



AFRICAN WILDLIFE FOUNDATION

FOUR CORNERS

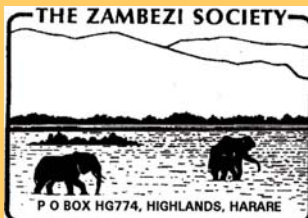
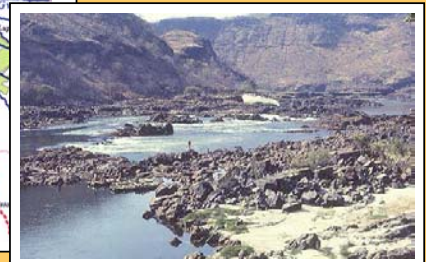
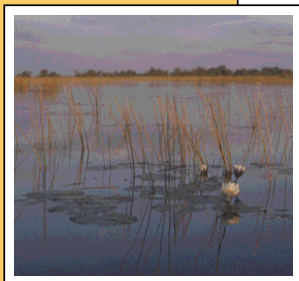
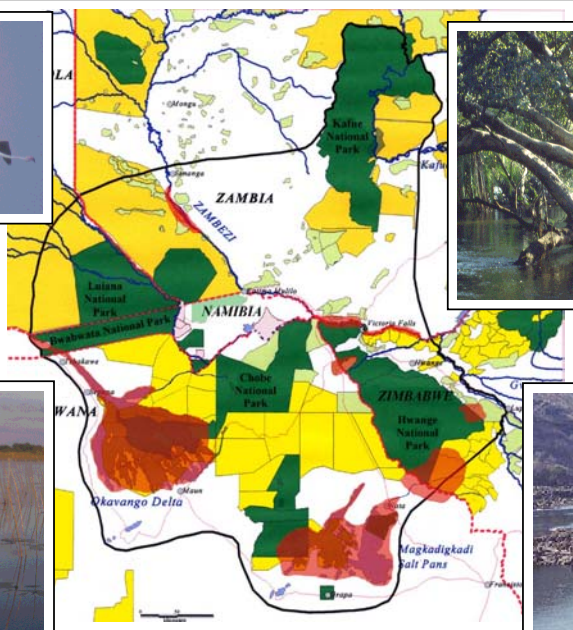
TBNRM PROJECT

Funded by USAID through the Regional Office for Southern Africa



BIODIVERSITY of the FOUR CORNERS AREA

TECHNICAL REVIEWS



Produced for
The African Wildlife Foundation
By
THE ZAMBEZI SOCIETY
And
BIODIVERSITY FOUNDATION FOR AFRICA



Published for
The African Wildlife Foundation's
FOUR CORNERS TBNRM PROJECT
 by
THE ZAMBEZI SOCIETY and
THE BIODIVERSITY FOUNDATION FOR AFRICA
2004



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The Zambezi Society and The Biodiversity Foundation for Africa are working as partners within the African Wildlife Foundation's Four Corners TBNRM project. The Biodiversity Foundation for Africa is responsible for acquiring technical information on the biodiversity of the project area. The Zambezi Society will be interpreting this information into user-friendly formats for stakeholders in the Four Corners area, and then disseminating it to these stakeholders.

THE BIODIVERSITY FOUNDATION FOR AFRICA (BFA) is a non-profit making Trust, formed in Bulawayo in 1992 by a group of concerned scientists and environmentalists. Individual BFA members have expertise in biological groups including plants, vegetation, mammals, birds, reptiles, fish, insects, aquatic invertebrates and ecosystems. The major objective of the BFA is to undertake biological research into the biodiversity of sub-Saharan Africa, and to make the resulting information more accessible. Towards this end it provides technical, ecological and biosystematic expertise.

THE ZAMBEZI SOCIETY was established in 1982. Its goals include the conservation of biological diversity and wilderness in the Zambezi Basin through the application of sustainable, scientifically sound natural resource management strategies. Through its skills and experience in advocacy and information dissemination, it interprets biodiversity information collected by specialists like the Biodiversity Foundation for Africa and uses it to provide a technically sound basis for the implementation of conservation projects within the Zambezi Basin.

THE PARTNERSHIP between these two agencies was formed in 1996 as a result of mutual recognition of their complementarity. They have previously worked together on several major projects, including the biodiversity component of IUCN's Zambezi Basin Wetland project and the evaluation of biodiversity in Tete province described in detail in the first Four Corners TBNRM Biodiversity Information Package.

ISBN 0-7974-2834-8

RECOMMENDED CITATION:

Timberlake, J.R. & Childes, S.L. 2004. *Biodiversity of the Four Corners Area: Technical Reviews. Volume One* (Chapters 1-4).

Occasional Publications in Biodiversity No 15,
 Biodiversity Foundation for Africa, Bulawayo/Zambezi Society, Harare, Zimbabwe.

INTRODUCING....



AFRICAN WILDLIFE FOUNDATION

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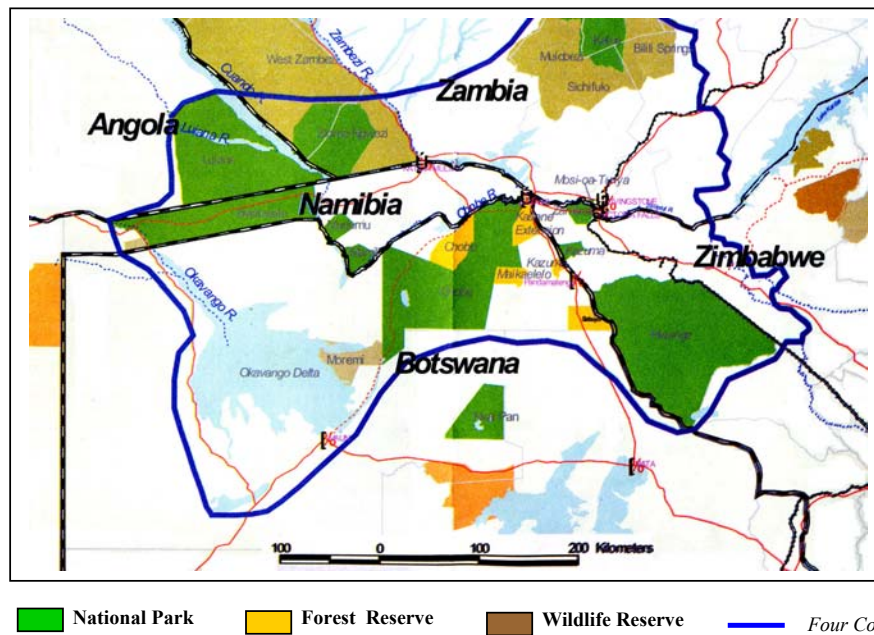


FOUR CORNERS TBNRMA INITIATIVE

The **Four Corners Transboundary Natural Resources Management Area (TBNRMA) Initiative** is being implemented by the **African Wildlife Foundation (AWF)** in collaboration with various regional partners in the area defined as Chobe-Hwange-Mosi-Oa-Tunya-Capriivi-Kafue. The initiative is supported by the United States Agency for International Development (USAID) Regional Center for Southern Africa (RCSA).

The Four Corners area covers some 220,000 km². Protected lands within it include the Hwange and Zambezi National Parks in Zimbabwe; the southern part of Kafue National Park, the Mosi-Oa-Tunya and Sioma Ngwezi National Parks in Zambia; and the Chobe National Park and Moremi Wildlife Reserve in Botswana, the Mudumo, Mamili and Bwabwata National Parks in Namibia. These cover an estimated 115,953 km² or just over 52% of the area.

Illustrative map of the Four Corners Area



The “Four Corners” initiative aims to provide the enabling environment (opportunities and mechanisms) for increased cooperation among the four constituent country interests in the management of the natural resources that are shared among them, particularly water, migratory wildlife and critical ecosystems.

AWF has packaged the Four Corners TBNRMA Initiative into a set of interrelated four key results that when achieved, should contribute to a significant increase in the adoption of sustainable natural resource management practices in shared water and wildlife resources. Such practices include natural resource management plans, ecological monitoring systems and conservation business ventures. The adoption of these viable practices in the four countries will only be made possible through the enabling environment that the initiative should provide. The four sets of results also form the four components of the project.

INTRODUCING....



AFRICAN WILDLIFE FOUNDATION

The *AFRICAN WILDLIFE FOUNDATION* is an international conservation organization that has been working solely in Africa since 1961. Most of AWF's work has been in East and Central Africa but it has now expanded to include Southern Africa.

The mission of AWF is as follows: *The African Wildlife Foundation, together with the people of Africa, works to ensure that the wildlife and wild lands of Africa will endure for ever.* To effect this mission across the continent, AWF has condensed its program operations into two essential themes, which are synergistic in application:

Landscape-level conservation through the AWF-African Heartlands Program: African Heartlands are large African landscapes of exceptional wildlife and natural value extending across state, private, and community lands. Heartlands are further defined in ecological, economical, socio-political, cultural and institutional terms. AWF works with landholders, governments, and others in the African Heartlands to conserve wild species, communities, and natural processes. A key tool for landscape conservation work is the heartlands planning process that prioritises what needs to be conserved in a particular landscape and rallies stakeholders to craft management strategies for conservation.

Several heartlands initiatives are currently being implemented with partners throughout Africa:

- East and Central Africa: Maasai Steppe; Kilimanjaro; Samburu; and Greater Virunga.
- Southern Africa: Lower Zambezi; Upper Zambezi; Limpopo.

Livelihood impact through the AWF-Conservation Service Centers (CSCs) Program. CSCs are small, multi-disciplinary teams of professionals based in strategic locations. CSCs prepare, broker, and sustain conservation business ventures to bring about positive economic and conservation impact. CSCs typically service beneficiaries situated in heartlands by offering a suite of services such as business planning, legal and contractual services, fund management, community mobilization. CSCs are currently located in:

- Victoria Falls, Zimbabwe;
- Livingstone, Zambia;
- Arusha, Tanzania;
- White River, South Africa;
- Nairobi, Kenya.

The two programs are inter-related. The livelihoods program is tasked to leverage conservation as a land use in strategic parts of landscape where AWF is working. Connectivity between protected areas is often a challenging issue. AWF is concerned that the necessity for economic development is compatible with biodiversity conservation and strives to ensure that it is an asset and not a liability in conserving wildlife habitat. Therefore, human livelihoods and wildlife habitats are locked in a dialectic that could be characterized by conflict or mutual benefit. Consequently, AWF wants tourism and natural resource enterprise to become the optimal and preferred land use in selected priority landscapes in order that Africa's unique wildlife is conserved in perpetuity.

ACKNOWLEDGEMENTS

In addition to all the authors of the chapters in this document, The Zambezi Society and the Biodiversity Foundation for Africa wish to thank the following for peer review or additional assistance:-

John Burrows
Colin Craig
Barbara Curtis
Cornell Dudley
Kevin Dunham
Peter Frost
Debbie Gibson
Mike Griffin
Michael Irwin
Bas Jongeling
Linley Lister
Gillian Maggs
Anthony Mapaura
Brian Marshall
Susan Ringrose

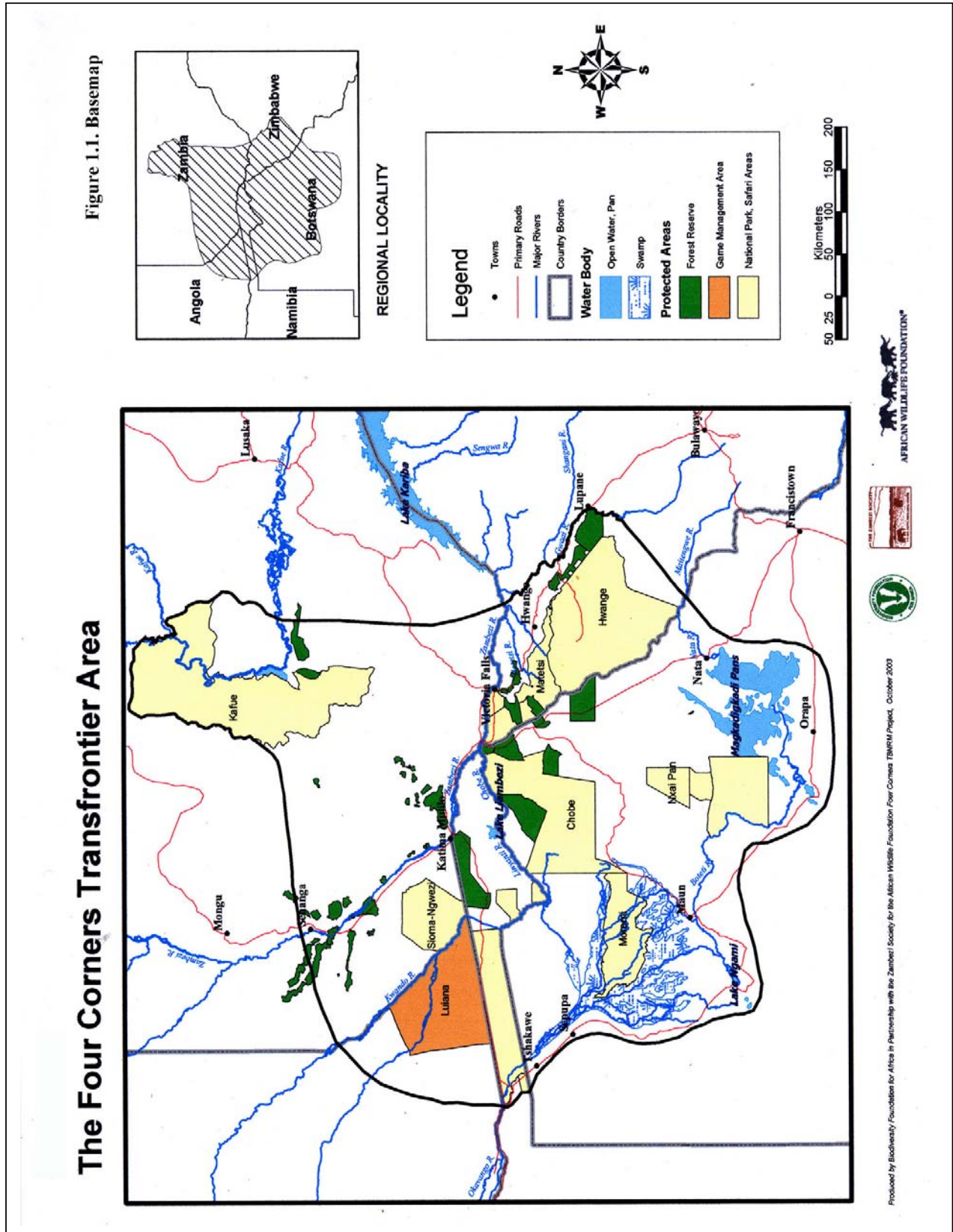
We also wish to thank Henry Mwima, Nesbert Samu, Othusitse Lekoko, Daudi Sumba, Gitonga Kathurima, Maureen Mashingaidze and Simon Metcalfe of the African Wildlife Foundation

CHAPTER 1. BIODIVERSITY OF THE FOUR CORNERS AREA: INTRODUCTION AND OVERVIEW

CONTENTS

FRONT COVER	
PUBLISHERS' DETAILS	i
THE AWF FOUR CORNERS TBNRM INITIATIVE (general information)	ii
INTRODUCING THE AFRICAN WILDLIFE FOUNDATION	iii
ACKNOWLEDGEMENTS	iv
TABLES	v
FIGURES	v
CHAPTER 1. BIODIVERSITY OF THE FOUR CORNERS AREA:	1
INTRODUCTION AND OVERVIEW	1
1.1 INTRODUCTION	1
1.2 AREA DESCRIPTION.....	1
1.2.1 Protected and Wildlife Management Areas.....	3
1.2.2 Geomorphology.....	3
1.3 MAIN FINDINGS ON BIODIVERSITY.....	3
1.3.1 Ecological Processes	5
1.3.2 Vegetation and Plants.....	6
1.3.3 Mammals.....	7
1.3.4 Birds	8
1.3.5 Reptiles and Amphibians.....	9
1.3.6 Fish	10
1.3.7 Invertebrates	11
1.3.8 Animal Movements.....	12
1.3.9 Elephant Populations and Impacts	12
1.3.10 Gaps in Knowledge.....	13
1.4 CONSERVATION ISSUES	14
1.4.1 Species of Concern / Interest.....	14
1.4.2 Flagship Species.....	15
1.4.3 Areas of Interest	16
1.4.4 Value of a Transfrontier Approach to Conservation.....	21
1.4.5 Effects of Climate Change	22
1.5 CONCLUSIONS.....	23
1.6 RECOMMENDATIONS	24
TABLES	
Table 1.1. Protected areas within the Four Corners area (in km ²).	4
Table 1.2. Overall state of knowledge on biodiversity (species composition and distribution) across the Four Corners area	5
Table 1.3. Total number of species (including subspecies and varieties), endemics (including near-endemics) and threatened species by group within the Four Corners area.	5
Table 1.4. Key or determinant species in the Four Corners Area.	14
Table 1.5. "Flagship" species of the Four Corners area.	16
Table 1.6. Threats to biodiversity and impacts upon ecological processes for major Four Corners habitats.....	17
FIGURES	
Figure 1.1 Basemap of the Four Corners TBNRM Area	vi
Figure 1.2 Main areas of biodiversity interest within the Four Corners TBNRM Area	19

Figure 1.1 Basemap of the Four Corners TBNRM Area



CHAPTER 1. BIODIVERSITY OF THE FOUR CORNERS AREA: INTRODUCTION AND OVERVIEW

Jonathan Timberlake & Susan Childes

1.1 INTRODUCTION

One of the main proposed outputs from the subgrant awarded by the African Wildlife Foundation (AWF) to the Biodiversity Foundation for Africa (BFA) / Zambezi Society partnership was a series of Technical Reviews on a range of biological groups and processes. The 14 reviews, presented in Chapters 2 to 15, are an account of our current knowledge on each topic and of the major gaps in it. They provide an assessment of what we know from a conservation perspective, and give an indication of the priority conservation issues for future study. Monitoring, the possible impacts of global climate change, and the value of a transfrontier approach to conservation for the area are also addressed.

Chapter 2 (Moore) paints the geomorphological background to the area and describes what we know of landscape changes, especially over the last 2 million years. The area has seen many changes in hydrology, and these have had a significant impact on the composition and distribution of biodiversity today. This is followed by a chapter outlining the major ecological processes affecting the area today, and a chapter describing the area's vegetation and what we know about it, including an account of the numerous vegetation surveys. Eight chapters covering a range of taxonomic groups (plants, mammals, birds, reptiles and amphibians, fish, butterflies, aquatic invertebrates, soil fauna) come next. Each gives an account of what we know about the group, outlines the main scientific literature relevant to the Four Corners area, and discusses the species, areas and issues important for conservation in that group. Where possible a species list is provided, and an indication of endemic and threatened species. The groups were initially chosen on the basis of their significance and whether sufficient useful information on them could be obtained. Finally, there are three reviews covering specific issues. Movements of large mammals across the area are discussed, showing the importance of a transfrontier approach to conservation and the problems posed by veterinary fences and habitat fragmentation. Elephants are not only the most charismatic animals of the Four Corners area, but one of the most important. Their numbers, distribution and movements are described in Chapter 14 (Hoare), while a comprehensive account of their impacts on other biodiversity, particularly vegetation, in the woodlands of south-central Africa is given in Chapter 15 (Conybeare).

The purpose of the reviews, and of this overview and synthesis, is to assist AWF and other interested conservation agencies by providing a sound technical base and rationale for future conservation interventions. This is enhanced by the production, based on information presented here, of more readable publications designed for a broader audience by The Zambezi Society under the same subgrant.

1.2 AREA DESCRIPTION

Covering over 322,000 km² of the continental plateau of south central Africa, the Four Corners area includes the south east corner of Angola, the Caprivi Strip in Namibia east of the Kavango River, and the Okavango Delta and Makgadikgadi pans in Botswana. In north west Zimbabwe it includes northern Tsholotsho communal land and areas north and east to the Gwayi River, while in Zambia it covers the south west Zambia corner north to Senanga. All of the Kafue National Park is included, but not the Kafue Flats (Figure 1.1 Basemap).

The extent of the area covered by these reviews differs from that used in some recent AWF publications (which is around 220,000 km²). We have adopted a more biological and inclusive approach, looking at ecological processes and species ranges as well as conservation issues. The Barotse floodplains and Kafue Flats were omitted from the reviews as they were adequately covered by similar reviews produced under the IUCN Zambezi Basin Wetlands Project (see Timberlake 2000¹), while the whole Kafue National Park and adjacent Game Management Areas were incorporated as it was intended initially that they would form part of the TFCA. The Makgadikgadi Pans in Botswana were included as, although a very different habitat, they have strong biological links to both the Okavango and Hwange drainages.

Geographically, the area is centred around the point where a number of major southward-draining rivers joined in the past, forming the palaeo-Upper Zambezi river (Moore, Chapter 2). Much of the drainage from a vast swathe of the plateau passed through here around 0.5-1 million years ago, forming a number of large lakes now only discernible by the presence of extensive calcareous lacustrine deposits. Virtually the entire area is now covered in a mantle of wind-blown Kalahari sands of varying depth. There is only a limited extent of outcropping bedrock - principally basalt and Karoo sandstone in the Matetsi/Victoria Falls area.

A number of unifying features of climate, geology and topography characterise the area:

- a continental interior location, within an narrow altitude range of ~ 900 to 1200 m;
- a savanna climate, with a dry season of 5-8 months;
- a rainfall gradient, from around 900 mm mean annual rainfall in the north to about 400 mm in the south;
- evapotranspiration rates that increase from north to south and exceed rainfall in all months;
- occasional severe winter frosts, increasing in frequency and severity to the south; and
- a mineral-poor surface geology consisting of Kalahari sands or deeply weathered basement rocks, with occasional exposures of mineral-rich rocks.

One of the area's key biological attributes is that it is a meeting place for the biodiversity of the old Upper Zambezi system with that of the Kalahari and younger rejuvenated Middle Zambezi drainage system. The lower-lying, non-plateau parts have been environmentally unstable for the last million or more years owing to radical changes in hydrology, and the composition of both flora and fauna reflect this in their distributions.

The most significant feature of the Four Corners area is the large drainage system running through it (the Zambezi, Kavango/ Okavango, Kwando and Chobe rivers) linked by grasslands, ribbons of riparian woodland, and in places, a high density of seasonal pans. The 'core' is a series of wetlands (Okavango, Chobe/Zambezi) and saline lakes (the Makgadikgadi Pans). Surrounding these wetlands are various types of woodland, dominated by species such as mopane, *Brachystegia*, *Acacia* and, especially, by the Zambezi Teak *Baikiaea plurijuga*. Another major linking biological feature is the presence of significant populations of the African Elephant *Loxodonta africana*. The area is thought to contain upwards of 178,000 individuals, or around 30% of the world's estimated population of this charismatic megaherbivore.

¹ Timberlake, J.R. [editor] 2000. *Biodiversity of the Zambezi Basin Wetlands*. Occasional Publications in Biodiversity No.8. BFA, Bulawayo/Zambezi Society, Harare.

1.2.1 Protected and Wildlife Management Areas

A large proportion of the Four Corners area is under some type of formal protection, whether National Park, Wildlife or Forest Reserve, and an additional significant part is utilised for wildlife management (e.g. Game Management Areas). Table 1.1 lists the formally protected or designated areas, showing that around 29% of the total Four Corners area is under formal State protection. In addition, areas where wildlife is a significant form of landuse (Wildlife Management Areas) cover 31,264 km², bringing the total area gazetted for conservation or sustainable utilisation to 123,885 km², or 38% of the total.

In addition to these areas, there are large parts of East Caprivi, northern Botswana and north west Zimbabwe under communal (e.g. CAMPFIRE or local conservancies) and private tenure that are managed primarily for wildlife trophy hunting. In extent this is probably in excess of a further 20,000 km². However, these areas are not formally designated for biodiversity conservation.

1.2.2 Geomorphology

An understanding of the geological and geomorphological events over the last 2 million years is important for an understanding both of present-day hydrological patterns and for the distribution of biodiversity. During this period the area has seen many changes in the quantity of water flowing and where it flows; large water bodies that existed even 50,000 years ago are now almost dry. These changes have been due to large fluctuations in precipitation and inflow, and to minor tectonic movements in this relatively flat area, resulting in river capture and significant changes in flow direction. Large inland lakes such as palaeo-Lake Caprivi and what are now the Makgadikgadi Pans have dried up, leaving extensive deposits of calcrete and soda, leading to major changes in vegetation and hence animal distributions. The extensive floodplains of the Upper Zambezi, most of which lie to the north of the Four Corners area, have been the site of evolutionary radiation in diverse groups of plants (for example, the "underground trees"), in lechwe antelope, and in birds such as cisticolas. With lower rainfall, and fragmentation of wetlands and floodplain grasslands, populations of such species started to diverge from each other, and now, for example, the various lechwe populations are quite distinct, some being regarded as different species (see Cotterill, Chapter 6).

Wetlands were much more extensive in the past, and are likely to become smaller or more confined in the future, especially given the predictions of 15-20% lower rainfall in the region over the next 50 years owing to global climate change. What is also being seen is the capture of the Okavango River at the top end of its delta by the Chobe-Linyanti-Zambezi, which will, in due course, result in substantive drying out of the Okavango swamps. However, this will probably only occur over hundreds of years. The Middle Zambezi, that section of the Zambezi below Victoria Falls, is also inexorably cutting back into the sluggish wetland section of the Upper Zambezi flowing over a mantle of Kalahari sand. This will slowly - over centuries - result in an extension of mopane and *Acacia* woodland on shallow soils at the expense of *Baikiaea* woodland, riparian woodland and wetlands.

1.3 MAIN FINDINGS ON BIODIVERSITY

An assessment of our knowledge on the biodiversity of the area is shown in Table 1.2, where it can be seen that we know a significant amount about mammals and birds, and about the general biodiversity of the Caprivi Strip, Okavango Delta and north west Zimbabwe, but very little indeed about invertebrates, or about biodiversity in Angola. The total numbers of species recorded for each taxonomic group, the number of species endemic (or near-endemic) to the Four Corners area, and the number of species found here that are globally threatened are shown in Table 1.3.

Table 1.1. Protected areas within the Four Corners area (in km²).

Protected Area	National Park, etc.	Forest Land	Wildlife Mgmt. Area
Angola			
Luiana National Park	10,740		
Botswana			
Chobe Forest Reserve		1880	
Chobe National Park	11,000		
Kasane Extension Forest Reserve		475	
Kasane Forest Reserve		162.5	
Kazuma Forest Reserve		237.5	
Maikaelelo Forest Reserve		625	
Makgadikgadi Pans Game Reserve	3900		
Moremi Wildlife Reserve	3880		
Nxai Pan National Park	2100		
Sibuyu Forest Reserve		1175	
Namibia			
Bwabwata National Park	5715		
Mahango Game Reserve	245		
Mamili National Park	320		
Mudumu National Park	1009.5		
Popa Falls Game Park	0.3		
Zambia			
Bilili Springs GMA			3080
Kafue National Park	22,400		
Mosi-oa-Tunya National Park	66		
Mulobezi GMA			3420
Mumbwa GMA			3370
Namwala GMA			3600
Nkala GMA			194
Sichifulo GMA			3600
Sioma Ngwezi National Park	5276		
West Zambezi GMA			c.14,000
Zimbabwe			
Deka Safari Area	510		
Fuller Forest		233	
Hwange National Park	14,651		
Kazuma Forest		240	
Kazuma Pan National Park	313		
Matetsi Safari Area	2955		
Mvutu Forest		21	
Ngamo Forest		1029	
Pandamasuie Forest		335	
Sikumi Forest		544	
Victoria Falls National Park	23.4		
Zambezi National Park	560		
TOTAL	85,664.2	6957	31,264
GRAND TOTAL (all types)	123,885 km²		

Table 1.2. Overall state of knowledge on biodiversity (species composition and distribution) across the Four Corners area.

	Vegetation	Plants	Mammals	Birds	Herps	Fish	Butterflies	Other Inverts	Overall
Angola	2	1	2	2	1	1	1	1	1
Caprivi Strip	3	2	3	4	4	4	3	2	4
Okavango	4	4	4	4	3	4	3	2	4
Makgadikgadi	2	2	2	4	2	2	2	1	2
N Botswana	3	3	4	4	3	2	3	1	3
NW Zimbabwe	4	4	4	4	4	3	4	2	4
SW Zambia	2	3	3	3	2	2	3	1	2
Kafue NP	2	3	3	3	2	2	3	1	2
Overall	3	3	4	4	3	3	3	1	

1 - insignificant/poor; 2 - basic; 3 - moderate; 4 – good

Table 1.3. Total number of species (including subspecies and varieties), endemics (including near-endemics) and threatened species by group within the Four Corners area.

	Vascular plants	Mammals	Birds	Herps	Fish	Butterflies	Other inverts
Total no. species	2356 ¹	197	601	178	109	295	000's
No. endemics/near-endemics	15	none	2	8	1	4	?
No. threatened species	none ²	10	17	none	2 ³	4 ⁴	?

NB. Threatened species are those classified on IUCN Red Data Lists as Critically Endangered, Endangered, Vulnerable or Near-Threatened.

¹ Excluding Kafue National Park.

² None on 2002 global IUCN Red List, but 18 on national Red Data Lists (Golding 2002).

³ None on 2002 global IUCN Red List, but 2 regarded as globally threatened.

⁴ Using RDL criteria, although no Red List yet exists.

The major findings, and points of interest or concern, for each aspect or taxonomic group are outlined below.

1.3.1 Ecological Processes

The Four Corners area is semi-arid with a long dry season of 5 to 8 months; evapotranspiration is high, so for all but the deepest-rooted plants or those by rivers, moisture is not available year-round. This leads to marked seasonality in forage and fruit production which animals, most obviously mammals and birds, have to develop strategies to overcome. There is little surface water available in the late dry season except in major rivers. Movement, often over large areas, is

the most common way that animals adjust to this. By restricting their ability to move, human activities and constructions can severely impair population viability.

As most of the area lies on nutrient-poor Kalahari sands, the vegetation is also primarily nutrient-poor, lacking in both phosphate and nitrate. Where these nutrients are more common, such as around termite mounds, in riparian woodland, or associated with outcrops of rocks such as basalt, forage quality is better, and such areas become nutrient "hot spots" for animals as well as supporting a different set of plant species. The continued diversity of the landscape, with hot spots in a matrix of nutrient-poor woodlands and grasslands, is what must be maintained if the present high levels of biodiversity are to be kept. It is the patchwork of habitats - primarily due to differences in soil moisture and nutrient content - that leads to high biodiversity. Of particular importance in this regard are riparian woodlands, the woodland-grassland zones where dambo or vlei grasslands form a network within broadleaved woodland, and (especially for birds) the pans.

Apart from herbivory, the other major ecological factor is fire. Woodland and grasslands in the area are adapted to fire; indeed they have evolved with it. But its frequency is now much higher than in the historical past, and fire-tolerant species are starting to predominate at the expense of the fire-sensitive ones. These effects are compounded by frost - not uncommon on the Kalahari sands - which has greater impact on vegetation once the tree canopy is opened up. Fire and frost, now coupled with the impacts of elephant, can cause woody vegetation to be "trapped" at a coppice shrub stage, and inhibit regeneration of closed canopy woodland. This is one of the main conservation concerns for the Four Corners area.

The main points concerning ecological processes are:

- The importance of a mosaic of often interconnecting habitats and nutrient-rich "hotspots" in maintaining present levels of diversity
- The network of rivers, wetlands and floodplains running through what is a seasonally-dry area is a key to biodiversity – the "Rivers of Life"
- The generally low nutrient status of much of the area, reflected in plant and animal livelihood strategies
- The importance of fire and frost.

1.3.2 Vegetation and Plants

Four main structural vegetation types are recognised in the Four Corners area: dry forest (*Cryptosepalum*) which is very localised in the north; various types of woodland (*Baikiaea*, miombo, mopane, *Acacia*) that cover by far the greatest portion of the area; grassland; and wetland. These form a mosaic over much of the area at varying scales. It is the juxtaposition of these types - their mosaic nature - that gives rise to the area's moderately high biodiversity, and greatly facilitates animal movement between habitats.

Perhaps the most important woodland type from a conservation perspective is that dominated by *Baikiaea plurijuga*, a type restricted to this part of south central Africa. The Four Corners area contains almost half of its total extent. Woodland dominated by *Colophospermum mopane* is also significant in terms of extent and ecological importance, while true miombo woodland (dominated by species of *Brachystegia*) is of much lesser extent. Wetland vegetation is of major importance, running through the area following the main rivers, and creates not only much of the diversity but is also the source of the uniqueness of the Four Corners area. The saline grasslands of the Makgadikgadi pans and other smaller pan systems, are unique.

The area has a moderately rich flora in terms of diversity with 2645 species listed (2356 excluding Kafue National Park). It supports a mixture of species characteristic of dry Kalahari, miombo and similar woodlands, as well as wetlands, and many are adapted to nutrient-poor soils and to periodic fires. In the northern part of the Kafue National Park species more typical of moist miombo woodland of northern Zambia and the DRC (Congolian elements) are found, hence this area is significantly different biologically from the rest of the Four Corners area. Our major gap in knowledge on plants is on the status and distribution of most of the species, particularly in Angola and south east Zambia.

The numbers of species endemic to the area is low (15). There are also no globally threatened species present, and only relatively few (18) that are considered to be nationally threatened; in part, this is due to the large proportion of formally protected area. The main threats are from elephant damage to riparian woodland, and land clearance for settlement and agriculture.

Eight main areas of interest for plant conservation are given: the Okavango swamps, three areas of riparian fringe along the Kavango/Okavango and Zambezi rivers, river gorges below Victoria Falls, Makgadikgadi pans, Kazuma pan, and dunes and mudflats around southern Hwange National Park. Some are limited in extent while others, such as the Okavango swamps, are much more extensive.

The main points are:

- The area contains a range of vegetation types, with wetland vegetation and *Baikiaea* woodland being the most important biologically
- It is the juxtaposition and mosaic nature of woodland, grassland and wetland that gives rise to the uniqueness and high diversity of the area
- The flora of the area is moderately diverse with a mix of species from different geographical areas - the Four Corners is a "meeting place"
- A low level of endemism, and few threatened species
- Eight areas of plant conservation interest have been identified
- Main threats are elephant impact on woody plants, especially in riparian woodland, and land clearance
- Major gaps in knowledge are in the distribution and status of species, particularly in Angola and SW Zambia.

1.3.3 Mammals

The Four Corners area has arguably one of the richest mammalian assemblages in southern Africa, with a full complement of both herbivores and carnivores so that natural predator/prey cycles can still occur. In addition, it supports around 30% of Africa's estimated elephant population. One of the major reasons is the high proportion of formally protected land in the form of national parks or similar areas. Of particular interest is the wide range of antelope species, reflecting the extent and variety of grasslands. The upper reaches of the Zambezi - a mosaic of grassland, wetland and woodland - have been an area of evolutionary radiation for a number of ungulate species over the last few million years, notably lechwe antelope. However, habitat fragmentation and disruption of historical movements is now threatening this diversity. From an evolutionary perspective, what is also interesting is the sympatry (populations of similar species living in the same or adjacent areas) of the Spotted-necked and Clawless otters on the Upper Zambezi River, and of three subspecies of Burchell's zebra in north east Botswana. Other species, e.g. puku, waterbuck, lechwe, are at the limits of their distribution here. The major gaps in our knowledge of the group are species presence, and the distribution and ecological function of such small mammals as shrews, rodents and bats.

Out of the 197 species listed as occurring, none is endemic to the Four Corners area, and 10 are considered threatened. These include the Spotted-necked otter, Painted hunting dog, lion, cheetah, black rhino and, ironically, the African savanna elephant. The Kafue lechwe, endemic to the Kafue Flats, is now not found inside the study area. Along with the Painted hunting dog and the charismatic and ecologically important elephant, the Puku is also considered an important "flagship" species for the Four Corners area and is confined here to a small population on the Chobe floodplain.

Historically, large mammal populations have been severely affected by hunting, commercial poaching, and animal diseases such as rinderpest. Over the last 10-20 years rhino have been heavily poached such that they are now critically endangered, and yet the elephant population has been increasing annually at almost 6% - close to its biological maximum.

Some large mammal populations, such as buffalo, zebra and elephant, move across the landscape seasonally, seeking water and forage. These movements often cross international borders (see Section 1.3.8) and a harmonised transfrontier approach to their management and conservation is required.

The main points are:

- Rich species assemblage, with good populations and diversity of predators. Extensive areas of protected habitat for large mammals
- Composition and distribution of small mammals is insufficiently known
- Area has been important in the past for speciation of grassland/floodplain antelope, but habitat and population fragmentation have led to local extinction
- No endemic species, but some are at the limits of their range. Ten globally threatened species present, including elephant
- Very high population of elephant - 30% of continental total - with overpopulation in some areas
- Marked historical effects of hunting and disease still seen in distribution patterns of some species
- Populations of some large mammals frequently move across international borders, so require a transfrontier approach to management or harmonisation of practices for continued effective conservation.

1.3.4 Birds

Many birds are charismatic and often highly mobile, hence our knowledge on them as a group is probably better than for any other. Bird checklists and atlases are available for much of the area, although our knowledge of the avifauna of south east Angola is minimal. Of the 601 recorded species from the Four Corners area - a moderately rich avifauna - 524 are known to breed here. There are 76 palaeartic migrants (species that migrate annually from the northern hemisphere during their winter period, but do not breed in the south) and an additional 52 intra-African migrants. Many reside for a number of months in wetlands, pans or floodplains, while others wander at will over grasslands and thornveld. These species know no boundaries, again showing the importance of a transfrontier approach to conservation.

Important habitats for birds are (a) grasslands, which are a centre for speciation for some genera, (b) wetlands, in particular the Okavango swamps, and (c) pans, particularly for waterfowl. For example, the Okavango has 450 recorded species, and the Makgadikgadi is one of only two breeding sites for the Lesser Flamingo in southern Africa. The Lesser Flamingo, Wattled Crane and African Skimmer are identified as charismatic flagship species for the conservation of the

Makgadikgadi pans, Okavango and Zambezi sandbanks, respectively. A splendid diversity of 60 species of raptors is listed, of which 36 have been recorded in the Batoka gorges.

There are 17 bird species of global conservation interest, of which six are of particular importance (Slaty Egret, Wattled Crane, Lesser Flamingo, Black-cheeked Lovebird, Taita Falcon, African Skimmer). Two of these, Slaty Egret and Black-cheeked Lovebird, are virtually endemic to the Four Corners area.

Ornithologists have identified 12 Important Bird Areas within the Four Corners using rigorous numerical and distribution criteria. Some of these are rather small (e.g. Lake Ngami and Batoka Gorge, each 100-250 km²), whilst others are very large (e.g. the Okavango swamps, Kafue and Hwange National Parks).

The main points are:

- The area has a moderately rich avifauna with many palaeartic and intra-African migrants, necessitating an international approach to conservation for many species
- Groups of particular significance are grassland birds, wetland birds and raptors
- There are 17 globally threatened species (two endemic), of which six are of particular conservation interest here; three of these can be regarded as "flagship" species
- Twelve areas of interest for conservation have been identified as Important Bird Areas using clear criteria; particularly important habitats are wetlands, pans and rocky cliffs.

1.3.5 Reptiles and Amphibians

As with plants, the Four Corners area is a meeting place of the reptilian and amphibian fauna from the Kalahari, the Upper Zambezi, and from the broad-leaved woodlands of Central Africa. There are 128 species of reptile and 50 species of amphibian recorded. Owing to the often sandy soils, burrowing or fossorial reptiles are comparatively common as they can more readily dig and their invertebrate food source is more frequent. As such animals cannot cross large perennial water bodies such as the Zambezi River, speciation occurs more readily.

Out of the 178 species recorded there are five endemic or near-endemic reptiles (Spiny agama *Agama makarikarica*, Tsodilo gecko *Pachydactylus tsodiloensis*, Long-tailed worm-lizard *Dalophia longicauda*, Barotse water snake *Crotaphopeltis barotseensis*, Okavango hinged terrapin *Pelusios bechuanicus*) and three endemic frogs (the Reed frogs *Hyperolius aposematicus*, *Hyperolius rhodesianus* and the Grass-frog *Ptychadena mapacha*), a comparatively high figure given the size of the area and its cosmopolitan assemblage. But only the gecko, snake and frogs appear to be threatened. Of the areas of particular conservation interest only the Eastern Caprivi, with its very rich fossorial reptile fauna, lies clearly within the Four Corners area. The Nile Crocodile is a major predator in aquatic ecosystems. As with other taxonomic groups, the gaps in our knowledge are the distribution and status of many species, particularly in Angola and south west Zambia.

The main points are:

- The area has a rich reptile fauna owing to it being a meeting place of different biogeographical zones
- It is particularly rich in fossorial species, especially in the East Caprivi
- There are five endemic or near-endemic reptiles and three frogs, but only four of these are considered threatened.

1.3.6 Fish

It is not very useful to separate the fish fauna of the Four Corners area from that of the upper reaches of the Kavango and Zambezi rivers. In fact, many of the species of conservation interest in these systems are found upstream of the study area, and others use the upper reaches as spawning grounds. The fauna is a mixture of Upper Zambezi elements from slow, sluggish rivers and floodplains, and Middle Zambezi elements from younger "high energy" rivers. Ecologically diverse as far as fish are concerned, as well as being biogeographically varied, there are 109 species recorded from the Four Corners area, and another 26 in the Zambezi and Kavango headwaters or immediately downstream. Tigerfish is the main predator; the relative abundance of fish species reflects their distribution. Habitats of particular interest are floodplains, which are very important for fish breeding, and fast-moving rivers with a rocky substrate. The latter in particular are under threat from dam construction.

There is one endemic killifish (*Nothobranchius* sp.) found in pans in the East Caprivi, and one other globally threatened species, Phongolo suckermouth *Chiloglanis emarginatus*, in a tributary of the Gwayi River. Other endemics or species of particular interest are found just outside the Four Corners area in the Upper Zambezi or Kafue rivers.

Changes in hydrology resulting from dam and barrage construction, particularly on the Kavango and Zambezi rivers (Victoria Falls, Batoka gorge), is the major conservation issue, along with water abstraction schemes. Pollution and sedimentation are not significant at present, but could become so. Another major concern is the introduction and spread of alien invasive fish species such as Nile tilapia *Oreochromis niloticus*, an escapee from aquaculture schemes, and the introduction of Sharptooth catfish *Clarias gariepinus* into pans or small water bodies. The aquatic weeds water hyacinth (*Eichhornia*) and Kariba weed (*Salvinia*) give rise to problems on large water bodies, but are now largely manageable using insects as biological control agents.

Fisheries are a major source of rural livelihoods in the area; much attention needs to be given to ensuring yields are sustainable yet retaining fish diversity. There is a need for better fisheries survey and management, and monitoring of fish stocks should be an important future TFCA activity.

The main points are:

- The fish fauna of the Four Corners area is not distinct from that of the Zambezi headwaters, and they should be considered together. Most species of interest are found in the headwaters
- There is a moderately rich ichthyofauna, with one endemic and two globally threatened species
- Important habitats are floodplains for fish breeding, and fast-flowing rocky rivers. The latter are under threat
- Gaps in our knowledge are on habitat preferences and seasonal changes in species distribution
- The major conservation concern is the change in hydrology resulting from dam construction and water abstraction schemes. Pollution and sedimentation are not yet significant issues, except locally
- Introduction and spread of alien invasive fish species, particularly from aquaculture schemes, is a major conservation concern
- Artesanal fisheries are very important in the area, and better management of these are required - a good entry point for the TFCA.

1.3.7 Invertebrates

Reviews on invertebrates cover the well-known butterflies and the much more poorly known soil fauna (particularly termites) and aquatic invertebrates. The latter two groups, although functional rather than taxonomic, were chosen as both are very important for the ecological functioning of the area, and our knowledge of them has not been reviewed before.

Among very many invertebrate groups, only the butterflies (one group of several families within the Lepidoptera) are particularly well-known. There are significant data on the distribution and diversity of Odonata (dragonflies and damselflies), but these are not reviewed here having been well covered by Fitzpatrick in the IUCN Zambezi Basin Wetlands Biodiversity study (see Timberlake 2000). Of the almost 300 butterfly species recorded, most are found in Zambia and Zimbabwe; Angola is poorly known. Wetlands and moist riparian woodland are the most important habitats, with some species (including one near-endemic form) confined to the Victoria Falls "rainforest". There are strong links between species distributions and vegetation type. Eighteen species of interest have been identified from the area, including two near-endemic subspecies, (Modest Bar, *Cigaritis modestus modestus* and Fiery Acraea *Acraea acrita ambigua*) and one endemic species (Norman's Copper *Eriksonia alaponoxa*) known only from miombo woodland near Kataba in SW Zambia. The latter is also considered threatened. The Broad-bordered Acraea, a form of *Acraea anemosa* (forma *alboradiata*) is known only from the Victoria Falls rainforest. The major threats to butterflies are habitat destruction, particularly to riparian and similar well-developed woodlands, either by clearance or by elephant.

For both soil fauna and aquatic invertebrates it is not possible to draw up species lists or look at the groups at a species level - our knowledge is just too poor to do anything but look at family or higher levels. The lack of specialists who can identify these organisms is a major constraint and concern. Soil fauna, particularly termites, play a major role in nutrient dynamics and decomposition, soil formation and structure in terrestrial ecosystems, while aquatic invertebrates play a similar role in aquatic systems.

Although forming a significant proportion of invertebrate diversity, only around 5% of soil fauna has been formally described. Up to 30 Orders of soil invertebrates and many thousands of species may be present in a single habitat. There is a high patchiness in distribution, and most species are affected by changes in moisture and temperature regimes. Recent research in terrestrial ecosystems has shown a possible 10 times decline in abundance and biomass of soil fauna when natural woodland is converted to arable land, or when canopy trees are felled.

For aquatic invertebrates, the most threatened habitat within the Four Corners area is fast-flowing rivers over rock as rocky substrates can be adversely changed through siltation. Pans and pools are also important habitats. Substrate and flow regime are important determinants of species composition. The group as a whole is very useful for monitoring of water quality by comparing proportions of functional groups, and there is a need within the TFCA to establish monitoring sites for this. There are concerns over possible changes in composition owing to pollution from insecticides (such as DDT), industry and urban settlements, although these are not yet apparent.

The main points regarding invertebrate groups are:

- Lepidoptera and Odonata are the only groups sufficiently well known for a comprehensive review
- Our knowledge on other groups, including the very important functional groups of soil fauna and aquatic invertebrates, is very poor indeed - at taxonomic, identification and

functional levels. A very low proportion of species in these groups has been described, let alone studied. Expertise in these groups is sorely lacking

- For butterflies, riparian and similar woodlands are important habitats, along with wetlands
- There are four endemic or near-endemic butterflies, one of which is of particular interest
- The major threats to butterflies are changes in vegetation cover and composition, especially to riparian woodland and wetlands
- Fast-flowing rivers are the most threatened habitat in the Four Corners area for aquatic invertebrates. Pans and pools are also important habitats
- Substrate of the river and flow regime are the main determinants for aquatic invertebrate composition and diversity
- Most species of both soil and aquatic invertebrates are very small and not readily visible
- Aquatic invertebrates are very useful for monitoring of water quality
- Termites are very important for ecosystem processes, including the effects of mound builders on hydrology
- Conversion of natural woodland to cultivated fields gives an order of magnitude decline in both abundance and biomass of soil fauna

1.3.8 Animal Movements

Within the study area the only true migrations are of birds (both Palaearctic and intra-African migrants) and, among the mammals, wildebeest and zebra (from Savuti to Chobe-Linyanti, and from Boteti to Makgadikgadi pans, both in northern Botswana). The primary driver of movement for both groups is access to food sources. In addition, there are many cases of opportunistic movement of large mammals and birds (especially waterfowl) in response to changing availability of forage and water. The best known are those of elephant which concentrate at permanent water sources (such as the artificial pans in Hwange, Chobe and Zambezi rivers) during the dry winter months.

A major constraint to movement of large mammals in northern Botswana has been the erection of veterinary fences, some of which cut off forage or water resources used seasonally by wildlife. There has been much controversy over these fences and their impacts on wildlife, and very many animal deaths have been recorded in drought years. Any transfrontier conservation initiative should address this issue, and attempt to harmonise the competing requirements of livestock (grazing, and especially disease control) and wildlife.

The main points are:

- Animal movements in the area are mostly nomadic in search of food or required habitat, not true migrations
- The only true migrations are of birds (Palaearctic and intra-African migrants), and of wildebeest and zebra in N Botswana
- A major constraint to movement in N Botswana are the veterinary fences. These cause many animal deaths in drought periods
- There has been no study on fragmentation of habitats and the impact on wildlife population dynamics caused by the erection of the veterinary fences and similar barriers.

1.3.9 Elephant Populations and Impacts

Perhaps the major biological feature of the Four Corners area, apart from the wetlands and woodlands, is the large population of African elephants. The most recent available census data gives a total of 178,000 head in an area of probably less than 200,000 km² (elephants are absent or at very low density over at least half of the Four Corners area), or around 0.9 head/km². This

population is around 30% of the total estimated global number of the species. The greatest concentrations are along the Chobe and Linyanti rivers in northern Botswana, on the northern side of the Okavango swamps, and in the northern part of Hwange National Park in Zimbabwe. Northern Botswana supports 122,700 head and north-west Matabeleland supports 49,300 head. Populations are comparatively low in the Caprivi (around 4500) and southwestern Zambia (around 2100), and unknown but minimal in Angola. Elephants in this area have increased considerably over the last 60 years; at present the estimated rate of increase is 6% per year, close to its biological maximum.

Elephants can have a marked impact on woody vegetation, not only through actual consumption but also through their feeding behaviour. They frequently push over trees and strip branches and bark, leading to the death of individual trees and extensive coppicing. Some species and woodland types are affected more than others. What was once woodland can be transformed to shrubland or even open savanna in a relatively short period of time, say 10 years. The effects of fire and frost then compound this impact. Reduced tree cover leads to more light reaching the ground, hence a higher biomass of grass, so that fuel loads for the inevitable fires are increased and fires are fiercer. These areas are also more prone to the damaging effects of frost, which kills back young plants and regrowth resulting in less regeneration of woody plants and extensive coppicing. Slowly, what was closed woodland becomes so open that many of the associated species can not survive there any more.

It is not always clear what causes heavy utilization to turn into habitat modification or destruction, but the density of elephant in an area is obviously a key component. At low to moderate densities, elephant impacts may increase habitat heterogeneity, but at high densities elephants can reduce heterogeneity and hence biodiversity. Obviously, this density is not evenly distributed across the area. An "acceptable" average density for elephants in conservation areas, where their ecological impacts are not considered excessive, is generally stated to be 0.5 head/km². High and concentrated populations, up to 5-6 head/km², such as found in the Four Corners area lead to localized damage to woodland and an increase in the shrub layer. Although this phenomenon has been described from many places in eastern and southern Africa, the situation is particularly acute here. Unless elephant densities are significantly reduced, further marked changes to the area's biodiversity and ecology will occur. Whether these changes are acceptable is a different question, but they are of sufficient magnitude to impact greatly upon many other conservation activities.

The main points concerning elephants are:

- Very large population, with high concentrations locally in N Botswana and NW Zimbabwe
- Individuals move, sometimes over long distances and regularly cross international borders
- Significant impact on woody vegetation in some areas, especially riparian woodland, such that it impacts negatively on other biodiversity
- The need for clear national and transfrontier elephant management policies and action rather than passive protection.

1.3.10 Gaps in Knowledge

What we know and do not know about organismal biodiversity in the Four Corners area depends on the biological group or species being considered. We have good information on what is present and where it is found for large mammals, birds, and perhaps fish, but negligible information on the diversity and distribution of both soil fauna and aquatic invertebrates (see Table 1.2). Even with the better-known groups, there is a scarcity of data from many parts of south west Zambia and from Angola in particular, which will only be overcome by further field

survey work. For soil fauna and aquatic invertebrates this will be a mammoth undertaking unless particular groups or localities are targeted.

With the exception of invertebrate groups, the taxonomy (or knowledge of which species is which) is moderately sound. Further taxonomic work will not greatly change the number of species known to occur here. However, with the increasing adoption of the Evolutionary Species Concept (for example, see Cotterill, Chapter 6), some varieties or subspecies of mammals and birds are likely to be elevated to full species.

Although better known for a number of larger mammals, plants, birds and fish, there is very little information available for most species on their ecological requirements. It is this lack of knowledge that limits conservation efforts directed at threatened species and those of particular conservation concern.

Perhaps the best-known animal in the area is the African savanna elephant. Its movements are moderately well understood in outline, if not in detail (Hoare, Chapter 14), and we are getting a clearer picture of its impact on other organisms (Conybeare, Chapter 15). From the perspective of conservation, however, we are still some way from being able to manage this impact constructively.

What then are the priorities for future study in order to conserve effectively the present range of biodiversity within the Four Corners area? For invertebrates, the priority is further survey focused on at least selected groups in selected areas. What organisms there are, and what roles they play, is just not known. For many of the other groups, such as plants, small mammals, reptiles and amphibians, fish and butterflies, the major initial gaps are in our knowledge of what species are present and their distributions, especially in south west Zambia and Angola. The distribution of birds and large mammals is now sufficiently well known for broad conservation planning. We need to be particularly concerned over endemic species, species of restricted distribution, and species thought to be threatened. It is not just existing populations that have to be looked at, but also whether the requirements for their successful reproduction and regeneration are in place.

1.4 CONSERVATION ISSUES

1.4.1 Species of Concern / Interest

Species of interest can be of three types - endemics or those of restricted distribution, those that are considered threatened, and those that play a key or major role in the area's ecology. Table 1.3 gives the total numbers of endemic, near-endemic or restricted range species, and the number that are threatened by group, while Table 1.4 lists four key species or groups.

Table 1.4. Key or determinant species in the Four Corners Area.

Species	Reason
Elephant	Ecological engineers - can cause major modification of vegetation structure, changing woodland into shrubland and wooded grassland. Can travel over large distances; need lots of space
Hippo	Ecological engineers - maintain waterways and channels in swamps and thus dynamism of the aquatic system
Termites	Ecological engineers - critical to recycling of nutrients, create islands of high nutrient content in otherwise impoverished environment (mainly <i>Macrotermes</i> spp.)
Tigerfish	Major vertebrate predator in aquatic systems

The number of plants endemic to the Four Corners area is very low (only 0.6% of the total flora), and there are no endemic mammals. Reptiles and amphibians with 4.5% endemism show a much higher level. This illustrates the point that the Four Corners area is very much a biological meeting place for species more widely distributed to the north, south or east, and shows generally low levels of endemism. There are too many endemic or near-endemic species to list here (most are given under the review summaries above, and in each review), and specific areas of endemism are described in section 1.4.3 below. Of particular note, however, are the Slaty Egret and Black-cheeked Lovebird among the birds, the Spiny Agama lizard *Agama makarikarica* on the margins of the Makgadikgadi pans and the Reed-frog *Hyperolius rhodesianus* on the Matetsi River, a killifish (*Nothobranchius* sp.) in pans in the East Caprivi, the butterfly Norman's Copper, *Erikssonina alaponoxa*, the succulent plant *Euphorbia fortissima* from between Hwange and Victoria Falls, and the riverine shrub *Acacia hebeclada* subsp. *chobiensis*.

A similar picture of low numbers is seen with threatened species - species that are considered to be under some risk of global extinction according to IUCN Red List criteria. In part this is due to limitations of global Red Data Lists and assessments, but even with the comprehensive national-level assessments available for plants, only 0.8% of species found are considered threatened. Mammals appear to be more threatened (4.6% of species are on the IUCN 2000 List), possibly due to our better knowledge on their distribution and status. There are a number of antelopes listed as being Lower Risk (Conservation Dependent), signifying that although their populations are stable much depends upon the existence of protected areas. Birds, with 2.8% of species threatened, are the group next most at risk.

Of the main ecological determinant ("keystone") species listed in Table 1.4, two are megaherbivores (elephant and hippo), and three modify the landscape and drainage patterns to a significant extent. The effect that *Macrotermes* termites have on hydrological patterns in the Okavango and other wetlands is often overlooked. It is important for conservationists to pay special attention to populations of all these species as they can have disproportionately large effects on other biodiversity.

1.4.2 Flagship Species

One way of focusing conservation attention and efforts is to identify charismatic species, the conservation of which will effectively protect the habitat and act as an "umbrella" for many others. Eight such species identified from these reviews are listed in Table 1.5, and their conservation should protect a wide range of special Four Corners habitats and areas. For example, conservation of the Puku antelope on the Chobe floodplains will also protect other floodplain-dependent antelope and birds; and conservation of the African Skimmer, which requires open river sandbanks, can only occur if the Zambezi flood regime is retained.

From a vegetation perspective, the small area of miombo woodland near Kataba where the endemic butterfly Norman's Copper *Erikssonina alaponoxa* is found, apparently supports a number of other interesting invertebrates and plants, and has not yet been fully investigated. Mature stands of Zambezi teak *Baikiaea* trees showing a good age structure are now very rare, and every effort needs to be made to keep them from being logged, cleared or subject to frequent fires. By doing this a unique vegetation type will be conserved, along with the assemblage of other plants and animals that live in it.

Table 1.5. "Flagship" species of the Four Corners area.

Species	Comment
Puku	Specialist floodplain grassland antelope, e.g. Chobe floodplain
Painted Hunting Dog	Large attractive carnivore, specialist, endangered; needs large areas of wildlife habitat; tourism value; potential conflict with cattle ranchers
Lesser Flamingo	Bird that only breeds in two localities in southern Africa, including the Makgadikgadi Pans. Globally near-threatened status.
African Skimmer	Attractive bird; indicator of open sandbanks (needed for breeding), which are only present if flooding is unregulated by dams and weirs
Zambezi Teak (<i>Baikiaea</i>) woodland with good size/age structure	Indicator of relatively undisturbed and well-functioning woodland; important timber species, very slow growing; well adapted to growing on Kalahari sands
Papyrus	Primary producer in swamps. Indicator of permanent swamp conditions.
Floodplain Acacia (<i>Acacia kirkii</i>)	Tree with relict distribution; grows on alluvial mudflats and ancient drainage fans; subject to very heavy elephant impact
Norman's Copper (<i>Eriksonia alaponoxa</i>)	Butterfly with interesting life-history; only known from one area of miombo woodland at Kataba, W Zambia

Some might say that the elephant is the most charismatic species in the Four Corners area and should also be a flagship. However, it can not now be considered threatened in any way and populations are more in need of management than conservation. Indeed, elephant numbers at present are such that some other components of biodiversity are actually under threat from them.

1.4.3 Areas of Interest

An outline of the threats to biodiversity by broad habitat type is given in Table 1.6. In terms of overall habitat, and given the wetland/woodland mosaic nature of the Four Corners area and the overriding importance of wetlands, the principal area of conservation concern is the Okavango swamps. This complex is not only the largest extent of perennial swamp in the wider palaeo-Zambezi Basin, but also contains a wide range of species. The other important extensive area is the Makgadikgadi pans complex and associated saline grasslands. Although not as diverse in terms of species, it is almost unique in southern Africa and is of significance as the remains of a vast lake that last dried up perhaps 50,000 years ago.

More locally, the most important, and perhaps the most threatened, habitat is riparian woodland. Although covering perhaps less than 1% of the total area, it supports a disproportionately high number of species and is an important refuge and feeding place for many birds and mammals. The threats, especially along the Zambezi River itself and immediate tributaries, are from both man (through clearance for cultivation and settlement) in unprotected areas and from elephant (through destruction of woodlands cover and associated biodiversity) in protected areas. Not only do these woodlands contain a number of threatened plants and animals, including the bushbuck that is becoming increasingly scarce, but they also protect against river bank erosion and siltation downstream. The so-called "rainforest" at Victoria Falls, really a particularly well-developed area of riparian forest, supports two butterflies of interest as well as some plants at the margins of their distribution.

Table 1.6. Threats to biodiversity and impacts upon ecological processes for major Four Corners habitats.

Habitat type	Main threats	Impact on ecological processes
Riparian woodland	<ul style="list-style-type: none"> Structural damage of woodland caused by removal of large trees by elephants and humans Invasive species, e.g. <i>Lantana camara</i> 	Loss of moist microclimate; riverbank instability ► erosion; loss of fish breeding and nursery areas ► decreased biodiversity. Impact of removal on soil hydrology not investigated. Invasive species out-compete indigenous plants.
<i>Baikiaea</i> woodland	<ul style="list-style-type: none"> Logging and increased fire 	Loss of canopy ► increased evaporation and aridity; increased grass ► increase of fire resistant species (fire cycle); vegetation structure changes from woodland to open shrubland with coppice
<i>Brachystegia</i> woodland	<ul style="list-style-type: none"> Structural damage of woodland through elephant feeding in dry season (bark stripping, felling), increased fire 	As above. Where woodland occurs on shallow or gravelly soils there is loss of ground cover and increased erosion. Impact of removal of woodland on hydrology of dambos not fully understood
<i>Acacia</i> woodland & savanna	<ul style="list-style-type: none"> Overgrazing or increased fire Elephant damage to <i>Acacia kirkii</i> 	Loss of woodland structure ► decreased biodiversity. Overgrazing ► bush encroachment ► decreased grazing (positive feedback) and decreased productivity.
Mopane woodland	<ul style="list-style-type: none"> Structural damage of woodland through elephant feeding 	Increased aridity, increased bare ground ► soil erosion ► decreased biodiversity
Wetlands / floodplains / dambos	<ul style="list-style-type: none"> Changes to hydrology, i.e. magnitude, frequency & timing of flooding through damming, diversion of water, streambank cultivation, siltation Overgrazing and trampling by cattle Frequent fires 	Loss of fish breeding grounds and waterbird habitat; drying up of critical habitat (Okavango). Loss of habitat for amphibians. Soil erosion
Pans	<ul style="list-style-type: none"> Changes to natural system through artificial water supply Breaking clay seal through hoof pressure Introduction of exotic fish 	Loss of aquatic and wetland vegetation ► loss of biodiversity
Freshwater rivers & lakes	<ul style="list-style-type: none"> Changes to hydrology, i.e. magnitude, frequency & timing of flooding through damming, diversion of water, streambank cultivation, siltation Invasion of aquatic weeds, e.g. <i>Salvinia</i>, <i>Pistia</i>, <i>Azolla</i>, <i>Eichhornia</i> Potential invasion of exotic fish, e.g. <i>Oreochromis niloticus</i> Spraying chemicals to control tsetse fly and mosquitoes 	Loss of fish habitat, breeding grounds and waterbird habitat ► loss of biodiversity. Invasive plants block river channels and lead to eutrophication of system ► loss of clean water. Invasives out-compete indigenous aquatic plants ► loss of biodiversity. Carpets of floating weeds reduce light and oxygen levels in waters ► reduced productivity and biodiversity. Chemical controls have negative impact on terrestrial and aquatic invertebrates, and in turn on fish.

Given the extensive areas of woodland, and various types of wetland and grassland, one of the most limited habitats is rocky outcrops. This includes stretches of rivers with rocky beds, so-called 'high energy' rivers, as well as rocky hills and gorges. Not surprisingly perhaps, it is here that some of the more restricted or endemic species are found, such as five species of plant and one lizard. Particular areas of interest are the basalt gorges below Victoria Falls, the Tsodilo Hills, and the sandstone hills around Hwange. These areas, by their very nature, are not under any particular threat.

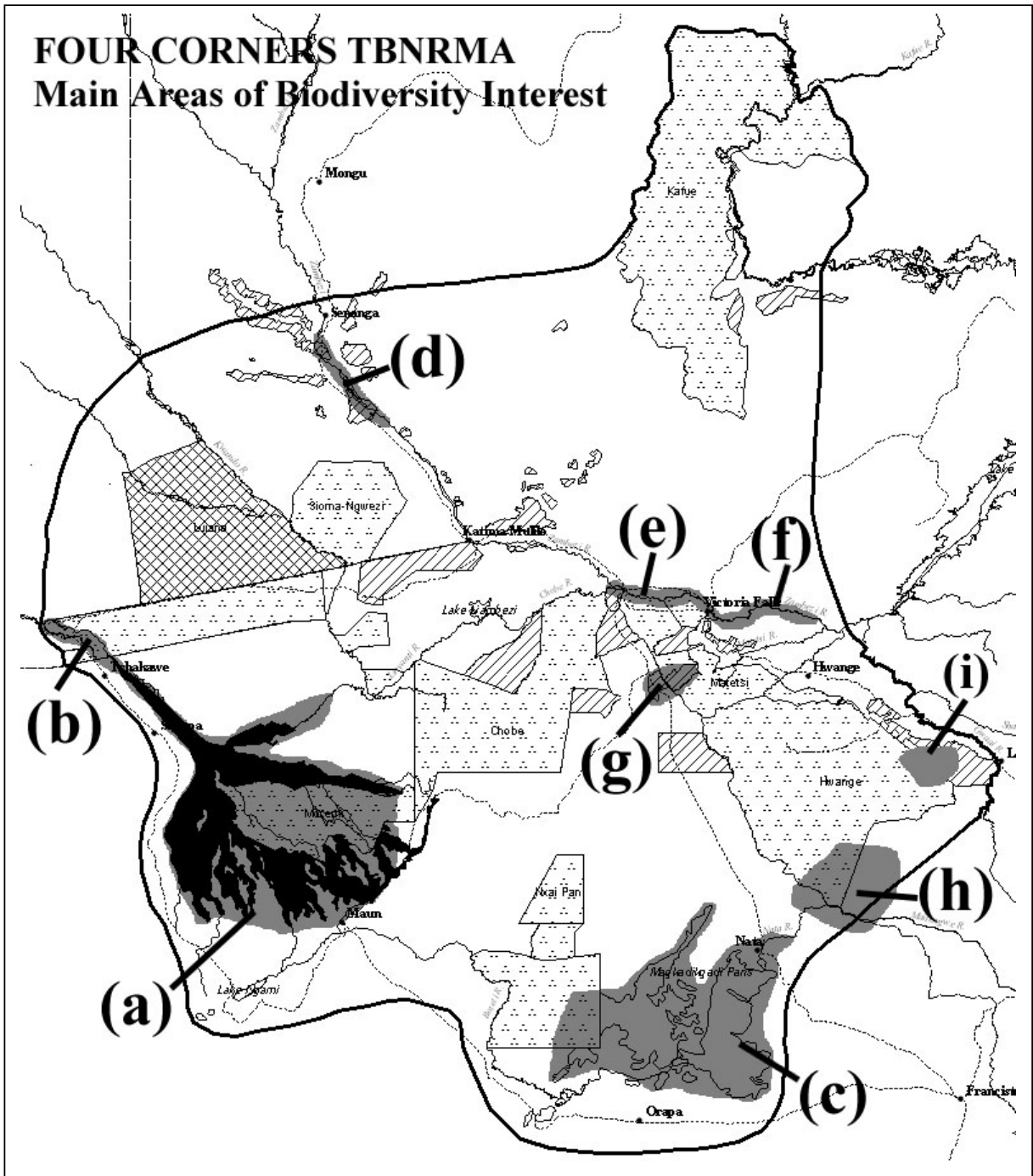
Much less threatened, but containing a number of species of interest, are some of the floodplains or grasslands in southern Zambia. Although the Kafue Flats are outside the presently-defined Four Corners area, these floodplains and grasslands are an important area of endemism (Kafue lechwe, one frog and one fish species).

Finally, much underrated in terms of their conservation importance for species with restricted distributions, are small natural pans and seeps. Moisture is the major limiting factor in the terrestrial ecology of the Four Corners area. These pans are not only important for various bird and mammal species, but also as habitat for some ephemeral plants, for killifish (*Nothobranchius* species) and of course for a range of aquatic invertebrates.

After looking at threatened habitats in general, and areas of particularly high biodiversity, nine areas - some large, some small - of conservation interest have been identified within the Four Corners area (see Figure 1.2), and are described below:

- (a) **Okavango Swamps:** An extensive area of perennial and seasonal swamp with numerous islands and backwaters in north west Botswana, fed by the Okavango/Kavango river from the Angolan Highlands. It is one of the largest and probably the most pristine wetland within south central Africa, and has a high habitat diversity. The swamps lie immediately adjacent to dry woodland dominated by mopane or Kalahari vegetation. Both perennial swamp, indicated by stands of papyrus, and seasonal swamp are present, with many heavily wooded islands. A significant portion is protected as Moremi Wildlife Reserve, and cattle raising as a land use option is curtailed in some parts by the presence of tsetse fly and cattle fences. Although it contains no endemic or particularly threatened species, it is the best example of an increasingly threatened habitat and has a rich biodiversity.
- (b) **Kavango / Okavango river fringes:** An area of woodland and grassland mixed with wetland vegetation flanking the Kavango/Okavango river in western Caprivi and northern Botswana (the "panhandle"). The woodlands are still fairly pristine over much of their extent and not severely impacted by elephant. Good riparian woodland is becoming increasingly scarce in southern Africa. There is a moderately high species diversity, although with no endemics or species under particular threat. The area is not formally protected, except on the east bank of the Kavango in Namibia. There is a real threat of implementation of a water abstraction scheme that would impact on both this area and, particularly, the Okavango swamps.
- (c) **Makgadikgadi Pans and lower Nata River:** An extensive area of north central Botswana containing salt flats surrounded by dry woodland (mostly mopane) and grassland of various types. Although not particularly under threat, the habitats here are very unusual. There is one endemic grass (*Panicum coloratum* var. *makarikariense*) and one endemic lizard, (the Spiny Agama *Agama makarikarica*). Sua Pan is one of only two breeding sites for the threatened Lesser Flamingo in southern Africa, and the Nata Delta in the north is also used for breeding by the White Pelican. The mouth of the Nata River supports woodland of an

Figure 1.2 Main areas of biodiversity interest within the Four Corners TBNRM Area



unusual type, and is important for waterbirds. Only a small part of the area is formally protected (Makgadikgadi Pans Game Reserve).

- (d) **Zambezi riparian woodland below Senanga:** Patches of riparian woodland in western Zambia flanking the Zambezi River upstream of Ngonye Falls. The area supports riparian woodland containing a number of plant species of restricted distribution. Such woodland is

becoming increasingly rare owing to damage by elephant as well as human settlement. The area is not formally protected, and it is not clear what its present status is. Any remaining patches are a conservation priority.

- (e) **Zambezi riparian woodland between Kazungula and Victoria Falls:** An area of what was well-developed riparian woodland with a rich assemblage of plant, mammal and bird species. The woodlands contain a number of rare woody species of very restricted distribution, and are also important for butterflies. However, much has been cleared on the Zambian side for agriculture and settlement. On the Zimbabwe side, although protected as the Zambezi National Park and Matetsi Safari Area, it has been heavily impacted by elephants; what was closed woodland has been opened up quite rapidly over much of its extent. Very unusual stands of Floodplain Acacia *Acacia kirkii* are found on mud flats at Kazungula and elsewhere dating from Pleistocene times, but have also been almost destroyed by elephants.
- (f) **Victoria Falls and Batoka Gorge:** The Zambezi abruptly changes its nature here from a wide, relatively sluggish river with many wooded islands to a narrow rushing river enclosed in a 100 m deep gorge carved into the basalt. The permanent spray zone at Victoria Falls, in both Zambia and Zimbabwe, allows for the development of mesic woodland and herbaceous vegetation with a number of unusual plants. The 'rainforest', essentially an extensive riparian forest caused by the permanent spray from the waterfalls, contains plant species which are localised in distribution or outlying populations. The Batoka gorge contains four endemic plants, and is important for birds such as the Taita Falcon and raptors (36 species identified). The gorges are mostly unprotected, although generally inaccessible. The Batoka Gorge dam, if built, will flood much of the bottom of the gorges and change the microclimate. The Victoria Falls area is protected on both the Zambian and Zimbabwe sides, although it is heavily utilised by visitors. Invasive plants such as *Lantana camara* are now a problem.
- (g) **Kazuma Pan:** A transfrontier area of northern Botswana and north west Zimbabwe centred on a large seasonal pan and grassland surrounded by various types of woodland, on both Kalahari sand and black clays. There is a high habitat diversity and such grasslands are very unusual in the region. Oribi found here may prove to be taxonomically different from other populations, and previously there were several White Rhinoceros. Roan antelope also occur, but their numbers have diminished in recent years. The whole area in Zimbabwe is protected as national park or forest land. A significant portion of the adjacent Pandamatenga grasslands in Botswana, just to the south, is under commercial farming.
- (h) **Southern Hwange dunes and Nata mudflats:** An extensive mosaic, mostly in Zimbabwe although crossing into Botswana, of relatively untouched dense woodland (Zambezi Teak *Baikiaea*, Camelthorn *Acacia erioloba* and Kalahari Sand Acacia *Acacia luederitzii*) on Kalahari sand dunes dating from the Pleistocene period, mudflats with grassland, *Acacia* and mopane, and shallow sand areas with *Combretum* scrub. Many small seasonal pans with ephemeral species are also present. There is a high habitat diversity with a number of unusual plant species as it is a meeting place of the Zambezian and Kalahari floras. The biodiversity of the area is very poorly known, and is likely to be rich. Much of the area lies within Hwange National Park, although a significant portion lies to the south in Tsholotsho communal land.
- (i) **Ngamo Pan and surrounds:** A large area straddling Hwange National Park and Ngamo Forest Land in western Zimbabwe with calcareous pans set in Kalahari sand and remnants

of old dunes. Many of the surrounding woodlands are open with Zambezi Teak *Baikiaea* and Mukwa *Pterocarpus angolensis*, while the grasslands have a high density of *Hyphaene* palms. The pans and grasslands are important for such mammals as gemsbok and wildebeest and for waterbirds. It is protected as either national park or as forest land, although the southern portion lies in communal land with no protection.

1.4.4 Value of a Transfrontier Approach to Conservation

The Four Corners is proposed as a transfrontier conservation area (TFCA), an area where natural resource and conservation management policies are harmonised across international boundaries. In the case of the Four Corners this includes five countries and over 1400 km of international borders.

One of the main forms of land use in this large area of 322,000 km² is wildlife-based tourism, as reflected in the high proportion of land given over to conservation and wildlife management. Some of the most obvious and charismatic animals present - elephant, buffalo, carnivores and a number of birds - readily and frequently cross these boundaries in search of food and water. As mentioned previously, the area as a whole has one of the best remaining assemblages of large mammals remaining in Africa, with healthy populations of both predators and prey. Such an assemblage needs a large area, one that is difficult to find in any one country. Thus for conservation to be effective, and for the economic benefits of tourism and other forms of utilisation to be optimised, some form of transfrontier management of both wildlife and habitat is required. Policies regarding exploitation and marketing, e.g. of timber, fisheries or tourism infrastructure at Victoria Falls, need to be harmonised, along with accepted management practices such as fire prevention and fishing techniques. A number of important habitats cross borders, for example Kazuma Pan, while the health of the Okavango Swamps depends on continued flows in the Kavango River from Angola through Namibia.

From a biological perspective, a transfrontier approach to conservation makes much sense in the Four Corners area. It is an area held together by perennial rivers and wetlands - Rivers of Life - and many of the habitats and species extend across border. These rivers and wetlands are dependent on flows from outside the national boundary of the country where they are situated. In the late Pleistocene the Four Corners area was a meeting place of waters and species from the wetter, more tropical areas of northern Angola and Zambia, with those of the drier Kalahari. Evolution took place against this backdrop as the mosaic of habitats shifted across the landscape. Allowing continued movements across it now ensures possibilities of evolutionary processes to continue - something that on such a scale is now very rare in Africa.

An additional set of reasons for harmonised cross-border management, and for collaboration across borders, relates to the ability to influence decision-makers, whether at central or local government level, and to attract resources to an area. A TFCA gives a stronger voice to the area and its conservation. If the five countries (including Angola) combine forces the area can be much more strongly marketed overseas as a tourist destination, and purely nationalistic concerns or constraints are overcome more readily.

In summary, the main advantages of a transfrontier approach to conservation here are:

- Management of fragmented or mobile populations, such as elephant and migrant birds
- Better conservation of wetlands and pans, and other transfrontier habitats
- A more "evolutionary" and landscape-scale approach to conservation
- Coordinated approaches to fire management
- Coordinated approaches to fisheries management

- Coordinated approaches to timber management
- Better control of invasive plants, fish and pests
- Improved anti-poaching abilities
- Better ability to influence decision makers in central and local government - "a louder voice, a bigger impact"
- Better marketing of tourism and wildlife utilisation; better use of existing infrastructure.

1.4.5 Effects of Climate Change

Climatic change appears to be real, but it is still not clear to what extent this is taking place, and what the major components of this change are. There seems to have been a decline in annual rainfall in the SADC region and an increase of about 0.05°C temperature per decade over the last century, but annual variability is greater than this recorded rise. The only regional study carried out to date² to try and model any potential effects of global climate change, suggested a global increase in mean temperature of 1.7°C, and used climate, soil properties and CO₂ concentrations as model parameters. Based on this, the most likely scenario was thought to be a modest drying over large parts of the region, or even a rainfall decline of up to 20%.

It is not clear what this would mean on the ground in the Four Corners area. The most likely situation is a replacement of grassland by *Acacia* savanna, while desert would expand northwards into larger areas of Botswana. *Baikiaea* and similar woodlands on deep Kalahari sands with good moisture storage will be comparatively buffered from such changes. However, mopane and other woodlands, particularly those on shallow soils, are likely to be much more affected. The riparian woodlands flanking the Zambezi are unlikely to be affected as the Zambezi is perennial, and is unlikely to become less so unless quite radical changes in climate occur. The headwaters and main charging areas are far away to the north on the Angolan plateau.

What is of perhaps more concern is the potential drying up of wetlands such as the Okavango and Linyanti swamps. Relatively small changes in inflow, continued over a number of years and coupled with higher evapotranspiration rates, are likely to lead to a reduction in the extent of permanent or papyrus swamp. Seasonal pans will, of course, be far more affected, and it is these that contain a number of ephemeral species of very restricted distribution, as well as being very important for many bird species. On the positive side, *Acacia* and Kalahari sand vegetation types are likely to expand, but these are not particularly species-rich and are already widespread outside of the immediate Four Corners area, so this will not lead to increased biodiversity or higher conservation value.

A major concern across a number of taxonomic groups is that climate change would lead to habitat fragmentation and increased patchiness of populations of species, with the result that a number of species would become locally extinct, depending partly on the speed of climate change and the rate at which species can adapt genetically or move. For rapidly breeding species with one or more generations per year, some adaptation may be possible, but this is unlikely to occur with species that have an inter-generation time of 10 years (many mammals and birds) or even 100 years (some trees). Given that a number of species of particular interest in the Four Corners area are confined to marginal habitats, it is likely that these would die out.

Finally, with migratory species such as birds, the dates of arrival of Palaearctic migrants from the northern hemisphere may well become later, while the Afrotropical migrants would arrive

²Hulme, M. [editor] (1996). *Climate Change and Southern Africa: an exploration of some potential impacts and implications in the SADC region*. Report commissioned by WWF International. Climatic Research Unit, University of East Anglia, Norwich.

sooner. Dates of departure from the region would be earlier as food sources declined. Breeding of amphibians would also be affected.

1.5 CONCLUSIONS

In conclusion, the Four Corners area is one of high biological diversity, encompassing aquatic, wetland, grassland and woodland habitats. It is a meeting place of flora and fauna typical of the drier Kalahari region with those of the central African woodlands and grasslands. Owing to the high proportion of the area that is formally protected, as well as extensive areas outside of these where wildlife is a significant form of land use, there is a relatively intact large mammal assemblage with large expanses of woodland that have not been cleared. Despite artificial barriers such as veterinary fences, and some habitat fragmentation, many species can move fairly readily across the Four Corners area. It has the key biological requirements for a transfrontier conservation area.

However, there are problems. Elephant numbers are excessively high and are impacting negatively, at least locally, on other forms of biodiversity by destruction of woodland. Veterinary fences stop ungulate movements, so necessary to cope with forage and water availability that varies greatly both in space and time. And human populations and demands are growing - often causing conflict with the requirements of conservation.

This study has identified some of the main conservation targets in terms of habitats and species - riparian woodland, grasslands, good Zambezi Teak *Baikiaea* woodland - and the 'flagship' species listed in Table 1.5. But there are still many gaps in our knowledge - on the distribution of species, their conservation status, and particularly on their biology, roles and importance. There is certainly enough information to guide conservation actions now in Botswana, Zimbabwe and the Caprivi Strip, but information on Angola is sorely lacking, hindering planning and conservation activity there, and to a lesser extent in south west Zambia.

The following four main conclusions concerning the biodiversity of the Four Corners area are made:

- A. The most important habitats for biodiversity are riparian woodland, wetlands, floodplain grasslands, pans, and rocky gorges or outcrops. However, these are relatively limited in extent, being found within a matrix of mostly broad-leaved woodlands (mopane, miombo, *Baikiaea*). *Baikiaea* woodland, although not particularly species-rich, is confined to this part of Africa. The Four Corners area can be considered as its "heartland".
- B. The number of species endemic or near-endemic to the area is not high by regional standards because the Four Corners is a biogeographical meeting place and also the landscape is constantly changing and relatively new. The major areas of endemism are the rocky gorges and riparian woodlands flanking the Zambezi River, the floodplains and grasslands associated with larger rivers, *Baikiaea* woodland, and pans.
- C. The major threats to the biodiversity of the area are posed by planned changes in hydrological regime (dams, canals, etc.) which would greatly modify existing wetlands and floodplains, perhaps the central biodiversity attributes of the area. This is followed by damage by elephants (particularly to riparian woodland) through the destruction of canopy trees and promotion of coppice growth and tall grasses, frequent burning (producing a similar effect), heavy logging or tree-felling in woodlands, and the spread of alien invasive

species. Transformation to agricultural land is not an immediate threat owing to the generally impoverished sandy soils and their unsuitability for crops.

- D. The biodiversity of the area needs to be managed collaboratively across international borders, in particular with regard to various large mammals and fishes. In very few cases are habitats or species ranges confined to just one country. A transfrontier approach would also enable the biological resources of the area to be better conserved and utilised for tourism.

1.6 RECOMMENDATIONS

Following on from the conclusions above, and given our still limited knowledge on the region's biodiversity, the following eight recommendations are suggested:

1. That a transfrontier and landscape-scale approach to conservation is implemented across the area, particularly with regard to hydrology, large mammal movements, fisheries and timber exploitation.
2. That elephant populations are managed regionally, and that some method of reducing elephant populations and therefore their impacts on the environment is implemented.
3. That a landscape-level vegetation survey is implemented in order to provide a framework for conservation planning.
4. That field survey work is undertaken, particularly in south west Zambia and south east Angola, for a number of biological groups. It is likely that these areas contain significant levels of biodiversity, including endemics additional to those listed in the reviews. Grasslands should be a special focus.
5. That a biological monitoring network is set up within some of the major vegetation types to determine initial species composition and abundance (i.e. to establish baseline data) as well as to detect any changes resulting from land use or climate change.
6. That a review is carried out of the effects of habitat fragmentation, especially veterinary fencing, on movements and population viability of large mammals across the area.
7. That strong attempts are made to control the frequency of burning in mature *Baikiaea* woodlands, particularly those in National Parks or Forest Areas.
8. That the uncontrolled exploitation of selected timber species, especially around Victoria Falls and Livingstone, is regulated as to its extent and the size class of tree felled. Some areas are becoming biologically impoverished.