechnology

The increasing amount of research and experimentation in biotechnology worldwide, particularly in developed countries, has resulted in controls being put in place in these countries. However, this has led to pressure for such research to be carried out in developing countries with much less stringent controls. The CBD recognises these problems by providing that

"Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, to provide for the effective participation in biotechnological research activities by those Contracting Parties, especially developing countries, which provide the genetic resources for such research, and where feasible in such Contracting Parties." (Article 19:1)

More specifically, Article 19 provides that

"The Parties shall consider the need for and modalities of a protocol setting out appropriate procedures, including in particular, advance informed agreement, in the field of safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity." (Article 19:3).

Therefore, the CBD tries to promote participation in biotechnology research by less developed countries, which often provide the genetic material for research. It also provides for the safe use and transfer of genetic material, and for the sharing of information in this regard. This requires the development of an appropriate protocol by Parties to the CBD, which will then incorporate the contents of such a protocol into their domestic legislation.

Namibia must ensure that its domestic law conforms with these provisions. This responsibility falls under the MAWRD, which administers the Animal Diseases and Parasites Act (13 of 1956), in addition to other statutes mentioned in section 5.5.

A survey must be undertaken to determine suitable legal controls before a decision can be made as to the best legislative framework for such controls. New, dedicated legislation covering the production and use of genetically modified organisms (GMOs) could be considered, for example, along the lines of Norway's Gene Technology Act (38 of 1993). GMOs may potentially be used, for example, to combat livestock and crop pests and diseases.

Access to and transfer of technology

A further biotechnology-related provision relevant to Namibia holds that:

"Each Contracting Party, recognising that technology includes biotechnology, ...undertakes... to provide and / or facilitate access for and transfer to other Contracting Parties of technologies that are relevant to the conservation and sustainable use of biological diversity or make use of genetic resources and do not cause significant damage to the environment". (Article 16:1)

This concept of free technology exchange seems to derive from the principle that genetic resources are the heritage of humankind and should be made available to anyone. In line with the goal of fair and equitable sharing in the benefits derived from the use of genetic resources, each party must take suitable legislative, administrative or policy measures aimed at achieving that goal. Here, therefore, user parties are meant to share benefits with providing parties. These benefits are: (1) the results of research and development, and (2) commercial and other benefits derived from use of the resources.

With reference to Articles 16 and 19, quoted above, Article 15:7 expands potential benefits to include:

Fig. 5.9 Biotechnology activities will be subject to policy and legislation development coordinated by the Namibian Biotechnology Alliance. Courtesy H Kaura

a. the access to and transfer of technology which makes use of genetic resources;

b. participation in biotechnological research activities based on the genetic resources;

c. priority access to the results and benefits from the use of biotechnology.[3]

Contracting parties must agree on exactly what is fair and equitable sharing.

Article 16 on technology transfer lays down obligations of parties regarding technology transfer, the basis of transfer to developing countries, and the measures to be taken to institute such transfers. Parties undertake to facilitate access to or transfer of technology to other parties, as long as it relates to the conservation of biodiversity, the sustainable use of its components, or the use of genetic resources. Access to developing countries is to be provided on fair and favourable terms, which could include concessions and preferences. But where technology is subject to patents or other intellectual property rights, terms of the transfer shall be consistent with protection of such rights.

For these measures to succeed, emphasis is laid on legislative, administrative and policy measures that need to be taken by each party to ensure such access. In particular, these measures must provide the private sector with a larger role in facilitating access to, transfer of, and joint development of technology.

Namibia currently has no legislation governing access to genetic resources and transfer of technology. Urgent attention must be given to developing a policy framework and legislation to regulate these areas.

5.7 Other aspects of the CBD

This section elaborates on provisions of the CBD which are particularly relevant to Namibia and require special attention.

Indigenous knowledge and resource rights

The CBD states that each contracting party shall respect, maintain and preserve indigenous knowledge of biodiversity and conservation, and share equitably any benefits from use of this knowledge. However, it does not refer to any particular legal instruments in this regard:

"Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological biodiversity..." (Article 8:j)

The article emphasises that communities should play pivotal roles in preserving and maintaining knowledge and practices.

Fig. 5.10 OvaHimba pastoralists have evolved appropriate land management strategies for arid environments. Courtesy National Archives of Namibia

The article stresses the significant relationship between culture and biological resources. Traditional societies have adopted many ways of husbanding resources in their attempts to adapt to local environmental conditions. If the languages and practices of traditional communities die out, so too a vast amount of information, accumulated over centuries, is lost.

One root cause of this process is government policies that result in the loss of both cultural and biological diversity. A starting point is to identify such policies and target them for re-evaluation. Just as important, the effective conservation of biodiversity and sustainable use of its components requires the elimination of perverse structural and financial incentives to overexploit agricultural, forest and fisheries resources (*e.g.* Dewdney[6]).

Environmental paradigms and the North-South conflict

As important as these policy effects are, the CBD fails to tackle another critical and closely related aspect. The interests of developing and developed nations regarding the environment differ widely. Although both groups discuss the conservation of biodiversity, one is left feeling that they speak totally different languages.

Environmentalists in developed nations focus largely on destructive human activities. They lament losses of natural habitat and wilderness, and the reduction of wildlife numbers through agriculture and urbanisation. The underlying belief is that nature must be protected from economic exploitation so that society can enjoy the aesthetic and recreational benefits of an unspoiled countryside.

On the other hand, as a Zimbabwe farmer said, conservation means the wise management of natural resources for economic use; it does not mean an absence of use at all costs. In poverty-stricken Africa, the land and its wild animals are not so much a source of aesthetic enjoyment as a resource to be managed so that people can survive.

Where the food supply is not secure, or where human needs of shelter, health care, and education can barely be met because of poverty, people cannot afford the 'luxury' of protecting the countryside from exploitation. The land is then not an arena for leisure pursuit, but a means of survival. If environmentalists from industrial nations fail to acknowledge African perspectives, there is every reason to expect that their projects will fail, and their costly advice will go unheeded. A balance must be struck between these two different perspectives on conservation.

The history of conservation in Africa is a story of the eviction of indigenous communities from land and resources that they once enjoyed. This was mostly done in the interests of a white minority and foreign investors. Evicted groups were settled in agriculturally poorer regions and were denied access to grazing, firewood and the wild animals they had hunted for subsistence in the new park area. This scenario has created a legacy of resentment towards conservation policies, which continues in Namibia to the present day. Unless conservation staff realise the depth of this antagonism and understand that economic benefits must return to local people, the existence of protected areas will be opposed, and poaching, the burning of fences, and other activities will only get worse.

Namibia has acknowledged this tension and moved to improve the situation in different ways. Most significant is the conservancy concept, whereby rural communities gain controlled rights over wildlife in defined areas (conservancies), and responsibility for its sustainable use. The recent Nature Conservation Ordinance Amendment Act (5 of 1996) gives effect to this concept.

The framework Environmental Management Act, which is currently in advanced draft form, includes a provision respecting the rights and knowledge of indigenous peoples. Namibia has not to date signed the Convention on Indigenous Peoples' Rights.

Fig. 5.11 Environmental assessment is a positive process intended to guide development in a sustainable direction. Courtesy R Simmons

Environmental assessment

Article 14 of the Convention requires each contracting party to carry out environmental impact assessments (EAs) of projects that are likely to adversely affect biological diversity. It further requires that the EA be aimed at avoiding or minimising such effects and, where appropriate, allow for public participation in the assessment. Such projects would include developments such as hydroelectric dams.

The aims of an EA are twofold: (1) to provide decision-makers with information on a project's environmental impact so as to help them take informed decisions on whether or not to proceed; (2) to produce environmentally sound projects in cases where these do proceed.[3]

EA is a planning tool, and looks beforehand at aspects like site selection, a project's magnitude, the displacement and resettlement of communities, and overall biophysical impact. In addition, an EA must identify specific elements of the project that could adversely affect biodiversity. It must identify the steps to be taken to avoid or minimise these effects, and ensure that the project complies with existing environmental laws. Also of importance is that the EA's design and implementation processes must involve key players and interested parties.

In a participatory process after Independence, Namibia developed an innovative EA policy which was formally approved by Cabinet in 1994. This will be formally incorporated as a chapter of the Environmental Management Act.

Namibia's EA policy provides that all policies, projects and programmes should be subjected to EA procedures, regardless of where these originate. These procedures should aim for a high degree of public participation, should consider the environmental costs and benefits of projects proposed, and so on. It refers to policies, areas and activities which may have significant environmental effects. Provision will be made to include other activities which may adversely affect biodiversity in Namibia. In line with IUCN guidelines, EAs are conducted at an early phase of project development, allowing for identification and avoidance of adverse impacts. Namibia's EA policy is an especially strong one. It would, however, benefit from more stringent mechanisms for incorporating biodiversity impact studies into the EA process.

5.8 Conclusions and the way forward

Although there is a body of legislation in place in Namibia which conserves biodiversity, it was formulated with general conservation ideals, rather than explicitly biodiversity, in mind. For example, parks and reserves were declared for general conservation and recreation purposes, not specifically to conserve biodiversity. New laws being developed under Namibia's environmental legislation project must take account of the country's unique and valuable biological diversity. Where necessary and appropriate, they must specifically provide for biodiversity conservation.

Policy principles underpinning future legislation

It is clear from our survey that current Namibian environmental laws adopt a traditional "command and control" approach to conservation. While we do not recommend a radical departure from this, a significant shift is clearly needed. Future legislation should be underpinned by the following general policy considerations.

• The integration of biodiversity conservation aims into land-use and national planning laws

A distinction must be made in Namibia between commercial and communal lands. Different tenure philosophies and legislation underpin each: while private individual ownership typifies the former, group and communal tenure is the main feature of the latter. The Agricultural Commercial Land Reform Act (6 of 1995) was recently passed, while a draft Communal Lands Bill has been circulating since 1995.

Ways to accommodate biodiversity conservation in these developments are:

- development of the conservancy concept;
- legal requirement of environmental assessment procedures for relevant development projects and policies;
- creation of intersectoral structures and mechanisms for improved information flow between sectors.

Each of these is linked to a number of general considerations set out below.

• Devolution of natural resource rights and responsibilities

Government administration in Namibia is characterised by strong central control. Thirteen administrative regions have been declared, but their Regional Councils lack legislative and executive capacity, and their powers, set out in the Regional Councils Act (22 of 1992), are ill-defined.

Conservation efforts will succeed only where there is direct community involvement in the management, conservation, and use of natural resources. New legislation must accordingly promote community policing and enforcement as far as possible. This will succeed only if the benefits of involvement accrue to local and regional levels. In the communal lands context, this principle is inherently linked to the role of customary law, as described below.

- *Recognition of the role of customary law*

The Namibian Constitution stipulates that customary law shall remain valid to the extent that it does not conflict with the Constitution or statutes (Article 66). It is clear that if Namibia is to succeed in conserving biodiversity, it must incorporate existing legislation into overall conservation structures. So too, related projects and policies of other ministries need to have biodiversity conservation in mind and consult with relevant actors.

At the end of the day, economic benefits must return to local people. The Traditional Authorities Act (17 of 1995) gives legislative recognition to traditional authorities, and requires rural communities to use the natural resources at their disposal in a sustainable way (section 10:2c).

A new conservation ordinance

The IUCN has evaluated different types of protected area, identifying six categories.[7] We urge Namibia to move now to declare multiple-use areas as outlined below. People could remain living in such areas, their animals may graze in certain zones, and communities need not be moved. A major advantage of multiple-use protected areas is that community alienation is normally minimised. Such protected areas bring a greater feeling of ownership to local communities, and hence enhance their understanding of conservation.

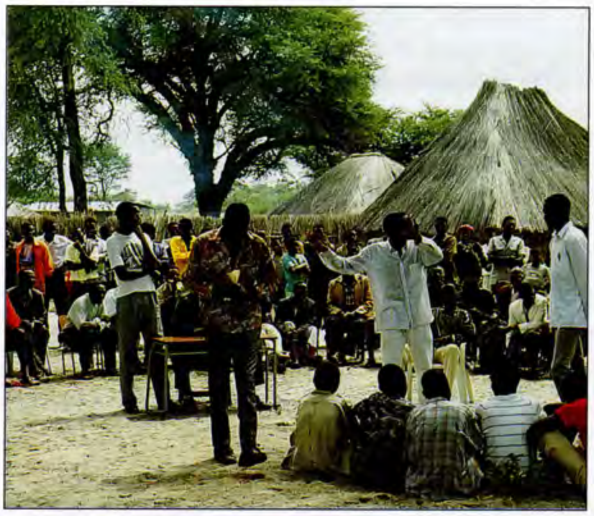

Fig. 5.12 The development of conservancies is a significant step towards returning rights to, and responsibilities for, biological resources to rural people. Courtesy P Tarr

Habitat protection

The IUCN protected area classification needs to be carefully adapted to Namibia's needs and incorporated into the proposed Wildlife and Parks Management Act. The categories are:

1 *Strict Nature Reserve*: protects ecological processes and genetic resources in a dynamic evolutionary state for research, environmental monitoring, education, and future potential.

2 *Wilderness Area*: protects large tracts of pristine natural habitat.

3 *National Park:* protects outstanding natural and scenic areas for use in science, education or recreation.

4 *Natural Monument*: protects areas with significant natural features.

5 *Habitat / Species Management Area:* protects areas with nationally significant species, species groups, biotic communities or other natural features. May allow controlled harvesting of some resources.

6 *Protected Landscapes and Seascapes:* protects areas of nationally significant and scenic natural and cultural landscapes for recreation and tourism, especially where traditional land use is maintained.

7 *Managed Resource Protected Area:* areas managed mainly for the protection and sustainable use of specific resources.

8 *Anthropological Reserve / Natural Biotic Area:* area which allows the traditional lifestyle and resource use of indigenous societies to continue in a sustainable manner, undisturbed by modern technology.

9 *Multiple Use Management Area / Managed Resource Area:* area allowing for sustained production of water, timber, wildlife, pasture or tourism, with conservation intended to support these economic activities.

10 *Biosphere Reserve*: area which conserves the diversity and integrity of natural ecosystems, biotic communities, and genomes for present and future use in research, education and training.

11 *World Heritage Site:* protects areas with natural or cultural features of outstanding global significance.

These categories were considered and debated at a 1997 workshop on the new Wildlife and Parks Management draft bill. A conference in June 1996 also debated the extent to which different wilderness concepts are compatible with Namibia's conservation strategy. Based on these and other discussions, the draft bill provides for seven categories of protected area (Box 5.3).

Species protection

The schedules of categories of protected species need re-examination and revision to ensure that they reflect current biodiversity conservation priorities, as reflected by Namibia's red data lists. Certain taxonomic groups enjoy no protection at all under the Ordinance, for example invertebrates. Members of the National Biodiversity Task Force and their colleagues should report whether taxa in their fields of expertise are adequately protected by the Ordinance.

Box 5.3 Protected area categories in draft Namibian legislation

The draft Wildlife and Parks Management Bill provides for seven categories of protected area modelled loosely on the IUCN system:[7]

a. **Strictly protected area**, to protect its outstanding or representative ecosystems, geological or physiological features or species to be made available primarily for scientific research or environmental monitoring;

b. **National park**, to protect the ecological integrity of one or more ecosystems for present or future generations, to exclude exploitation or occupation inconsistent with such protection or to provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities;

c. **Multiple use park**, to ensure long term protection and maintenance of its biological diversity while providing at the same time a sustainable flow of natural products and services to meet community needs;

d. **People's park**, to enable people who traditionally live in the area to engage in a variety of consumptive uses;

e. **Site of interest**, to protect a particular site of scientific, natural, cultural, historical or archaeological interest;

f. **Recreational area**, to develop particular recreational opportunities;

g. **Private park**, to enable a private owner to engage in wildlife management opportunities.

In terms of these provisions, the Minister of Environment and Tourism may declare any area of land and adjoining waters as one of these categories, by notice in the Government Gazette, and may provide interim protection to any area being surveyed for such purpose.

Devolution of rights and responsibilities

The Regional Councils Act (22 of 1992) sets out the general powers of Regional Councils, but does not clearly state the responsibilities of central and regional government. For example, it stipulates that traditional authorities are responsible for ensuring that resources are used on a sustainable basis (section 12), but makes no reference to central government agencies which play a key role in regulating and monitoring resource use. The new Wildlife and Parks Management Act will have to address this issue.

Incorporation of customary law

It is evident that the success of any biodiversity project in the communal areas will to a large extent depend on the active participation of local communities. New legislation is taking cognisance of customary laws which apply in different contexts, and a research project has been initiated by the Environmental Legislation Programme to assess the best way of incorporating customary law.

Concluding remarks

The success of Namibia's National Biodiversity Programme will to some extent depend on whether appropriate legal, administrative and institutional mechanisms are put in place. The involvement of all sectors -- public and private -- should be sought in this regard. This chapter has shown that a beginning has been made with the legal aspects.

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Future priorities, research needs and actions 6

Chris Brown and Phoebe Barnard, chapter coordinators

Courtesy G Williamson

6.1 Introduction

Until the mid-1900s, biodiversity was largely the concern of museum and herbarium taxonomists who described different organisms and their relationship to each other. This work was far removed from the lives of ordinary people, and was very much an isolated specialisation of individuals and institutions who had a passion for discovering, describing and curating new and little-known plants and animals.

At about the middle of this century, biologists began to take a broader approach to conservation. In the past, protected areas were identified mainly on the presence of game animals (generally large mammals) which were threatened by overhunting and were monitored by 'wildlife biologists.' A new generation of 'conservation biologists' then began to look at the ecological roles and conservation status of a range of different groups, including birds, lower vertebrates, insects and plants. Species in different taxa became the units of measurement for conservation management, conservation prioritisation (*e.g.* red data books), and conservation action. Interested members of the public became more aware of rare and endangered plants, birds, fish, and insects, of high profile 'flagship' species such as rhinos and cranes, and of habitats under pressure such as wetlands.

During the last decade of this century a further shift in biodiversity thinking has taken place. We now realise that the diversity of life on earth constitutes the essential elements which underpin human survival on this planet -- the food we eat, the natural resources we use for medicines, housing, clothing and energy, the natural resources on which our economies are based, and the species which support ecological life-support processes such as water purification, oxygen production, soil generation and biological decay and nutrient cycling. These resources and processes support human life and human livelihoods, and their depletion or disruption therefore has severe and direct social, economic, and political consequences.

The emphasis of biological diversity has thus evolved from purely taxonomy to conservation management focused on game mammals, to conservation biology analyses of the viability and protection of many taxa, to our belated realisation that biological diversity is central to virtually all interactions of people and their environment. In short, there is now a clear understanding that the wise management of biodiversity and the sustainable development of people are inextricably linked.

This realisation has only recently dawned in Namibia. At least in key circles, government and non-government planners understand that actions need to be taken, awareness must be raised among decisionmakers and the public, and key institutions need to act, often in new and innovative ways. However, this is not to say that in Namibia matters are in hand, that appropriate actions are taking place and that things are uniformly moving in the right direction. The preceding chapters have highlighted a large number of gaps in information and action. They have highlighted the past lack of coordination and cooperation between different institutions responsible for biodiversity conservation, the removal of data and specimens by some foreign researchers, the potential damage done by inappropriate incentives, policies, and legislation, and indeed the many lost opportunities for sustainable development and environmental protection.

However, more important than this, the preceding chapters tell us that Namibia has

(a) a good -- though far from complete -- body of information on which to work,

(b) a small -- though far too small -- body of dedicated and experienced biodiversity scientists who wish to work cooperatively, complemented by a network of scientists from abroad,

(c) a number of well placed -- though often understaffed and underfunded -- institutions which are starting to understand the synergistic value of collaboration,

(d) a protected area network covering 13.8% of the country's land surface -- though with important gaps,

(e) a clearly identified range of issues to address as we move into the 21st century with biodiversity conservation high on our list of useful tools to direct human development in a sustainable way, and

(f) a National Biodiversity Task Force, experienced in working together, to direct and guide this process.

6.2 Research priorities

The following research priorities have been identified from the preceding chapters.

1. To *improve our information base* for:

- the *current conservation status of habitats and biomes* in Namibia, improving upon classifications, descriptions, and accuracy of mapped units;

- the *taxonomy, ecology and biogeography of little known groups* such as viruses, fungi (especially mycorrhizae), algae, soil bacteria, nematodes, aquatic invertebrates, most arthropods, lower plants, and lower vertebrates, especially where these aid our understanding of the protection of biodiversity and ecological processes.

  Assessments must be carried out of the minimum levels of information needed to conserve different taxa effectively and make informed planning and management decisions, taking into account time and financial constraints. Patterns emerging from the little known taxa may be similar to those of better known and more easily monitored groups. A major gap needing urgent research attention is how these lesser known groups support essential ecological processes, particularly in wetlands, the ocean, and the savannas which support agriculture in Namibia.

- *little-known biomes, habitats and features of ecological importance* such as the escarpment and inselbergs, and inland wetlands, wherever possible using teams from different disciplines and agencies to stimulate debate, uncover novel scientific paradigms and biogeographic processes, explore options for future research and management, and raise awareness.

2. To use the best available biodiversity data to *analyse the effectiveness of the protected area network and other land use types* in protecting biodiversity, Namibian and regional endemics, red data species and our archaeological

heritage; to identify and test indicator groups as well as umbrella and keystone species for monitoring (a) conservation parameters and environmental health, and (b) impacts of environmental degradation, with sensitive species providing early warning of climate change, desertification, genetic erosion, habitat fragmentation, and pollution.

3. To better understand *current resource exploitation and harvest potentials* in Namibia's variable environment, and to monitor and regulate exploitation accordingly. Monitoring and regulation must cover commercial and subsistence use of genetic and species resources, and where appropriate include socioeconomic and ethnobiological research as well as study of behaviour, life histories, and population dynamics.

4. To better understand the important role that community management through conservancies is expected to have on biodiversity conservation, and the *potential for conservancies and other land uses to augment the protected area network.*

5. To study selected *endemic and red data species* to obtain sufficient information on their distribution, population size, life histories, behaviour, habitat needs and, in the case of threatened species, the sources of threat, to ensure their sound management and wellbeing. Research must take account of biological, not just national, boundaries.

6. To gather data on *genetic diversity of selection, fragmentation and isolated populations* of:

- *locally domesticated crops, livestock and their wild relatives* to ensure the protection of an appropriate gene pool of diversity;
- *restricted range species*;
- *species in fragmented riparian forests and other habitats under direct threat.*

6.3 Other priority actions

The following priority actions are drawn from the preceding chapters of the Country Study.

1. All land in Namibia not allocated to the protected area network, mining and municipalities is generally considered open for *agricultural use*. This notion needs to be challenged, especially in an arid country like Namibia, for which food self-sufficiency is an illusory goal. In Botswana, for example, in addition to national parks, large areas are zoned as 'wildlife areas,' providing options for tourism and trophy hunting, while buffer zones exist around protected areas and corridors for migration, gene flow, and overall biodiversity protection. A number of similar opportunities exist in Namibia to zone areas for priority wildlife management, such as around the Khaudum and Skeleton Coast Parks. Nevertheless, agriculture will remain the dominant land use in Namibia for the foreseeable future. Better collaboration between agricultural and land use agencies (MAWRD, farmers' groups, NGOs, agricultural projects) and the Biodiversity Task Force must thus be established, and agricultural biodiversity planning, management and strategies for sustainability must be developed.

2. *Critical vegetation types and habitats needing urgent protection*, not currently part of the national protected area network, include:

- *vegetation types:* mountain, thornbush, highland, dwarf shrub, camelthorn, and mixed tree/shrub savannas, semi-desert and savanna transition, and forest savanna;
- *karst caves and sinkholes, ephemeral and saline pans, springs and seeps*;
- Okavango, Zambezi and Kunene *riparian forests and islands*;
- *upper reaches of ephemeral rivers*;

- *mountains and inselbergs* including Brandberg, Auas Mountains, mountains in Kunene Region, Brukkaros, Omaruru granite domes, etc.;

- the *marine environment*, with littoral, shelf and abyssal habitats.

  The *protected area network* must be expanded where possible to safeguard the unique biological diversity which these habitats and features support. Where national proclamation is not possible, innovative means must be explored for securing their protection, including transboundary approaches.

3. In the past there has been *insufficient collaboration* of individuals within and between institutions in biodiversity planning and management at all levels. This has resulted in poor coordination and prioritisation. A concerted effort is needed on the part of these people and institutions to ensure that they are fully involved in the national biodiversity initiative. The Biodiversity Task Force must continue to play an active role in bringing people together.

4. Namibia faces a *critical shortage of upcoming biologists* interested in biodiversity protection or management. An ongoing outreach programme should be launched to advise students about what such careers entail, and why they are critical for the nation. Trainees must be encouraged and supported with postgraduate bursaries. Yet we cannot expect to attract biologists to institutions where jobs are unavailable, unsupported or marginalised. As Namibia's often inefficient civil service is streamlined, for example, it is critical to ensure that productive and essential sectors related to environmental sustainability are not undermined, but are built up through the transfer of posts away from redundant or unproductive sectors. Awareness of this need must be urgently built among top management.

   One mechanism to attract young scientists and supplement the Government's work effectively may be the establishment of a small but dynamic institute for biodiversity and conservation biology, which works collaboratively with the Desert Research Foundation of Namibia, Etosha Ecological Institute and others (Appendix 2). We need to invest aggressively in the future of biodiversity conservation by ensuring that good personnel will follow in our footsteps.

5. The term *'biodiversity' is not readily understood* by laypeople. We need to make terms and concepts much more accessible. One approach would be an atlas of Namibian biodiversity, showing overall diversity, endemics, threatened species, and the role of protected areas in simple style. Biodiversity specialists should collaborate on the production of learning materials for schools, teachers' colleges and the University of Namibia.

6. Existing legislation is inadequate for the protection of biodiversity and biological resource use, and is not yet in line with Namibia's commitments under the CBD. The Biodiversity Task Force must ensure that it reviews and influences the emerging draft legislation.

7. Biodiversity planning is still very centralised in Namibia. Enhanced involvement of regional government and non-government agencies is necessary to ensure that local decisions are possible, appropriate, and responsible, upholding the national interest.

8. Funding always constrains biodiversity work. Government funds are limited and, to date, donor funds have been limited to seed-funding. Bilateral agreements must be established for more substantial and flexible funding, for longer periods (at least 3-4 years), so that subgrants can be given to address the priorities identified above.

Finally, the National Biodiversity Task Force and the broader community involved with natural resource management will formalise a national biodiversity strategy in 1998. The key elements of a core part of this strategy were developed by the Task Force at a workshop in late 1997 (Box 6.1).

6.4 Conclusion

The role of biodiversity in the larger scheme of things has shifted dramatically, from back-room taxonomy to mainstream environmental management and sustainable development. The importance of the science has increased significantly, as has the need for clearer information. There may not be a need for more information *per se* -- just accessibility of information, and a culture of public responsibility that prompts people to act on information.

This poses a considerable challenge. If biodiversity information is to be used in the planning and development process, in resource management, in monitoring, in the development of effective legislation -- and this is in everyone's best interests -- then we must present our information in an easily accessible, understandable and compatable form. This is an overriding priority if Namibia's decision makers are to take biodiversity seriously in their development planning.

Box 6.1 Elements of a future National Biodiversity Strategy for Namibia
National Biodiversity Task Force Workshop, 2 December 1997

The following four broad categories were agreed by the group as a basis for discussion (prepared by the programme coordinator on the basis of several existing national strategies, chiefly Australia's):

I. CONSERVATION ACTIONS

* systematics, identification, & basic conservation status research
* conservation planning and management
* protected areas
* non-protected areas
* threatened species, genomes and habitats
* indigenous knowledge
* information management

II. INTEGRATING POLICY AND PLANNING

* national policies
* agriculture, including pastoralism
* fisheries
* forestry, water and catchment management
* tourism and wildlife
* genetic resources

III. MANAGING THREATENING PROCESSES

* habitat alteration
* alien species & genetically modified organisms
* pollution
* poor land management, incl. fire management
* climate change
* environmental assessment
* habitat rehabilitation

IV. AWARENESS AND INVOLVEMENT

* education and training
* incentives
* natural and cultural heritage
* building a culture of civic responsibility

The group workshopped Category I, Conservation Actions, as the major area in which it could make detailed strategy recommendations, and agreed on a list of threatening processes in Category III. Categories II and IV were felt to be more obvious, and could be left up to Programme Coordinator to draft for a later workshop in 1998.

(cont.)

Box 6.1 (continued)

Priority	Objectives	Responsibility:	Threats (constraints)
Systematics and identification	Clarify status of and support for National Museum (+ NBRI) Network databases Inventory key taxa and habitats Develop sectoral action plans to fill gaps Develop fully integrated mapping capabilities	MBEC and MAWRD Biodiversity Programme MET DEA'S Biodiversity Information System Unit and others	Lack of funds Suboptimal coordination, cooperation, communication Lack of relevant expertise and staff Lack of ministerial support
Planning and management: • Protected areas • Non-protected areas • Marine and aquatic environments • Transboundary areas • Threatened species, genomes, habitats	Make planning + management more pro-active and scientifically based Establish an appropriate decision makers' body Develop additional creative methods of conservation Improve scientific review process for EAs Incorporate users in planning and management Gather information on non-protected areas Establish appropriate structure to coordinate and facilitate applied biological research	MET MFMR MAWRD Regional governors Environmental Commisioner's Office Transboundary management bodies such as Okavango Basin Commission	Conflict of interests Ad hoc development Unilateral decisions
Indigenous knowledge	Develop and implement strategy to capture this in order to enhance biodiversity knowledge and return benefits to indigenous people	NBRI, NMN Biodiversity Programme NGOs	Language and cultural barriers History of exploitation Inadequate control of trade
Information management	Analyse databases Maximise compatability of databases Train sectoral components Standardise databases where possible Accelerate production of red data books etc. Encourage scientific and popular publications / outputs Compile and network environmental information sources	All relevant database holders Biodiversity Programme MBEC (libraries) MET (information support, media liason) DEA (Environmental) Information Service) National Remote Sensing Centre DRFN library Other NGOs	TIme Facilities (computers) Expertise (cont.)

Box 6.1 (continued)

Priority	Objectives	Responsibility	Threats (constraints)
Conservation status monitoring and targeted research for biodiversity and ecological processes	Evaluate every habitat and taxon as far down as feasible Identify indicator groups for: a) overall biodiversity b) habitat health c) habitat degradation d) environmental change * Support their evaluation and implementation * Evaluate conservation status (local, with ref. to IUCN) * Re-evaluate biome scheme - physical - floral - faunal * Establish cost effective biodiversity monitoring and evaluation programmes	Aquatic - MAWRD Terrestrial - NAPCOD - NBP - CBNRM MET MFMR DRFN Tree Atlas Project and similar projects	Time Manpower Co-ordination/overview Lack of clear national priorities

There was broad consensus that the following sub-categories of 'Threatening Processes' applied, or could apply, to Namibia:

III. MANAGING THREATENING PROCESSES

* habitat alteration
* alien species & genetically modified organisms
* pollution
* poor land management, incl. fire management
* climate change
* desertification (a process to some extent distinct from poor land management and climate change)
* ad hoc or unilateral development decisions, and lack of political accountability

Appropriate tools for dealing with threatening processes include:

* integrated and appropriate national and regional policies
* environmental assessment and audit procedures
* habitat rehabilitation
* environmental education
* development programmes for poverty alleviation
* development of mechanisms for greater environmental accountability

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Appendix 2 Environmental conservation, research, education and awareness agencies and their capacities

As a large country with a small population, Namibia has a relatively simple network of conservation bodies, with relatively clearly defined portfolios. The major players are outined below, and annual budgets for several are given in Chapter 4. The technical and scientific community in Namibia is small, but the large majority of staff in most agencies are Namibian, rather than expatriate advisors.

Government organisations

In Namibia, the **Ministry of Environment and Tourism (MET)** is the government agency responsible for biodiversity conservation and planning at a national level. Three other government ministries have substantial practical responsibilities for ecosystem, habitat, species or genetic conservation, as outlined below. A further set of ministries is peripherally involved in the trade or use of biological resources. Ambiguous jurisdiction has therefore sometimes led to resource control disputes between ministries. There has been a danger of species and habitats 'falling through the cracks' due to this ambiguity and occasional conflict.

The MET's 1994 mission statement is *"to maintain and rehabilitate essential ecological processes and life support systems, to conserve biological diversity and to ensure that the utilisation of natural renewable resources is sustainable for the benefit of all Namibians, both present and future, as well as for the international community."*

In 1991, the Nambian Cabinet vested a broad environmental responsibility in the MET, as well as a 'watchdog' function over natural resource managers and users, including other ministries.

Within the MET, there are four primary divisions, three of which have direct responsibilities for biological diversity conservation. The *Directorate of Resource Management (DRM)* manages wildlife and other natural resources, chiefly through maintaining protected areas such as national parks and game reserves. In the last two years, it has also begun to promote the establishment of wildlife conservancies by rural communities on communal and commercial farmland. The DRM oversees the Etosha Ecological Institute (EEI) at Okaukuejo, which has been an important centre of conservation research since the 1970s. The DRM employs 176 staff in management, administrative and unskilled posts, of whom 95% are Namibian citizens or permanent residents.

The *Directorate of Environmental Affairs (DEA)* is the government body responsible for environmental planning, protection and coordination, within the national framework of promoting sustainable development. Its three main functions are national planning, policy development and programme implementation. The DEA coordinates the National Biodiversity Programme. It also manages or co-manages national programmes on desertification, community-based conservation, regional environmental profiles, industries and pollution, environmental legislation, resource economics, and natural resource accounting in cooperation with other bodies. The DEA was set up in 1992 to assume the overarching needs of planning and national coordination of activities in a much broader environmental sphere than were then being handled by the ministry.

The DEA currently has a core permanent professional staff of seven, plus about 22 contract staff and associates. All core staff and about 50% of associates are Namibians, with an increasing number of young Namibian professional graduates. The DEA has an in-house library on environmental issues, including biodiversity, of over 1000 titles plus about 40 films.

The *Directorate of Forestry (DF)* also recognises the link be tween environmental health and economic development in its forestry strategic plan:

"to practice and promote the sustainable management of forests and other woody vegetation with the involvement of local communities, in order to supply products and services to enhance socioeconomic development of Namibians, while maintaining and enhancing the other environmental and conservation functions of the resources."

The DF addresses its mission through a number of new programmes in community forestry, resource mapping and indigenous forest development. In the past it has relied heavily on foreign expertise, mainly from Finland, but Namibians are being trained at an increasing rate for technical and management positions. The DF currently has a Kenyan director, 14 scientific staff and 19 technicians, of whom 73% are Namibians.

Housed together with the DF, the *National Remote Sensing Centre (NRSC)* serves potential users, government and non-government, by providing digital information and maps from satellite images and conventional geographic information systems. Initiated with funds from Denmark and the Netherlands, the NRSC now has a Namibian director and five permanent or contract technical staff.

The MET's fourth directorate, the Directorate of Tourism and Resorts, has no direct responsibilities for biodiversity conservation. However, tourism provides considerable revenue to Namibia and is heavily dependent on biodiversity protection for its continued existence (Chapter 4).

Apart from these four directorates, and run as an autonomous section, is the *Division of Specialist Support Services (DSSS)*. This section, set up in 1996, carries out those resource management functions which cannot be decentralised, and provides specialist support to senior management. The DSSS is centrally involved in biodiversity conservation in Namibia through its Windhoek-based scientific staff. These include a biodiversity inventory coordinator specialising in biogeography of reptiles, amphibians and mammals; an avian ecologist specialising in endemic and threatened birds; and a wetlands biologist. The DSSS is headed by a biologist and reports to the Permanent Secretary of the MET. It has 12 scientific and veterinary staff plus 15 wardens and rangers, of whom about 90% are Namibians.

The **Ministry of Fisheries and Marine Resources (MFMR)** is tasked with the sustainable management and conservation of the marine environment, freshwater fish resources and marine and inland fisheries. The boundary between the marine and terrestrial environment has been drawn at the high-water mark for this purpose. The MFMR's primary work is in support of the commercial and subsistence fisheries industries in Namibia. Broader biological diversity and conservation issues, while a stated policy aim, are in practice subservient to technical support of the economically important fisheries sector. The MFMR employs 31 biologists and 55 technical staff, 90% of them Namibians, to support decision-making.

The MFMR has recently completed a state-of-the-art research facility in the coastal town of Swakopmund, including the *National Marine Information and Research Centre (NatMIRC)*, with a library of 100 periodicals and 1735 titles, and the National Marine Aquarium with a total capacity of about 400 m^3 and a variety of marine species for public education.

The **Ministry of Agriculture, Water and Rural Development (MAWRD)** is another important player on Namibia's biodiversity scene, and houses two institutions directly engaged in biodiversity research and conservation (below). However, the agricultural and rural development sections of this ministry do not specifically plan or operate with biological diversity in mind.

As land zoned for agriculture accounts for about 85% of Namibia's surface area, there is an urgent need for the National Biodiversity Programme to work closely with these directorates to evaluate and minimise biodiversity loss on farmlands.

The MAWRD's two institutions directly involved in biodiversity conservation are the National Botanical Research Institute (NBRI) and the Water Ecology Section of the Department of Water Affairs (DWA).

The *National Botanical Research Institute* (sections 2.7 and 2.9) houses the National Herbarium, the National Plant Genetics Resources Centre and the Vegetation Survey of Namibia. The Herbarium and Plant Genetic Resources Centre are important repositories of plant diversity, and play an active role in steering the National Biodiversity Programme. They collectively employ 12 technical and professional staff, of whom 92% are Namibians.

The *Department of Water Affairs* has broad responsibilities for water supply control and the protection of water bodies. Its Water Ecology Section is responsible for protecting the ecological integrity of water bodies throughout Namibia. However, some overlap exists with other agencies. The MFMR is currently responsible for freshwater fish, and the MET employs a wetlands biologist to provide overall coordination of wetland conservation issues. The DWA Water Ecology Section is staffed by 8 persons, of whom 75% are Namibian citizens or permanent residents.

In addition to these two sections within the MAWRD, this ministry also houses an innovative programme called the *Sustainable Animal and Range Development Programme (SARDEP).* SARDEP works with rural communities to achieve sensible and environmentally sustainable livestock densities. It employs 21 staff members (16 at technical level, 1 at administrative level, 2 professionals and 2 advisors) of whom 90% are Namibians.

The **Ministry of Lands, Rehabilitation and Resettlement (MLRR)** is unfortunately not a major player in conservation issues, although it participates in related inter-ministerial committees on land use planning. It presently has little technical capacity for implementing programmes to achieve sustainable land use. There is a need to build further awareness within the MLRR of biological diversity and its importance to human livelihood and land productivity. MET staff have already provided some ecological training input, including biodiversity input, to courses for land use planners in the MLRR.

The **Ministry of Basic Education and Culture (MBEC)** houses the *National Museum of Namibia (NMN)*, which curates national cultural, historical, archaeological and natural history collections. It is therefore the major repository of animal biodiversity specimens, both study skins and 'wet' specimens preserved in alcohol. These collections are detailed in section 2.7. The NMN currently has many vacant curatorial and technical posts.

The newly formed **Ministry of Higher Education, Science and Technology (MHEST)** has not so far played a role in biodiversity conservation, but in principle could be involved in the future. Specifically, it could play an integral role in the development of a national policy for scientific research which recognises and supports applied and pure research in conservation biology, biogeography, biosystematics and related fields. This policy should facilitate and encourage collaboration, within Namibia and with international research bodies, but also create mechanisms to ensure that results remain in Namibia and that local scientists and students are likely to benefit from collaboration. Finally, the MHEST is the parent ministry for Namibia's two major tertiary education institutions (below), which are increasingly involved in training natural resource professionals.

Education and training bodies

The **University of Namibia (UNAM)** has a Faculty of Science and a Faculty of Agriculture and Natural Resources, which train graduates in biology, chemistry, statistics, agriculture, forestry, fisheries, soil science, mapping methodology, environmental law, resource economics and resource politics. The Science Faculty was officially formed in 1986. Since then, more than 150 students have graduated with a BSc from this faculty. Until 1996 this was a three-year course, and the faculty did not offer postgraduate training in the natural sciences; in 1997 it accepted its first three masters students in biology. The Agriculture and Natural Resources Faculty was founded in 1996, and plans to train students to BSc and postgraduate levels.

Finally, the **Polytechnic of Namibia** offers a three-year diploma in agriculture and nature conservation. This course aims to train conservation rangers, wardens, agricultural extension and technical staff, and management staff for government and non-government posts in Namibia. From 1995 to 1997 it graduated 49 diploma students, but there are no data available to show how many of these graduates have remained in the fields of agriculture or nature conservation. The curriculum of this course, originally heavily drawn from traditional courses in South Africa, has been extensively updated and made more relevant and progressive.

Non-government and community-based organisations

Namibia has a variety of NGOs (non-government organisations) that deal directly or indirectly with environmental issues, including the conservation of biodiversity (Box A2.1).

The **Desert Research Foundation of Namibia (DRFN)** has as one of its aims to create a public well informed about environmental matters as well as to enable Namibians to manage natural resources appropriately and sustainably. This important NGO also has research, training and environmental education as core objectives. Linked to the DRFN is **Enviroteach**, which produces environmental education resource materials. The DRFN incorporates the **Desert Ecological Research Unit (DERU)** at Gobabeb in the central Namib. DERUN is Namibia's foremost ecological institute which has been an internationally respected centre for desert studies since its inception in 1965. Research includes Long-Term Ecological Research (LTER) studies of ecosystem processes and the relationship of biodiversity and desertification. The DRFN makes this information available through a computer-managed library (17 000 reprints, 1600 books) and compiled databases.

Integrated Rural Development and Nature Conservation (IRDNC) has as its main aim the promotion of sustainable development in Namibia's communal areas through two central objectives: building up the natural resource base, especially wildlife, and building up rural communities' capacity to share with government in the conservation and management of such resources. It also aims to facilitate the return of direct social and economic benefits from such resources to local rural communities.

Save the Rhino Trust (SRT) aims to promote the conservation of rhino in Namibia, and conducts monitoring and research activities towards this end, as well as environmental education.

The **Namibia Nature Foundation (NNF)** is the major fundraising and financial management support agency for environmental projects in Namibia. It has as its objectives the promotion of nature conservation in Namibia, the education of the general public, and fund raising for nature conservation projects. It cooperates with national and international organisations with compatible aims.

Several environmental awareness and advocacy NGOs are active in Namibia which are concerned with biodiversity conservation. The **Wildlife Society of Namibia** fosters awareness of the importance of the natural environment and promotes the conservation of Namibia's natural resources. Its other aims are to monitor development programmes in Namibia and assess their possible impacts on the environment.

The urban environmental group **Greenspace** is a voluntary community organisation in Windhoek with working groups addressing environmental issues of concern to urban dwellers of different backgrounds. Founded in 1994, this group works at scales both large and small, from urban open space mapping and planning to community protection of individual sites and promotion of indigenous tree planting.

The **Botanical Society of Namibia** was initiated in 1997 to involve the Namibian public in plant conservation and identification activities supporting the work of the National Botanical Research Institute.

Earthlife Africa (Namibia Branch) collects information and conducts research on environmental issues. It also aims to create environmental awareness and apply public pressure on specific issues. It seeks to strengthen regional and international cooperation on environmental protection.

Box A2.1 (below) gives contact details for NGOs in Namibia.

Box A2.1 Environmental research and awareness NGOs in Namibia

Africat Foundation, PO Box 793, Otjiwarongo, Tel. (0651) 304563/4, Fax (0651) 304565, email: Africat@iwwn.com.na

Cheetah Conservation Fund (CCF), Box 1755, Otjiwarongo, Tel./Fax (0658) 11812

Club for the Advancement of Voluntary Environmentalism, PO Box 60287, Katutura, Tel. (061) 232154 or 263281

Desert Research Foundation of Namibia (DRFN), PO Box 20232, Windhoek, Tel. (061) 229855, Fax (061) 230172, email: drfn@iwwn.com.na.

Desert Ecological Research Unit (linked to DRFN), PO Box 1592, Swakopmund, Tel. (061) 205089, Fax (061) 205197, email: gobabeb@iafrica.com.na

Earthlife Africa, Namibia Branch, PO Box 24892, Windhoek, Tel. (061) 2022041, Fax (061) 221962

Enviroteach (linked to DRFN), PO Box 20232, Windhoek Tel. (061) 229855, Fax (061) 259181, email: enviroteach@iwwn.com.na

Greenspace, PO Box 1194, Windhoek, Tel. (061) 235065, Fax (061) 232969, e-mail: nina@iwwn.com.na

Integrated Rural Development and Nature Conservation (IRDNC), PO Box 9681, Windhoek, Tel. (061) 228506/9, Fax (061) 228530, email: irdnc@iafrica.com.na

Namibia Animal Rehabilitation, Research & Educational Centre (Narrec), PO Box 11232, Windhoek, Tel. (061) 264409 or 264256, email: Liz@narrec.mac.alt.na

Namibia Business Forum for the Environment (NBFE), PO Box 3594, Windhoek, Tel. (061) 236810, Fax (061) 224141

Namibia Centre For Holistic Resource Management (HRM Centre), PO Box 23600, Windhoek, Tel./Fax (061) 228886

Namibia Environmental Education Network (NEEN), c/o Rossing Foundation, PO Box 20746, Windhoek, Tel. (061) 211721

Namibia Nature Foundation (NNF), PO Box 245, Windhoek, Tel. (061) 248345, Fax (061) 248344, email: nnf@iwwn.com.na

Namibian Evolutionary Ecology Group, PO Box 5072, Windhoek, Tel./Fax (061) 232313, email: c/o Phoebe Barnard: pb@dea.met.gov.na

Rössing Foundation, Private Bag 13214 Windhoek, Tel. (061) 211721, Fax (061) 211273

Save The Rhino Trust (SRT), PO Box 224, Swakopmund, Tel/Fax. (064) 403829

Wildlife Society of Namibia, PO Box 3508, Windhoek, Tel. (061) 241786. Namib Centre: PO Box 483, Swakopmund

World Wildlife Fund (Namibia), PO Box 9681, Windhoek, Tel. (061) 239945, Fax (061) 239799, email: sybil@life.wwf.org.na

-- Compiled by Sem Shikongo & Phoebe Barnard

Forage grasses

Andropogon chinensis, A. gayanus
Anthephora pubescens, A. schinzii
Brachiaria deflexa, B. nigropedata
Cenchrus ciliaris
Centropodia glauca
Chloris virgata
Cynodon dactylon
Dactyloctenium aegyptium
Danthoniopsis ramosa
Dichanthium annulatum
Digitaria eriantha, D. seriata
Echinochloa colona, E. stagnina
Enneapogon desvauxii, E. scoparius
Eragrostis echinochloidea, E. nindensis, E. rotifer, E. superba
Fingerhuthia africana
Monelytrum luederitzianum
Panicum maximum, P. novemnerve
Paspalum scrobiculatum
Pennisetum foermerianum, P. glaucocladum, P. mezianum
Schmidtia pappophoroides
Setaria appendiculata, S. verticillata
Stipagrostis ciliata, S. hirtigluma, S. hochstetteriana, S. obtusa, S. uniplumis
Themeda triandra
Tricholaena capensis
Triraphis schinzii
Urochloa brachyura, U. bolbodes

Forage legumes

Acacia spp.
Colophospermum mopane
Cullen biflora
Faidherbia albida
Indigofera spp.
Parkinsonia africana
Ptycholobium biflorum
Rhynchosia spp.
Sesbania spp.
Tylosema esculentum
Vigna spp.
Zornia spp.

Other forage species

Atriplex spp.
Boscia spp.
Monechma spp.
Petalidium spp.
Phaeoptilum spinosum

Wild crop relatives

Amaranthus spp.
Citrullus spp.
Corchorus spp.
Cucumis spp.
Dioscorea spp.
Gossypium spp.
Momordica spp.
Oryza spp.
Pennisetum spp.
Sesamum spp.
Solanum spp.
Sorghum spp.

Wild species with economic potential

Acanthosicyos horridus
Berchemia discolor
Harpagophytum procumbens
Schinziophyton rautanenii
Sclerocarya birrea caffra
Tylosema esculentum

Wild species of horticultural interest

Aloe spp.
Anacampseros spp.
Conophytum spp.
Crinum spp.
Cyphostemma spp.
Lithops spp.
Pachypodium spp.

Landraces of crop plants

Arachis hypogaea
Citrullus lanatus
Sorghum bicolor
Pennisetum glaucum
Vigna unguiculata, V. subterranea

Wild species threatened or locally extinct

Protea gaguedi

-- Compiled by the National Plant Genetic Resources Committee

Appendix 4 *International herbaria housing Namibian plant specimens**

Before the establishment of the National Herbarium of Namibia (WIND) in 1953, plant specimens collected in Namibia were sent to herbaria around the world, particularly in Europe. Locating these specimens today is complicated by the following:

* the **size of these herbaria** (e.g. Kew Gardens, London, has over 7 million specimens)
* the **age of the collections**, which means that many collections were made before current political boundaries were demarcated
* the **lack of computerisation in large herbaria**
* the **variety of plant name synonyms and old spellings** in herbarium accessions
* the **number of unspecified duplicates (including type specimens)** in different herbaria, making information on specimen numbers, including type specimens, potentially unreliable. Some duplicates may even be identified as different taxa.

The accompanying tables can be summarised as follows:

1. Large and important collections of Namibian specimens are held outside the country and can be mainly found in major European herbaria, especially Berlin, Kew and Munich.

2. The National Herbarium of Namibia presently houses 65000 plant specimens, mainly from Namibia. Most of the collection is post-1950.

3. The most important historic collections of Namibian plants in Southern Africa are housed in Cape Town at the South African Museum and Bolus Herbarium, and the National Botanical Institute at Pretoria has the largest collection.

An expanded version of this material, with fuller data on the collections of each herbarium and individual collectors, is available from the National Botanical Research Institute. Data are updated to 10-10-1996.

1 OVERSEAS HERBARIA

Code	Herbarium	Total Namibian specimens	Estimated no. type specs*	Computerised?	Access
AMES	Cambridge USA	?	2	50% of types	Internet
AMD	Amsterdam	?	?	partly, not Africa	
B	Berlin	few thousand	47	no	fairly easy
BM	British Museum	few	21	small portion	difficult
BR	Meise Belgium	?	3		
BTU	Berlin University	many monocots incl. live specs	1	no	
C	Copenhagen	few if any	none?	no	types fairly easy
CGE	Cambridge UK	?	?		
CORD	Cordoba Argentina	?	?		
DBN	Dublin	?	?		
E	Edinburgh	?	3		
FI	Firenze	?	1		
FR	Frankfurt	?	2		
G	Geneva	?	8	no	
GB	Göteborg	?	?		
H	Helsinki	1700	20	fully	requested list
HBG	Hamburg	?	?	no	requested list
HOH	Hohenheim	?	?		
K	Kew, London	many	60	no	difficult
L	Leiden	?	3		
LD	Lund	?	1		
LE	Leningrad	?	7		
LISC	Lisbon	?	2		
LY	Lyon	?	?		
M	Munich	25 000	88	no	fairly easy
MO	Missouri, St Louis	480 computerised	10	20%	difficult
MSTR	Münster	few, live specs		?	
OXF	Oxford UK	?	1		
P	Paris	?	?		
S	Stockholm	?	63+	no	Internet
UC	Berkeley USA	?	?		
UPS	Uppsala	?	?	5%	Internet
W	Vienna	? from 1800s	1	no	
WAG	Wageningen	?	?		
WBM	Würzburg	?	?		
Z	Zurich	?	46	no	
ZSS	SSS Zurich	149	?	fully	

** includes all forms of type specimens, e.g. holotypes and isotypes*

(continued)

2 SOUTHERN AFRICAN HERBARIA

Code	Herbarium	Total Namibian specimens	Estimated no. type specs*	Computerised?	Access
BLFU	Bloemfontein	few hundred	1	started	
BOL	Bolus, Cape Town	?	20	no	easy
GRA	Grahamstown	few	7	no	copies at WIND
J	Moss, Johannesbg	120 computerised	0	not fully	
JRAU	RAU, Johannesbg	?	?	no	
NBG	Compton, Cape Town	?	13-14	no	
NH	Natal, Durban	?	0	no	
NPB	Mtubatuba, Natal	?	?	?	
NU	Natal, Pieterm'bg	?	0	no	
PRE	NBI Pretoria	?	92	yes	
SAM	S A Museum	?	24+	no	
SRGH	Harare	few	19	no	
UWC	UWC, Cape Town	?	?		

** includes all forms of type specimens, e.g. holotypes and isotypes*
-- Compiled by Patricia Craven

Appendix 5 Viruses, bacteria, fungi and nematodes of major quarantine concern recorded in southern Africa

Species	Hosts	Species	Hosts
Viruses		**Nematodes (cont.)**	
Cassava brownstreak potyvirus	cassava	*H.typica*	polyphagous
Maize streak monogeminivirus	maize, Graminae	*Heterodera* spp.	polyphagous
		H. humuli	hops
Bacteria		*H. schachtii*	various, incl. beets
		Hirschmanniella oryzae	rice
Clavibacter michiganensis	lucerne	*Hoplolaimus* spp.	polyphagous
Erwinia cypripedii	?	*H. pararobustus*	banana, sugarcane
Pseudomonas avenae	Graminae	*H. seinhorsti*	cowpea, sugarcane
P. syringae	oats, other cereals	*Longidorus* spp.	polyphagous
Xylophilus ampelinus	grapes	*L. elongatus*	polyphagous
		L. (Paralongidorus) spp.	polyphagous
Fungi		*Meloidogyne* spp.	highly polyphagous
		M. acronea	cotton, sorghum
Asperisporium caricae	papaya	*M. africana*	coffee
Calonectria rigidiuscula	cocoa, coffee, rice	*M. arenaria*	groundnut, vegetables
Colletotrichum kahawe	coffee	*M. hapla*	various, pyrethrum
Gibberella xylarioides	coffee	*M. incognita*	highly polyphagous
Pseudophaeolus baudonii	forest trees, tea	*M. javanica*	highly polyphagous
		Pratylenchus spp.	polyphagous
Nematodes		*P. brachyurus*	groundnut
		P. coffeae	coffee, banana, yam
Anguina tritici	wheat	*P. thornei*	cereals
Aphelenchoides besseyi	rice	*P. penetrans*	polyphagous
A. ritzemabosi	crysanthemums	*P. zeae*	maize, rice
Criconemella spp.	polyphagous	*Radopholus similis*	banana, tea, spices
C. onoensis	polyphagous	*Rotylenchulus reniformis*	polyphagous
C. sphaerocephala	polyphagous	*R. parvus*	maize, sweet potato
Criconomella xenoplax	polyphagous	*R. variabilis*	maize, sweet potato
Ditylenchus africanus	groundnut	*Scutellonema* sp.	polyphagous
D. dipsaci	onion, flowers	*Trichodorus* spp.	polyphagous
Globodera rostochiensis	potato	*Paratrichodorus* spp.	polyphagous
Helicotylenchus spp.	polyphagous	*Tylenchulus* sp.	citrus
H. dihystera	polyphagous	*Xiphinema* spp.	polyphagous
H. mucronatus	polyphagous	*X. americanum*	polyphagous
H. multicinctus	banana	*X. diversicaudatum*	polyphagous
Hemicycliophora spp.	polyphagous	*X. index*	grape

-- Source: G.B. Rhodes, MAWRD (see ref. 168 in Chapter 2)

Appendix 6 Some veterinary disease-causing micro-organisms in Namibia

(see refs.98, 170, 171 in Chapter 2)

Common name	Causative agent*
Viral	
Bluetongue	Orbivirus (Reoviridae)
African horse sickness	Orbivirus (Reoviridae)
Rabies	Lyssavirus (Rabdoviridae)
African swine fever	unclassified DNA-virusiridovirus
Lumpy skin disease	Capripoxvirus
Orf / Contagious pustular dermatitis	Parapoxvirus
Rinderpest	Paramyxovirus
Newcastle disease	Paramyxovirus
Hog cholera / Classical swine fever	Pestivirus (Togaviridae)
Rift Valley fever	Phlebovirus (Bunyaviridae)
Foot-and-mouth disease	Aphthovirus (Picornaviridae)
Infectious bovine rhinotracheitis	Bovine herpesvirus 1
Bovine malignant catarrh	Alcelaphine herpesvirus 1
Papillomatosis	various Papilloma viruses
Bacterial and mycoplasmal	
Actinomycosis / Lumpy jaw	*Actinomyces bovis*
Actinobacillosis / Wooden tongue	*Actinobacillus lignieresii*
Anthrax	*Bacillus anthracis*
Brucellosis	*Brucella abortus, B. ovis, B. melitensis*
Glanders	*Pseudomonas (Actinobacillus) mallei*
Johne's disease	*Mycobacterium paratuberculosis*
Tuberculosis	*Mycobacterium bovis*
Black quarter	*Clostridium chauvoei*
Tetanus	*Clostridium tetani*
Malignant oedema	*Clostridium septicum*
Botulism	*Clostridium botulinum*
Pulpy kidney	*Clostridium perfringens*
Colibacillosis	*Escherichia coli*
Corynebacteriosis	*Corynebacterium* spp., possibly *Actinomyces pyogenes*
Dermatophilosis	*Dermatophilus congolensis* (Actinomycetales)
Footrot	*Bacteroides nodosus, Fusobacterium necrophorum*
Contagious bovine pleuropneumonia	*Mycoplasma mucoides mucoides*
Infectious bovine keratoconjunctivitis	*Moraxella bovis, Mycoplasma* spp.
Infectious ovine keratoconjunctivitis	*Mycoplasma* spp./ *Chlamydia* spp. / *Moraxella ovis*
Leptospirosis	*Leptospira* spp.
Listeriosis	*Listeria monocytogenes*
Pasteurellosis	*Pasteurella haemolytica, P. multocida*
Salmonellosis	*Salmonella* spp.
Streptococcal infections	*Streptococcus* spp.
Rickettsial/ chlamydial and fungal	
Anaplasmosis	*Anaplasma marginale*
Heartwater	*Cowdria ruminantium*
Q fever	*Coxiella burnetti*
Psittacosis / Enzootic abortion	*Chlamydia psittaci*
Ringworm/ fungal infection	*Trichophyton verrucosum, Microsporum* spp.
Protozoan	
Babesiosis	*Babesia* spp.
Dourine	*Trypanosoma equiperdum*
Nagana / trypanosomiasis	*Trypanosoma congolense, T. vivax*
Toxoplasmosis	*Toxoplasma gondii*

Scientific names and classifications were kindly provided by Dr JF Mettler & Dr G Hoffmann (ref. 171, Chapter 2)

Appendix 7 Recorded fungal diversity in Namibia

Phylum	Order	Family	Genera	Species
ASCOMYCOTA	Dothideales	Pleosporaceae	1	1
		Sporormiaceae	1	1
		incertae sedis	1	1
	Erysiphales	Erysiphaceae	1	1
	Hypocreales	Clavicipitaceae	1	1
	Pezizales	Terfeziaceae	1	1
	Sordariales	Chaetomiaceae	1	2
		Sordariaceae	1	1
BASIDIOMYCOTA	Agaricales	Agaricaceae	5	12
		Amanitaceae	1	1
		Bolbitiaceae	2	2
		Coprinaceae	1	5
		Pluteaceae	2	3
		Podaxaceae	3	4
		Strophariaceae	1	1
		Tricholomataceae	3	5
	Boletales	Boletaceae	1	1
		Gyrodontaceae	1	1
		Paxillaceae	1	1
	Cortinariales	Cortinariaceae	2	2
	Dacrymycetales	Dacrymycetaceae	1	1
	Ganodermatales	Ganodermataceae	1	1
	Lycoperdales	Broomeiaceae	1	2
		Geastraceae	1	7
		Lycoperdaceae	4	6
		Mycenastraceae	1	1
	Nidulariales	Nidulariaceae	1	2
	Phallales	Phallaceae	1	1
	Poriales	Coriolaceae	3	4
		Lentinaceae	1	2
	Schizophyllales	Schizophyllaceae	1	1
	Stereales	Hyphodermataceae	1	1
		Peniophoraceae	1	1
		Steccherinaceae	1	1
	Tulostomatales	Battarreaceae	1	1
		Phelloriniaceae	1	1
	Uredinales	Pucciniaceae	2	9
	Ustilaginales	Ustilaginaceae	5	11
CHYTRIDIOMYCOTA	Liceales	Lycogalaceae	1	1
		Physaraceae	1	1
	Stemonitales	Stemonitidaceae	1	1
OOMYCOTA	Pythiales	Pythiaceae	1	1
	Sclerosporales	Sclerosporaceae	1	1
ZYGOMYCOTA	Entomophthorales	Entomophthoraceae	1	1
	Glomales	Glomaceae	1	5
	Mucorales	Choanephoraceae	1	1
		Cunninghamellaceae	1	1
		Mucoraceae	4	5
Subtotal			72	118
		Deuteromycotina		71
TOTAL				189

**Source: National Botanical Research Institute, Windhoek*
--Compiled by Coleen Mannheimer & Kathryn Jacobson

Appendix 8 *Freshwater macro-invertebrates recorded from Namibian wetlands, with numbers of potential endemics.*

The number of species includes identified and unsubscribed species (updated from Curtis, ref. 254 in Chaper 2).

Phylum	Families	Species	Endemics
Porifera	2	3	0
Cnidaria	2	2	0
Platyhelminthes	6	9	0
Ectoprocta	2	5	0
Nematoda	6	10	1
Annelida			
Oligochaeta	5	13	1
Hirudinea	3	16	3
Mollusca			
Gastropoda	9	26	0
Bivalvia	5	13	0
Arthropoda			
Crustacea			
Ostracoda	3	52	18+
Copepoda	2	19	1
Branchiopoda			
Anostraca	3	19	6
Cladocera	5	19	1
Notostraca	1	2	0
Conchostraca*	6	15	3
Malacostraca			
Amphipoda	2	6	6
Isopoda	1	4	4
Decapoda	3	6	0
Insecta			
Ephemeroptera	6	19	0
Plecoptera	1	2	1
Trichoptera	6	35	3
Odonata	10	77	0
Diptera	13	179	14
Neuroptera	1	1	1
Coleoptera	10	200	17
Hemiptera	12	45	3
TOTAL	125	797	83+

** Conchostraca is split into the Spinicaudata and Laevicaudata by some authors.*

--Compiled by Barbara Curtis, Kevin Roberts & Shirley Bethune

Appendix 9 Preliminary list of mollusc, nematodes and arthropod agricultural pests in Namibia

Common name	Crop or place	Usual causal organism
MOLLUSCS		
Garden snail	Vegetables	*Theba pisana*

NEMATODES

The nematodes of veterinary importance in Namibia are fairly well known,[98] but almost nothing is known about phytophagous nematodes in Namibia.

Burrowing nematode	Vegetables	*Radopholus similis*

ACARI : MITES, TICKS, AND TAMPANS

Very little is known about phytophagous mites from Namibia. Acari of veterinary importance are, however, quite well recorded, as they are often vectors for animal diseases. Only the most important vectors are listed.

Blue tick	Veterinary	*Boophilus decoloratus*
Brown dog tick	Veterinary	*Rhipicephalus sangineus*
Ticks	Veterinary	*Rhipicephalus zambeziensis*
		Amblyomma variegatum
		Haemaphysalis leachi
		Hyalomma spp.
Spinose ear tick	Veterinary	*Otobius megnini*
Fowl tampan	Veterinary	*Argas persicus*
Sand tampans	Veterinary	*Ornithodorus savignyi*
		Ornithodorus moubata
Mange mites	Veterinary	*Psoroptes ovis*
		Sarcoptes sp.
		Demodex sp
		Cnemidocoptes spp.

COLLEMBOLANS : SPRINGTAILS

Lucerne flea	Lucerne	*Sminthurus viridis*

ISOPTERANS : TERMITES

Serious reduction of vegetation cover by termites can occur during droughts or in overgrazed pastures. Termite colonies reach peak densities where grass cover has been largely depleted, and pastures may not be able to recover naturally.

Northern harvester termite	Pasture/grazing	*Hodotermes mossambicus*
Southern harvester termite	Pasture/grazing	*Microhodotermes viator*
Snouted harvester termite	Pasture/grazing	*Trinervitermes trinervoides*

ORTHOPTERANS : GRASSHOPPERS, LOCUSTS & CRICKETS

Until recently, locusts have been regarded as natural disasters because of the difficulty of controlling their outbreaks. For several decades synthetic insecticides have been in use, but environmentally acceptable alternatives are urgently needed.

Armoured bush cricket	Millet, maize, sorghum	*Acantoplus discoidalis, A. longipes, A.speiseri*
Crickets	Seedbeds, gardens	Gryllidae spp.
		Brachytrupes membranaceus
		Acheta bimaculatus
Mole crickets	Irrigated gardens	*Gryllotalpa africana*
Migratory locust	Pasture & crops	*Locusta migratoria migratorioides*
Brown locust	Pasture & crops	*Locustana pardalina*
Red locust	Pasture & crops	*Nomadacris septemfasciata*
Tree locust	Trees & shrubs	*Anacridium moestum*
Elegant grasshopper	Various	*Zonocerus elegans*

(continued)

Common name	Crop or place	Usual causal organism

PHTHIRAPTERANS: LICE

Lice are very host specific, and are only of minor veterinary importance in Namibia. Severe infestations have been recorded in winter, droughts or other periods of malnutrition.

African sheep louse	Small stock	*Linognathus africanus*
Sheep leg louse	Small stock	*Linognathus pedalis*
Long-nosed cattle louse	Cattle	*Linognathus vituli*
Short-nosed cattle louse	Cattle	*Haematopinus eurysternus*
Cattle biting louse	Cattle	*Damalinia bovis*
Sheep biting louse	Sheep	*Damalinia peregrina*

HEMIPTERANS: LEAF- AND PLANTHOPPERS, APHIDS, PSYLLIDS, WHITEFLIES SCALE INSECTS AND BUGS

The order Hemiptera includes most plant-sucking insects. As a group, they have high host diversity and are well adapted to plant parasitism. Because of this diversity, nearly every crop in the world can serve as a host for hemipteran species.

Lace bug	Vegetables	*Gargaphia torresi*
Capsid bug	Vegetables	*Helopeltis* sp.
Bagrada bug	Crucifera	*Bagrada hilaris*
Twig wilters	Flowers and vegetables	*Anoplocnemis curvipes*
Shield bugs	Vegetables	*Coridius viduatus*
Stink bug	Flowers and vegetables	*Nezara viridula*
Antestia bug	Vegetables	*Antestia orbitalis*
Leaf hoppers	Various	*Cicadulina mbila*
		Hilda patruelis
Citrus psylla	Citrus	*Trioza erytreae*
Tobacco whitefly	Vegetables	*Bemisia tabaci*
Cochineal	Prickly/spineless pear	*Dactylopius* spp.
Australian bug	Various	*Icerya purchasi*
Red scale	Citrus	*Aonidiella aurantii*
Grey scale	Peppers	*Phenacoccus solani*
Aphids	Various	*Myzus persicae*
	Pines	*Pineus pini*
	Ground nuts	*Aphis craccivora*
	Cruciferae	*Brevicoryne brassicae*
	Citrus	*Toxoptera aurantii*

THYSANOPTERANS : THRIPS

Flower thrips	Various	*Frankliniella* spp.
Onion thrips	Vegetables	*Thrips tabaci*

COLEOPTERANS : BEETLES

Beetle larvae may cause damage to field crops, especially root systems, though most damage is usually on stored products.

Carpet beetles	Storage premises	*Anthrenus* spp.
Hide beetles	Hides and skins	Dermestidae spp.
Wire worms	Plant roots	Elateridae spp.
Black maize beetle	Ground nuts, maize	*Heteronychus arator*
Blister beetles	Beans	*Mylabris oculata*
Shotgun borer	Vegetables	*Heterobostrychus brunneus*
White coffee borer	Vegetables, maize	*Anthorus leuconotus*

(continued)

Appendix 9 (cont.)

Common name	Crop or place	Usual causal organism
Fig tree borer	Figs	*Phryneta* sp.
Lesser grain borer	Storage	*Rhizopertha dominica*
Granary weevil	Storage	*Sitophilus granarius*
Sweetpotato weevil	Vegetables	*Alcidodes dentipes*
Lady bird beetles	Potatoes	*Solanophila dregei*
	Vegetables	*Epilachna chrysomelina*
False wire worm	Sorghum, maize	Tenebrionidae spp.
Flour beetles	Storage	*Tribolium* spp.
White grubs	Plant roots	Scarabaeidae spp.

DIPTERANS: MOSQUITOES AND FLIES

Apart from many parasitoids and pollinators, the Diptera include a large number of important plant pests, parasites of animals including humans, and vectors of pathogenic viruses, micro-organisms, and nematodes.

Common name	Crop or place	Usual causal organism
Mosquitoes	Veterinary	Culicidae spp.
Black flies	Veterinary	*Simulium chutteri*
Biting midges	Veterinary	*Culicoides* spp.
Tsetse fly	Veterinary	*Glossina morsitans*
Biting flies	Cattle	Tabanidae spp.
Fruit flies	Various fruits	*Ceratitis capitata*
		Dacus bivittatus
Pumpkin flies	Cucurbits	*Didacus ciliatus*
		Pterandus rosa
Millet grain midge	Pearl millet	*Geromyia penniseti*
Sorghum midge	Sorghum	*Contarinia sorghicola*
Bean seed fly	Vegetables	*Delia platura*
Bean fly	Vegetables	*Ophomyia phaseoli*
Sorghum shoot fly	Sorghum	Atherigona soccata
Flies	Veterinary	Muscidae spp.
Nasal bot flies	Veterinary	*Oestris ovis*
		Gedoelstia spp.
Stomach bot flies	Veterinary	*Gasterophilus* spp.

LEPIDOPTERANS: BUTTERFLIES AND MOTHS

Lepidoptera larvae are key economic pests of agriculture and forestry worldwide. Species in the families Noctuidae and Pyralidae figure prominently as pests of vegetable and fruit crops, and secondarily as economic pests of corn.

Common name	Crop or place	Usual causal organism
Cutworms	Seedlings, vegetables	*Agrotis* spp.
Stalk borer	Maize, sorghum	*Busseola sorghicida*
Stem borer	Maize, sorghum	*Chilo partellus*
Lucerne caterpillar	Lucerne	*Colias electo*
False codling moth	Citrus	*Cryptophlebia leucotreta*
American bollworm	All crops	*Heliothis/Helicoverpa armigera*
Spiny bollworm	All crops	*Earias cupreoviridis*
Orange dog	Citrus	*Papilio demodocus*
Diamond-back moth	Cruciferae	*Plutella xylostella*
Pink stalk borer	Maize	*Sesamia calamistis*
Tobacco stem borer	Vegetables	*Scrobipalpa heliopa*
Grain moth	Storage	*Sitotroga cerealella*
African army worm	All crops, pasture	*Spodoptera exempta*
Cabbage web-worm	Cruciferae	*Hellula undalis*
Prickly pear moth	prickly/spineless pear	*Cactoblastis cactorum*
Hawk moth caterpillars	Vines, Solanaceae	Sphingidae spp.
Semi-looper	Potatoes, cotton	*Chrysodeixis* sp.
		Anomis flava
Looper	Vegetables	*Trichoplusia* sp.
Potato tuber moth	Solanaceae	*Phthorimaea operculella*
False hawk moths	Veterinary	*Sphingomorpha* sp.
Silk cocoons	Veterinary	*Gonometa postica*

— Compiled by E. Marais & B. Wohlleber (see refs. 98 and 169 in Chapter 2)

Appendix 10 Conservation status categories used to classify reptile, amphibian and mammal fauna in Namibia

Because detailed population data are unavailable for most species, Namibia is so far generally unable to apply the recent IUCN red data categories (ref. 338 in Chapter 2), which rely on accurate population estimates.

EXTINCT Taxa definitely not located in the wild in Namibia during the past 50 years, and supported by reasonable evidence that the species is no longer locally extant. Reintroductions from non-Namibian populations do not negate this status.

ENDANGERED Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so reduced that they are deemed to be in immediate danger of extinction.

VULNERABLE Taxa believed likely to move into the ENDANGERED category in the future if present causal factors continue operating. Included are taxa of which all or most of the populations are decreasing due to overexploitation, intensive destruction of habitat or other environmental disturbance: taxa with local populations which have been depleted; those whose ultimate security is not assured; and taxa with populations that are still abundant but under threat throughout their range.

RARE Taxa with small populations not thought to be presently ENDANGERED or VULNERABLE, but potentially at risk. These species can be thinly scattered over an extensive range in Namibia. They may be species which are seldom recorded but may be more common than supposed, although there is some indication that their numbers are low. Also includes taxa which have a restricted geographical range in Namibia, have an intermediate endemicity (26% - 74% of global population in Namibia), and may be locally abundant. Since the taxon's overall range is limited, it may not be SECURE.

INDETERMINATE Taxa known to be ENDANGERED, VULNERABLE, or RARE but for which insufficient information is currently available to assign them to the appropriate category.

INSUFFICIENTLY KNOWN Taxa suspected but not known to belong to any of the above categories, because of poor information.

SECURE No special threat status. Taxa with no known local conservation problems, and no reason to believe that the conservation status of the taxa will change. A decline in status would, however indicate a deterioration of the Namibian environment.

ENDEMIC Restricted to, or found almost exclusively in Namibia. This category states a national obligation to conserve the taxon. No conservation problems are implied. Endemic in the context of amphibians, reptiles and mammals includes all taxa with 75% or more of the entire taxon's population residing in Namibia. In the case of most smaller terrestrial vertebrates, estimates are based on proportions of geographic range/required habitat.

PERIPHERAL Taxa with a limited distribution in Namibia (25% or less), whose main distribution falls outside the nation's boundaries. In addition, the Namibian population could be threatened and the status should be monitored. Namibia is not the sole guardian, but declines reflect a deterioration of the local environment affecting the taxon's conservation status. Includes taxa with limited overall distributions (therefore VULNERABLE), taxa with specific (and vulnerable) habitat requirements, and taxa of international concern (*e.g.* cetaceans & marine turtles). Often used as an additional suffix to a threatened category. Does not include VAGRANTS, individuals of mobile species, for which Namibia has minimal responsibility.

STATUS PROVISIONAL (SP) Qualifier suffix attached to conservation status categories, indicating inadequate information on the taxon's systematc and/or biogeographical status. Further information would probably change the species' conservation status ranking, and is given in brackets (*e.g.* taxonomy).

NOT YET RECORDED Taxa not yet recorded from Namibia, but because of known habitat/ distribution and environmental factors, can reasonably be expected to occur. No conservation status ranking is implied in this definition. However, most taxa would probably be initially classified as 'PERIPHERAL' or 'RARE.' The expected conservation status is sometimes appended to this category. This category implies the qualifier suffix SP (STATUS PROVISIONAL).

NOT YET CONFIRMED TO OCCUR Taxa previously recorded, but which need confirming.

-- Compiled by Mike Griffin

Appendix 11 *List of birds endemic and near-endemic to Namibia and southern Africa* (including south-west arid zone species) with c. 40% or more of their world population within Namibia. Included are species with a southern African population isolated from a similarily sized or smaller population elsewhere in Africa, usually East Africa, and (c) special cases where Namibia sometimes supports important components of the world population.

a Namibian endemic species

Hartlaub's francolin *Francolinus hartlaubi*
Rüppell's korhaan *Eupodotis rueppellii*
Damara tern *Sterna balaenarum*
Rüppell's parrot *Poicephalus rueppellii*
Rosyfaced lovebird *Agapornis roseicollis*
Violet woodhoopoe *Phoeniculus damarensis*
Monteiro's hornbill *Tockus monteiri*
Dune lark *Certhilauda erythrochlamys*
Barlow's lark *Certhilauda barlowi*
Gray's lark *Ammomanes grayi*
Carp's tit *Parus carpi*
Barecheeked babbler *Turdoides gymnogenys*
Herero chat *Namibornis herero*
Rockrunner *Achaetops pycnopygius*
Whitetailed shrike *Lanioturdus torquatus*

b Southern African endemic species

Ostrich *Struthio camelus*
African penguin *Spheniscus demersus*
Cape gannet *Morus capensis*
Cape cormorant *Phalacrocorax capensis*
Bank cormorant *Phalacrocorax neglectus*
Crowned cormorant *Phalacrocorax coronatus*
Slaty egret *Egretta vinaceigula*
South African shelduck *Tadorna cana*
Cape shoveller *Anas smithii*
Maccoa duck *Oxyura maccoa*
Pale chanting goshawk *Melierax canorus*
Pygmy falcon *Polihierax semitorquatus*
Orange River francolin *Francolinus levaillantoides*
Redbilled francolin *Francolinus adspersus*
Kori bustard *Ardeotis kori*
Ludwig's bustard *Neotis ludwigii*
Whitequilled black korhaan *Eupodotis afraoides*
African black oystercatcher *Haematopus moquini*
Chestnutbanded plover *Charadrius pallidus*
Burchell's courser *Cursorius rufus*
Doublebanded courser *Smutsornis africanus*
Hartlaub's gull *Larus hartlaubii*
Namaqua sandgrouse *Pterocles namaqua*
Burchell's sandgrouse *Pterocles burchelli*
Doublebanded sandgrouse *Pterocles bicinctus*
Bradfield's swift *Apus bradfieldi*
Whitebacked mousebird *Colius colius*
Southern yellowbilled hornbill *Tockus leucomelas*
Bradfield's hornbill *Tockus bradfieldi*
Acacia pied barbet *Tricholaema leucomelas*
Monotonous lark *Mirafra passerina*
Clapper lark *Mirafra apiata*
Sabota lark *Mirafra sabota*
Longbilled lark *Certhilauda curvirostris*
Barlow's lark *Certhilauda barlowi*
Spikeheeled lark *Chersomanes albofasciata*
Pinkbilled lark *Spizocorys conirostris*
Sclater's lark *Spizocorys sclateri*
Stark's lark *Eremalauda starki*
Greybacked finchlark *Eremopterix verticalis*
Blackeared finchlark *Eremopterix australis*
Greater striped swallow *Hirundo cucullata*
South African cliff swallow *Hirundo spilodera*
Ashy tit Parus *cinerascens*
Cape penduline tit *Anthoscopus minutus*
Pied babbler *Turdoides bicolor*
Redeyed bulbul *Pycnonotus nigricans*
Shorttoed rock thrush *Monticola brevipes*
Mountain chat *Oenanthe monticola*
Tractrac chat *Cercomela tractrac*
Sicklewinged chat *Cercomela sinuata*
Karoo chat *Cercomela schlegelii*
Anteating chat *Myrmecocichla formicivora*
Karoo robin *Erythropygia coryphaeus*
Kalahari robin *Erythropygia paena*
Titbabbler Parisoma *subcaeruleum*
Layard's titbabbler *Parisoma layardi*
Karoo eremomela *Eremomela gregalis*
Barred warbler *Calamonastes fasciolatus*
Cinnamonbreasted warbler *Euryptila subcinnamomea*
Greybacked cisticola *Cisticola subruficapilla*
Blackchested prinia *Prinia flavicans*
Spotted prinia *Prinia hypoxantha*
Rufouseared warbler *Malcorus pectoralis*
Marico flycatcher *Melaenornis mariquensis*
Chat flycatcher *Melaenornis infuscatus*
Pririt batis *Batis pririt*
Grassveld pipit *Anthus cinnamomeus*
Longbilled pipit *Anthus similis*
Crimsonbreasted shrike *Laniarius atrococcineus*
Bokmakierie *Telophorus zeylonus*
Whitecrowned shrike *Eurocephalus anguitimens*
Burchell's starling *Lamprotornis australis*
Palewinged starling *Onychognathus nabouroup*
Whitebellied sunbird *Nectarinia talatala*
Dusky sunbird *Nectarinia fusca*
Cape white-eye *Zosterops pallidus*
Redbilled buffalo weaver *Bubalornis niger*
Sociable weaver *Philetairus socius*
Cape sparrow *Passer melanurus*
Scalyfeathered finch *Sporopipes squamifrons*
Chestnut weaver *Ploceus rubiginosus*
Violeteared waxbill *Uraeginthus granatinus*
Redheaded finch *Amadina erythrocephala*
Shafttailed whydah *Vidua regia*
Blackheaded canary *Serinus alario*
Yellow canary *Serinus flaviventris*
Whitethroated canary *Serinus albogularis*
Cape bunting *Emberiza capensis*
Larklike bunting *Emberiza impetuani*

c Special cases

Blacknecked grebe *Podiceps nigricollis*
Greater flamingo *Phoenicopterus ruber*
Lesser flamingo *Phoeniconaias minor*
Blue crane *Anthropoides paradiseus*
Cinderella waxbill *Estrilda thomensis*

-- Compiled by Chris Brown, Alice Jarvis, Tony Robertson & Rob Simmons

Appendix 12 Threatened Namibian birds classified as Critically Endangered, Endangered and Vulnerable

Critically Endangered species

African penguin *Spheniscus demersus*
Great crested grebe *Podiceps cristatus*
Whitebacked night heron *Gorsachius leuconotus*
Saddlebilled stork *Ephippiorhynchus senegalensis*
Egyptian vulture *Neophron percnopterus*
Cape griffon *Gyps coprotheres*
Western banded snake eagle *Circaetus cinerascens*
Wattled crane *Bugeranus carunculatus*
Crowned crane *Balearica regulorum*
African finfoot *Podica senegalensis*
Blackcheeked lovebird *Agapornis nigrigenis*
Pel's fishing owl *Scotopelia peli*

Endangered species

White pelican *Pelecanus onocrotalus*
Pinkbacked pelican *Pelecanus rufescens*
Cape gannet *Morus capensis*
Crowned cormorant *Phalacrocorax coronatus*
Slaty egret *Egretta vinaceigula*
Black stork *Ciconia nigra*
Greater flamingo *Phoenicopterus ruber*
Lesser flamingo *Phoeniconaias minor*
Whiteheaded vulture *Trigonoceps occipitalis*
Bateleur *Terathopius ecaudatus*
Black sparrowhawk *Accipiter melanoleucus*
African goshawk *Accipiter tachiro*
Blue crane *Anthropoides paradiseus*
Stanley's bustard *Neotis denhami*
Damara tern *Sterna balaenarum*
African skimmer *Rhynchops flavirostris*
Greyheaded parrot *Poicephalus cryptoxanthus*
Ground hornbill *Bucorvus leadbeateri*
Olive woodpecker *Mesopicus griseocephalus*
Rufoustailed palm thrush *Cichladusa ruficauda*
Greyheaded bush shrike *Malaconotus blanchoti*
Cinderella waxbill *Estrilda thomensis*

Vulnerable species

Bittern *Botaurus stellaris*
Marabou stork *Leptoptilos crumeniferus*
Yellowbilled stork *Mycteria ibis*
Sacred ibis *Threskiornis aethiopicus*
Glossy ibis *Plegadis falcinellus*
Hadeda ibis *Bostrychia hagedash*
Hooded vulture *Necrosyrtes monachus*
Lappetfaced vulture *Torgos tracheliotus*
Cuckoo hawk *Aviceda cuculoides*
Bat hawk *Macheiramphus alcinus*
Tawny eagle *Aquila rapax*
Ayre's eagle *Hieraaetus ayresii*
Martial eagle *Polemaetus bellicosus*
African fish eagle *Haliaeetus vocifer*
African marsh harrier *Circus ranivorus*
Grey kestrel *Falco ardosiaceus*
Rednecked francolin *Francolinus afer*
Crested guineafowl *Guttera pucheran*
Blackrumped buttonquail *Turnix hottentotta*
Blackbellied korhaan *Eupodotis melanogaster*
African black oystercatcher *Haematopus moquini*
Chestnutbanded plover *Charadrius pallidus*
Redwinged pratincole *Glareola pratincola*
Rock pratincole *Glareola nuchalis*
Hartlaub's gull *Larus hartlaubii*
Caspian tern *Hydroprogne caspia*
Swift tern *Sterna bergii*
Schalow's lourie *Tauraco schalowi*
Emerald cuckoo *Chrysococcyx cupreus*
Copperytailed coucal *Centropus cupreicaudus*
Wood owl *Strix woodfordii*
Cape eagle owl *Bubo capensis*
Natal nightjar *Caprimulgus natalensis*
Boehm's spinetail *Neafrapus boehmi*
Narina trogon *Apaloderma narina*
Pygmy kingfisher *Ispindina picta*
Trumpeter hornbill *Bycanistes bucinator*
Crowned hornbill *Tockus alboterminatus*
African broadbill *Smithornis capensis*
Arnot's chat *Thamnolaea arnoti*
Natal robin *Cossypha natalensis*
Great swamp warbler *Acrocephalus rufescens*
Redfaced cisticola *Cisticola erythrops*
Croaking cisticola *Cisticola natalensis*
Sousa's shrike *Lanius souzae*
Yellowbilled oxpecker *Buphagus africanus*
Malachite sunbird *Nectarinia famosa*
Coppery sunbird *Nectarinia cuprea*
Purplebanded sunbird *Nectarinia bifasciata*
Lesser double collared sunbird *Nectarinia chalybe*
Goldenbacked pytilia *Pytilia afra*
Broadtailed paradise whydah *Vidua obtusa*

— *Compiled by Chris Brown*

Appendix 13 Freshwater fish species of conservation concern

Austroglanis sclateri	Rock catfish	Apparently rare, endemic to Orange River system
Barbus breviceps	Shorthead barb	Found in isolated pools in Otjihipa Mountains near the Kunene River, still under investigation
Barbus hospes	Namaqua barb	Endemic to lower Orange River and Fish River, abundant but vulnerable due to its restricted range
Barbus kimberleyensis	Largemouth yellowfish	Present but declining in the Orange River system
Chetia welwitschi	Angolan happy	Known only from museum specimens, but present in the Kunene River
Clariallabes platyprosopos	Broadhead catfish	Rare red data species from the Okavango and upper Zambezi Rivers, still under investigation
Clariallabes sp.		Undescribed species found in Kunene River in 1992
Clarias cavernicola	Cave catfish	Endangered species endemic to the Aigamas Cave near Otavi, threatened by lowering of water table
Kneria maydelli	Kunene kneria	Little-studied, known only from the Kunene River
Nothobranchius sp.	Caprivi killifish	Endangered species endemic to the Caprivi Region, remains undescribed, threatened by road building and pollution
Sargochromis coulteri	Kunene happy	Endemic to the Kunene River
Schwetzochromis machadoi	Kunene dwarf happy	Endemic to the Kunene River, although abundant
Thoracochromis albolabris	Thick-lipped happy	Endemic to the Kunene River
Thoracochromis buysi	Namib happy	Endemic to the Kunene River, although abundant
Tilapia guinasana	Otjikoto tilapia	Endangered species endemic to Namibian sinkhole lakes, threatened by lowering of water table in Lake Guinas which will impede breeding

— Compiled by Clinton Hay

INDEX

please refer also to Table of Contents

A

B

C

D

E

L

M

N

O

T

U

V

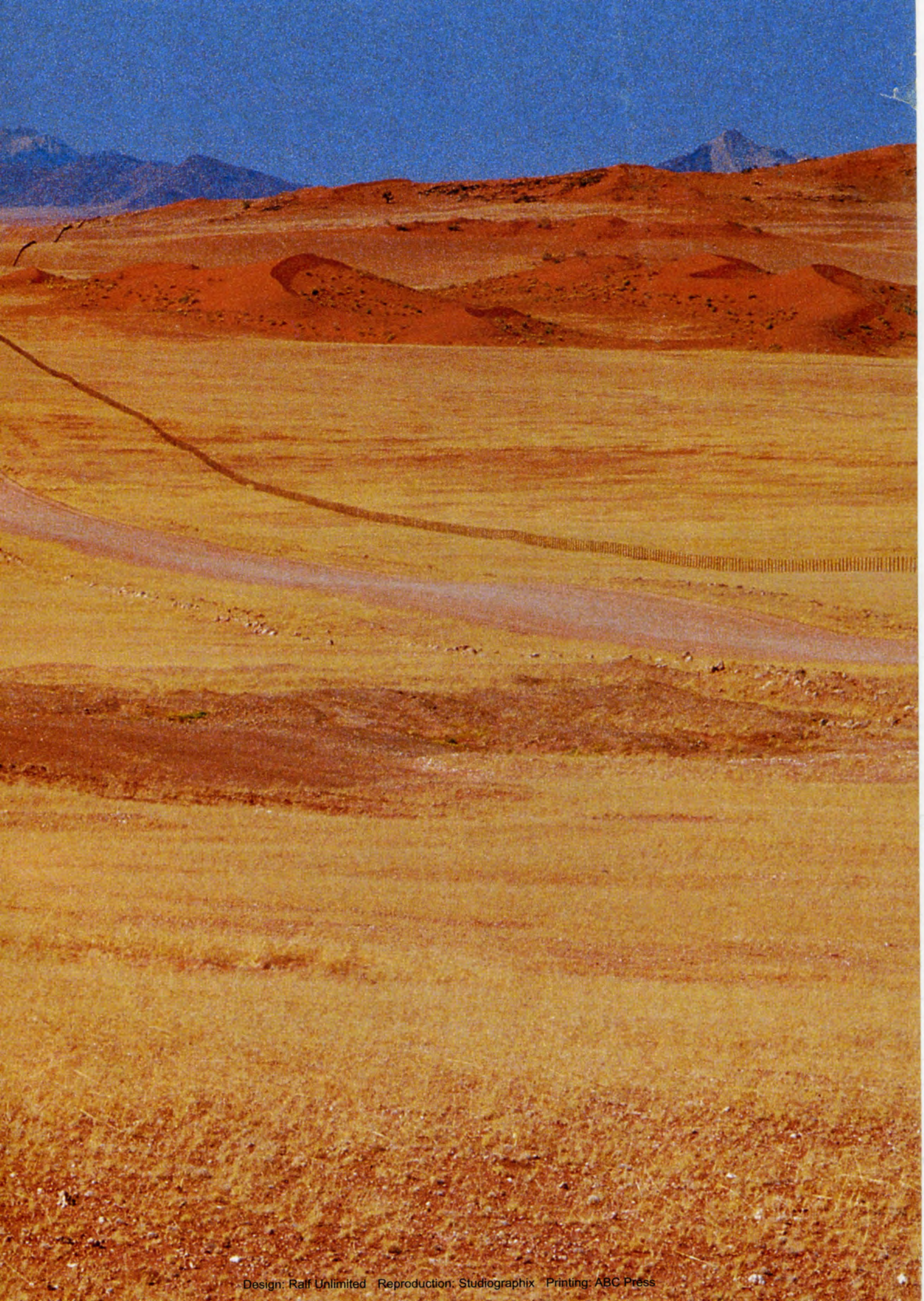
W

X

Y

Z

— compiled by Conny Pimenta and Phoebe Barnard



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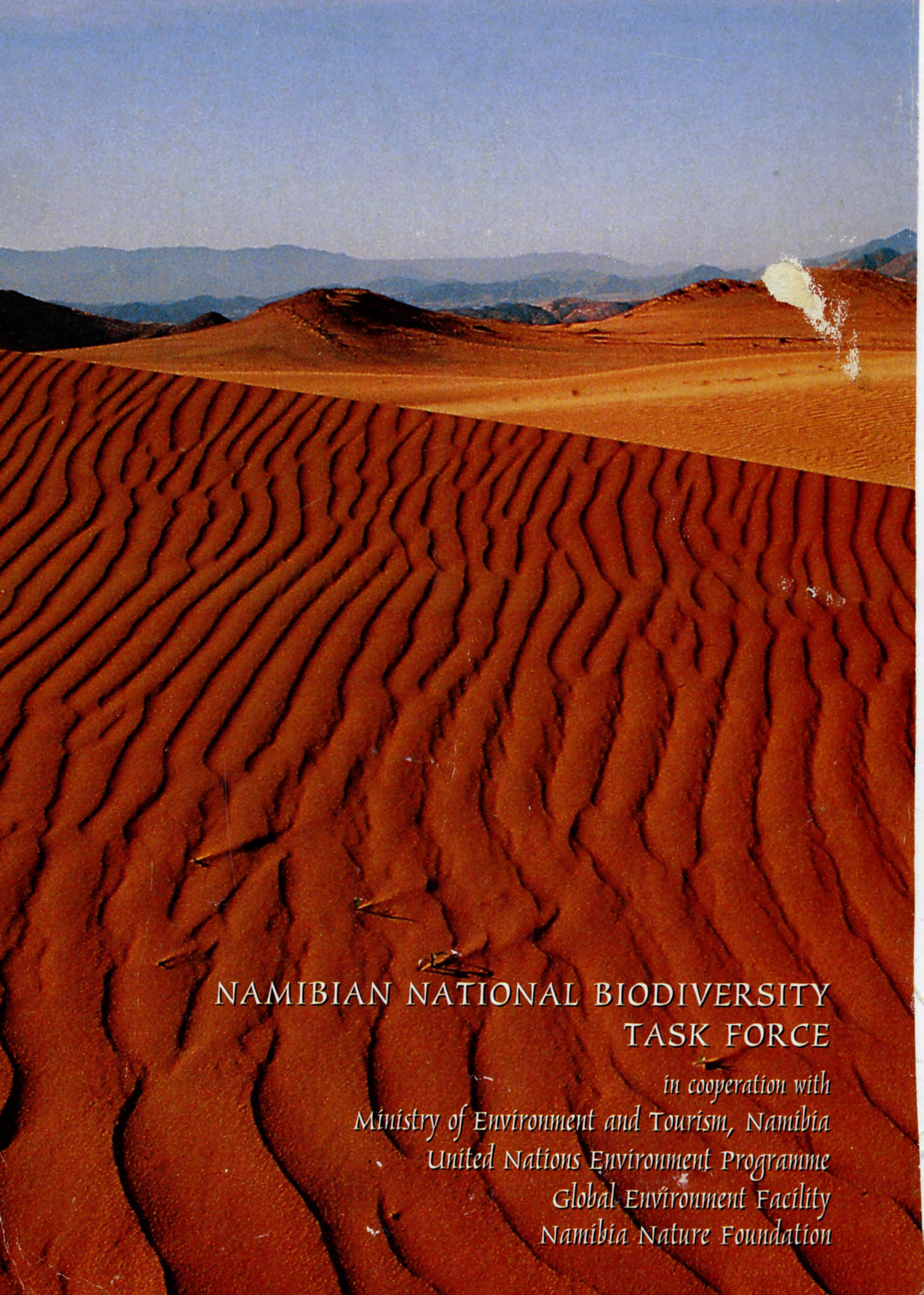
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