



Chapter 11

Range Ecology

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Report details

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This report is authored by Dr Jeremy Perkins, with input from the following persons: Dr Graham McCulloch, Dr Chris Brooks, Dr Frank Eckardt, Thoralf Meyer and Kelley Crews, and James Bradley.

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Abbreviations

AIS	Alien Invasive Species
BD	Biodiversity
BLB	Birdlife Botswana
BRIMP	Botswana Range Inventory Monitoring Programme
BSAP	Biodiversity Strategy and Action Plan
BNWMP	Botswana National Water Master Plan
CBD	Convention on Biological Diversity
CBNRM	Community Based Natural Resources Management
CBO	Community Based Organisation
CHA	Controlled Hunting Area
CITES	Convention on the International Trade of Endangered Species
CMS	Convention of Migratory Species
CSO	Central Statistics Office
DAR	Department of Agricultural Research
DFRR	Department of Forestry and Range Resources
DGS	Department of Geological Surveys
DMS	Department of Meteorological Services
DSS	Decision Support Systems
DWA	Department of Water Affairs
DWNP	Department of Wildlife and National Parks
EC	European Commission
EIA	Environmental Impact Assessment
ENSO	El Nino –Southern Oscillation
EVI	Enhanced Vegetation Index
FAO	UN Food and Agriculture Organisation
FMP	Framework Management Plan
GIS	Geographic Information Systems
GoB	Government of Botswana
GPS	Global Positioning System
HOORC	Harry Oppenheimer Okavango Research Centre (now ORI)
IBA	Important Bird Areas
IMP	Integrated Management Plan
IPA	Important Plant Area
ITCZ	Inter-Tropical Convergence Zone
IUCN	The World Conservation Union
KNP	Kruger National Park
LHB	Large Herbivore Biomass
MCA	Multicriteria Analysis
MFMP	Makgadikgadi Framework Management Plan
MoA	Ministry of Agriculture
MODIS	Moderate Resolution Imaging Spectroradiometer
MSB	Millennium Seed Bank
MSSH	Multiple Stable States Hypothesis
MWS	Makgadikgadi Wetlands System
NBI	National Botanical Institute
NCS	National Conservation Strategy
NDP	National Development Plan
NDVI	Normalised Difference Vegetation Index

ODMP	Okavango Delta Management Plan
OKACOM	Okavango River Basin Permanent Commission
PET	Potential Evapo-transpiration
PRECIS	National Herbarium Pretoria Computerised Information System
RBG	Royal Botanic Gardens
RDL	Red Data List
RWL	Rest Water Levels
SD	Sustainable Development
SABONET	Southern Africa Botanical Diversity Network
SADC	Southern African Development Community
SANBI	South African National Biodiversity Institute
SRTM	Shuttle Radar Topography Mission (1km resolution data)
TDS	Total Dissolved Solids
TFCA	Trans-Frontier Conservation Area
WCU	Water Conservation Unit (Department of Water Affairs)
WMA	Wildlife Management Area
WMC	Water Management Consultants
WWF	World Wide Fund
ZAB	Zambian Air Boundary

1 Introduction

The main objective of this report is to define the current threats to biodiversity and ecosystem functioning, identify the optimal stocking rates and carrying capacities for the different vegetation types, identify potential indicator species, define existing opportunities and challenges to strengthening the effective conservation of wildlife species within the boundaries of the Makgadikgadi Framework Management Plan area.

1.1 Objectives

The objectives of the Ecosystem Functioning and Indicator Species Report, as defined by the Makgadikgadi Framework Management Plan (MFMP) Inception Report are to report on the vegetation communities of the MFMP study area and include details of those habitat classes that are prone to overgrazing / fire and subsequent soil erosion, with recommendations for land use changes / policy change to help improve issues of land use degradation and / or land use conflict.

1.1.1 Terms of Reference

- a) Assess land use carrying capacity for grazing herbivores within the MFMP study area.
- b) Working closely with the GIS vegetation mapping specialist the Rangeland ecologist should provide a detailed habitat summary for each of the classes identified within the MFMP's vegetation map, listing species communities within each class and the resultant herbivore carrying capacity (in LSU per km). A brief summary of the potential for soil erosion, over grazing and risk of fire within each class should be provided.
- c) Summarise the potential for soil erosion, over-grazing and potential risk of fire within each habitat class, using the Normalised Difference Vegetation Index (NDVI) map produced by the GIS mapping specialist to provide a land use degradation sensitivity scale for each habitat class, while identifying hotspots within classes
- d) Identify rangeland indicator species, selected according to defined criteria; habitat type, type of impact assessment and sensitivity to impact/change.
- e) Using GIS maps and Multicriteria Analysis (MCA), establish spatial impact on rangeland species distribution according to development scenarios.
- f) Identifying indicator species thresholds to establish monitoring Limits of Acceptable Change (LAC) framework, highlighting information gaps and research needs. Establish the extent to which different vegetation types contribute to the primary production tropic level and their importance to the biodiversity dependent upon them, concentrating on the important ecological interactions with indicator species.
- g) Identify the importance of the Makgadikgadi Wetland System (MWS) rangeland to other systems in the region and globally, and establishing the important routes of interplay with these systems through migration corridors, highlighting information gaps and research needs.

1.1.2 Outputs Required

- a) Detailed species inventory for each of the habitat classes within the detailed vegetation map produced for the MFMP by the GIS mapping specialist;
- b) A report on the vegetation community of the MFMP study area should include details of those habitat classes that are prone to overgrazing / fire and subsequent soil erosion, with recommendations for land use changes / policy change to help improve issues of land use degradation and / or land use conflict;

- c) The report should estimate the herbivore carrying capacity within each habitat class, with a review of the potential for growth in the cattle sector within the region, identify the indicator species according to habitat type and sensitivity to impact, contributions to trophic level from vegetation types, GIS analysis of impacts from development scenarios, and the importance of the MWS rangeland in the regional context;
- d) Recommendations on improving the agro-pastoral sector within the MFP area system should be included;
- e) A report on the key rangeland indicator species with specific thresholds for each to determine LAC monitoring parameters.

1.2 Methods and Activities

To achieve these objectives it was important to gather and analyse the following data:

- 1) Past reports and research undertaken within and around the Project area;
- 2) Historical census data on wildlife populations in the region;
- 3) Historical and anecdotal evidence of ecological conditions in the study area; and
- 4) Undertake targeted research within the MFMP area.

The approach to the study has been largely desk-top although two field trips were undertaken. One through the Pans (focusing on the southern Pans area) and the other along the Boteti River (from Moreomaoto to Xhumaga).

In addition, the vegetation mapping and Enhanced Vegetation Index analysis was carried out using GIS analysis of Landsat 5 TM imagery.

1.3 Linkages with other Components within the MFMP

1.3.1 Hydrology

The area is remarkable in that it is driven by the nature of rainfall in the Angolan highlands and its passage through the Okavango Delta. The return of flows down the Boteti River in recent years emphasises the need to exercise caution in the management of semi-arid ecosystems in general, and transboundary river systems, in particular, the Nata River that originates in Zimbabwe.

1.3.2 Tourism

There are strong linkages between the ecology and tourism potential of the Project area. One of the objectives of this report is to emphasise that tourism should not be seen as being diametrically opposed to livestock-keeping, but as a valuable route to economic diversification and sustainability.

1.3.3 Economic valuation

Healthy and intact ecosystems are essential to the conservation of biodiversity and the maintenance of ecologically effective populations. Changes that have occurred as a result of the livestock sector, such as bush encroachment and soil erosion, are effectively irreversible and have greatly reduced the economic value of the land towards the southern end of the Boteti River and around the margins of Makgadikgadi.

1.3.4 Land Use

The ecology component emphasises the need for strategic land use planning in order to protect key wildlife refuge areas on the one hand and allow for the progressive expansion of the livestock sector on the other. The opportunities for a meaningful balance between the livestock and wildlife sectors are emphasised.

1.3.5 Socio-economic

Through the provision of ecosystem goods and services socio-economic livelihoods are inextricably linked to ecosystem functioning. The need to re-instate the integrity and functioning of the ecosystems in and around Makgadikgadi is emphasised by this report. Currently important links between the Makgadikgadi and the Kalahari ecosystem have been lost and the management regime has shifted to an expensive and risky form of manipulative management.

1.3.6 Policy

In order to avoid excessive duplication, the ecology section has avoided Wildlife related Acts and Strategies as these have been covered in the wildlife component of the MFMP. A critical policy to the land use changes and improvements envisaged within the ecology component is that of CBNRM. The component has deliberately sought not to create new legislation but identifies critical areas where the existing legislation is challenged, such as that of 'dual grazing rights' and communal rangeland management. The equity issue lies at the heart of natural resource management in the Project area and remains a key Policy goal of Vision 2016 and District Development Plans.

2 Findings

The major findings of this component have been broken down into a number of subsections. In order to avoid the duplication of material they are presented so as to flow from the general to the specific. However, there is a striking connectivity between all the major findings of the study.

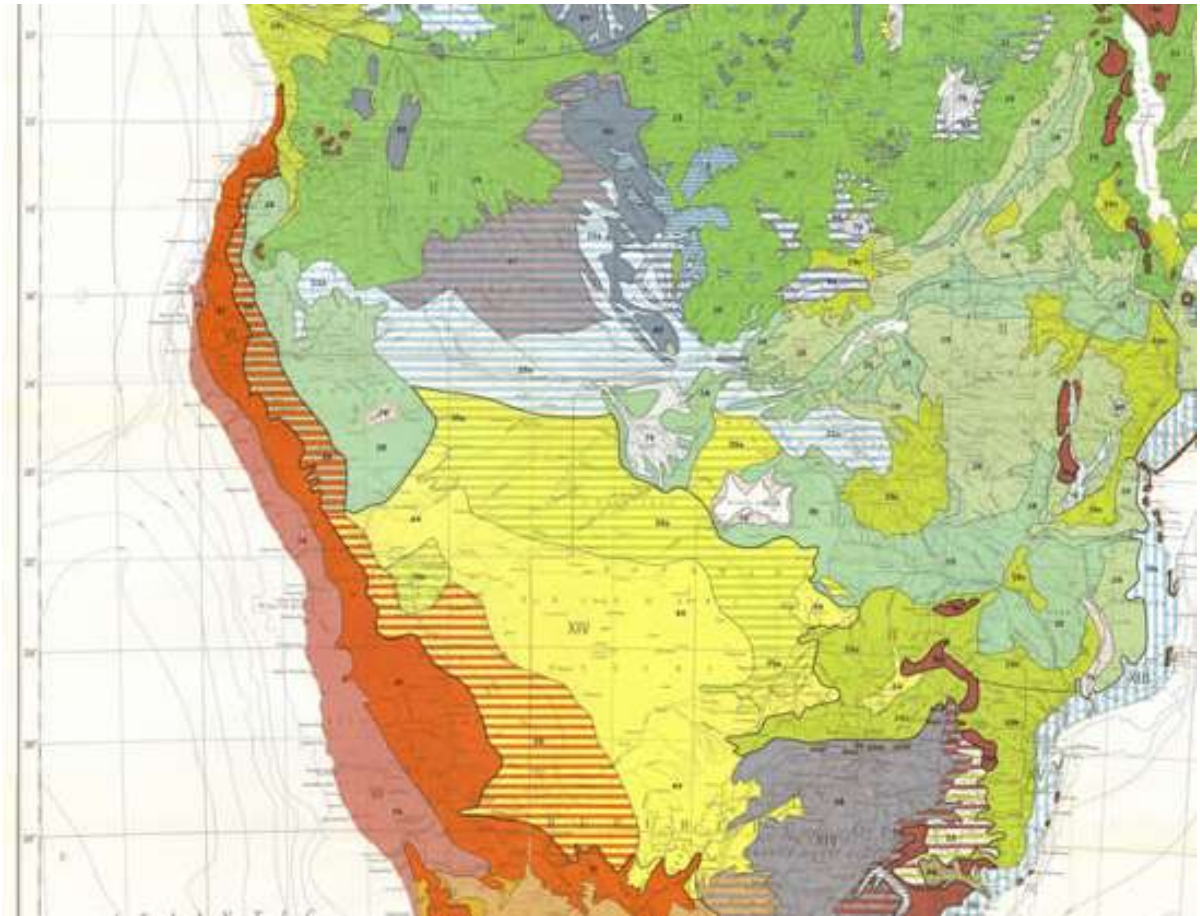
2.1 Chorological position of Makgadikgadi

In his overview of the vegetation and plant geography of Africa, White (1983) defined a number of phytogeographical regions or phytochoria, in addition to the more commonly used physiographically-defined vegetation types. Phytochoria are based on richness (or otherwise) of their endemic floras at the species level. Endemism is the property of being found nowhere else in the world.

In Botswana a broad distinction is made between the Zambezian Regional Centre of Endemism and the Kalahari-Highveld Regional Transition Zone, the latter sometimes being recognized as transitional in the south western part of the country with the Karoo-Namib region. The Karoo-Namib region is characterised by sparse, shrubby, *Acacia*-dominated Kalahari Xeric Savanna and to the north, as the climate becomes moister, the vegetation grades into a mesic savanna or woodland dominated by *Baikiaea plurijuga*, the so called Zambezian *Baikiaea* Woodland ecoregion. To the southeast, the vegetation of the hardveld grades into a complex mix of vegetation types sometimes typified as Southern African Bushveld. The vegetation of the southern two thirds of Botswana is therefore more closely related to the vegetation of Namibia and South Africa, with the vegetation of Northern Botswana part of a shared zone with Zambia, Zimbabwe, Mozambique and southern Angola and Democratic republic of Congo (see Figure 1).

The Kalahari-Highveld transition zone separates Zambezian and Karoo-Namib regional centres of endemism in the Kalahari Basin. In effect, regional centres of endemism are separated by regional transition zones, with the Zambezian Centre much higher in terms of endemism relative to that of the Kalahari Highveld Zone (Table 1). The total number of plant taxa listed for Botswana is 1422 with 1046 recorded from the Okavango and only 215 taxa from the Makgadikgadi Pans – primarily due to the paucity of botanical surveys.

It is important to be clear about the phyto-chorography of the Makgadikgadi Region as it has profound implications for the status, importance and conservation of the area. Unfortunately the vegetation types of Africa comprehensively portrayed by White (1983) have often been misrepresented in the plethora of generalised 'vegetation' maps that have followed from it. As such it is important to go back to the original. White's (1983) original map serves to emphasise the in between nature of the Makgadikgadi System, lying directly between the Zambezian and Kalahari Highveld domains, the latter strikingly following a north-western boundary defined by the Boteti River (Figure 1).

Figure 1: Regional Phytochoria of southern Africa

- I Guineo-Congolian centre of endemism
- II Zambezi centre of endemism
- III Sudanian regional centre of endemism
- IV Somali-Masai regional centre of endemism
- V Cape regional centre of endemism
- VI Karoo-Namib regional centre of endemism
- VII Mediterranean regional centre of endemism
- VIII Afromontane archipelago-like regional centre of endemism, including
- IX Afroalpine archipelago-like region of extreme floristic impoverishment
- X Guinea-Congolia/Zambezia regional transition zone
- XI Guinea-Congolia/Sudania regional transition zone
- XII Lake Victoria regional mosaic
- XIII Zanzibar-Inhambane regional mosaic
- XIV Kalahari-Highveld regional transition zone
- XV Tongaland-Pondoland regional mosaic
- XVI Sahel regional centre of endemism
- XVII Sahara regional transition zone
- XVIII Mediterranean/Sahara regional transition zone
- XIX East Malagasy regional centre of endemism
- XX West Malagasy regional centre of endemism

Table 1: Biogeographic zones in Botswana (from Hannah et al, 1988; p5.).

Centre of Endemism	Mammals Species	Mammals Endemism	Birds Species	Birds Endemism	Plants Species	Plants Endemism
Zambeian	55	4%	650	15%	8,500	54%
Kalahari Highveld	32	0	172	5%	2,000	5%
Average for African Zones	37	5%	343	15%	3,700	34%

Floristic connectivity with both domains is striking and was significantly also reflected, until the end of the last century, by the movements of the key ungulate populations – wildebeest and zebra. Relative to established phytochoria the Boteti River is thus a key divide across which the change from Kalahari-Highveld to Zambeian occurs. Many species are thus at the edge of their distribution along this boundary, with linkage between the two centres of Endemism important with respect to climate change and the ability of species to track the environmental conditions to which they are adapted. It follows that linkage between the Kalahari-Highveld (and therefore also the Karoo-Namib) and the Zambeian Centres is important at a landscape level. It is a link that has been severed by the layout of fences with as yet unknown consequences.

2.2 Traditional biodiversity assessments

Large, seemingly homogenous, wilderness areas of low endemic biodiversity (Figures 2 and 3) consistently show up on global (James *et al*, 1999), continental (Burgess *et al*, 2006), regional (Timberlake and Childes, 2004) and national (Hannah *et al*, 1988) biodiversity assessments as under low existing and potential threat (4 and 5). Indeed, this has more to do with the inherent constraints of using species diversity as indexes of biodiversity, and often surrogate measures of ecosystem health, than the realities occurring on the ground. For example, the species diversity of the Kalahari ecosystem, as calculated by the number of species it contains, has not changed over the last four decades even though over half a million wildebeest and hartebeest and two thirds of the springbok population have been lost, with drastic consequences for rural livelihoods and opportunities.

As Dangerfield (1997) put it, biodiversity is a wide ranging concept based on biological and, in particular, ecological principles that:

- i) Describes the variety of life on earth
- ii) Attempts to assess the value of this biological richness to human societies, especially the resilience and homeostasis of ecosystems; and
- iii) Provides the scientific information necessary for the identification and sustainable utilisation of biological resources (Dangerfield, 1997; p.272).

Figure 2: Area corrected species richness for vertebrates and plants

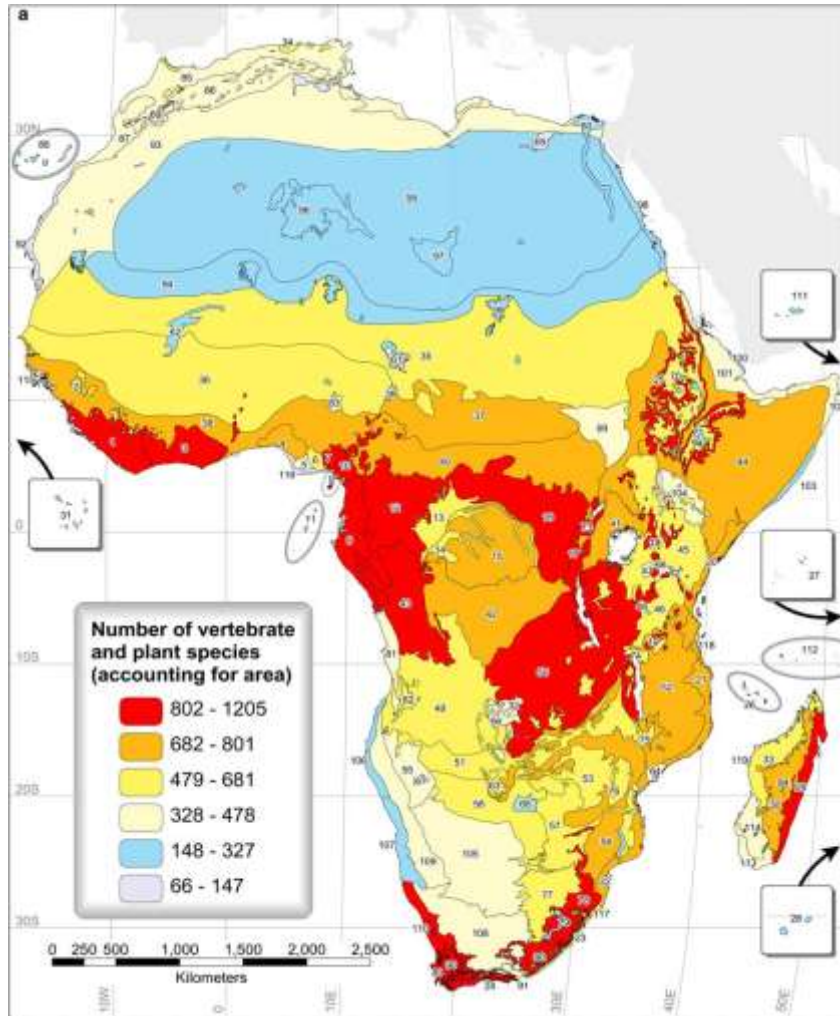


Figure 3: Biological distinctiveness index

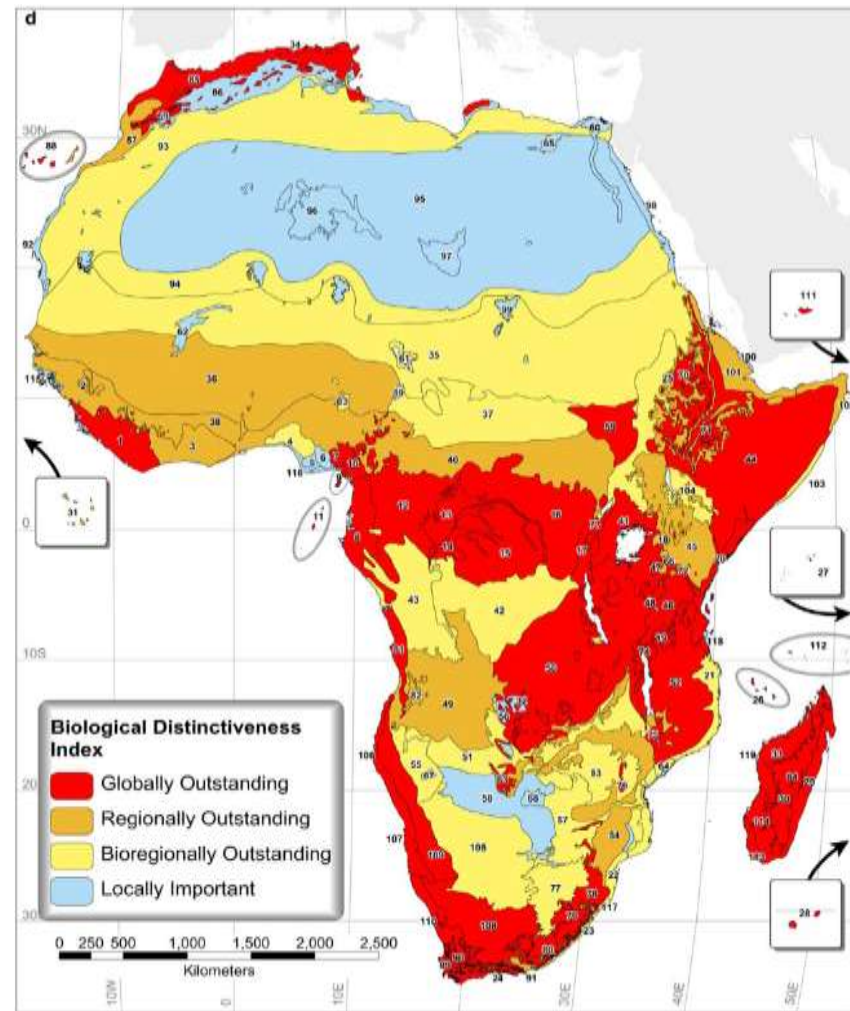


Figure 4: Current conservation status index

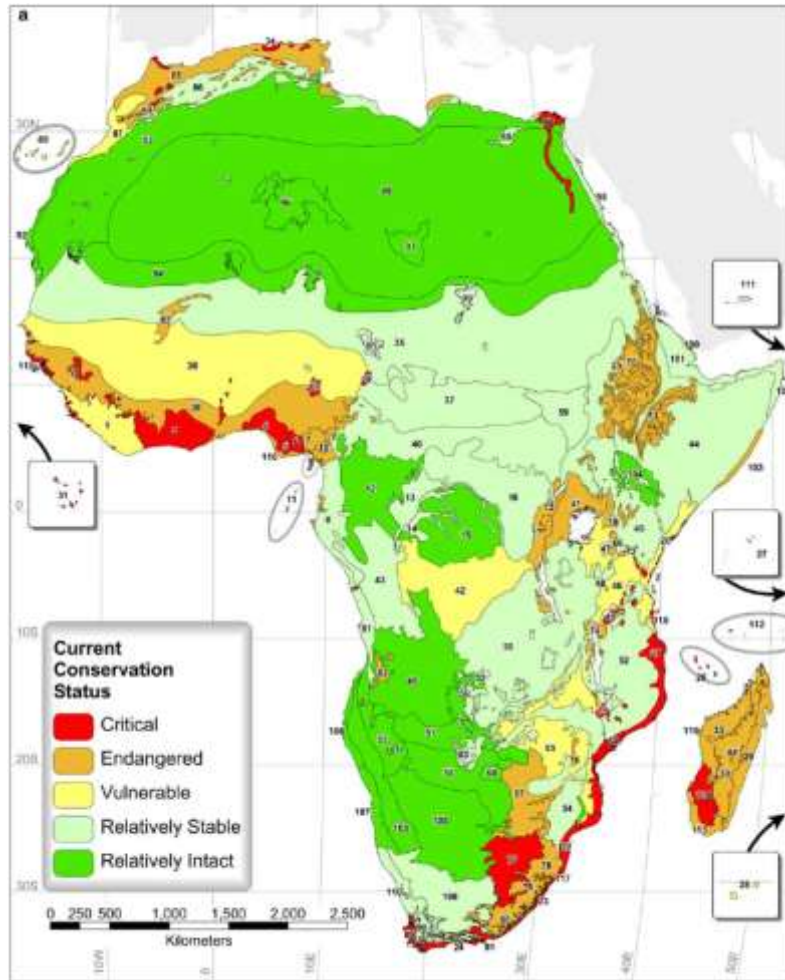
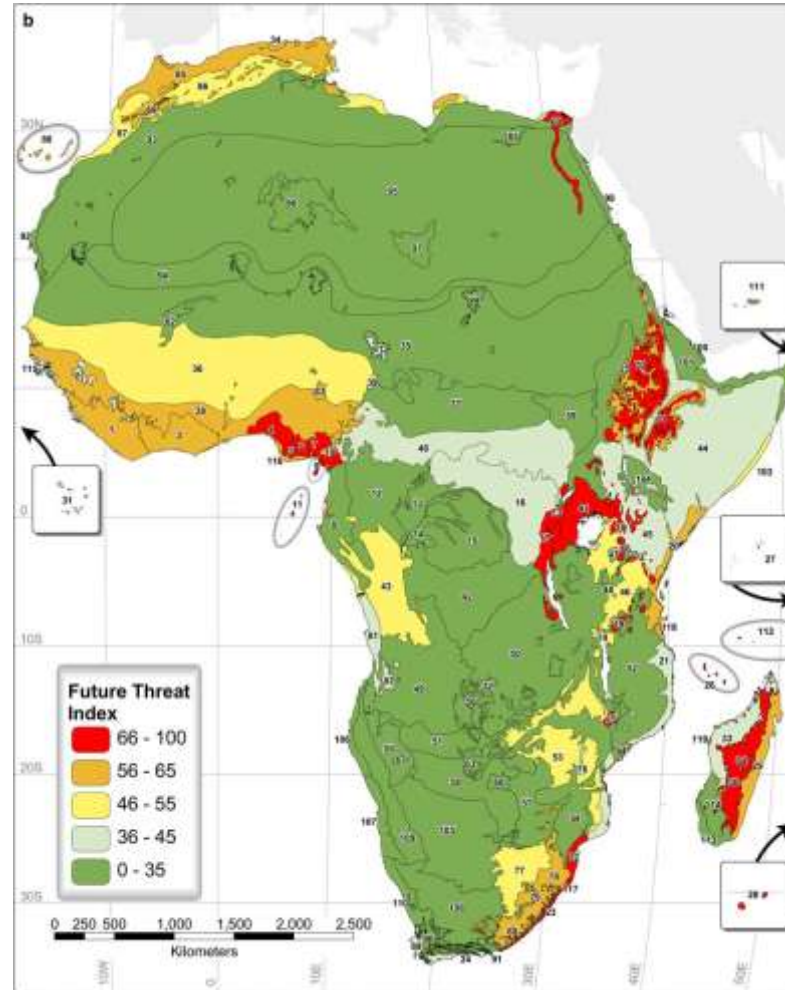


Figure 5: Future Threat Index



The BSAP-SR (2003) identified Makgadikgadi as one of Botswana’s biodiversity “hotspots”, along with the Okavango Delta, the central Kalahari, and the east. Areas of high priority within the MFMP boundary include the Boteti River (including Lake Xau), Ntwetwe’s northern pan, the Thabatsukudu-western Ntwetwe Pan area, and Sua Pan, where the south basin is of particular importance (Figure 6). There are currently 43 species on Botswana’s national Red Data list (BSAP-SR, 2003). Of these, 13 species are classed as threatened, 3 endangered and 10 vulnerable, of which *Hoodia lugardi* is the only species to have been found in the MWS, 8 species are near threatened and an additional 22 species are of uncertain status. Areas in the MWS high in RDL species include the Boteti River, near Xhumaga and close to Rakops and Mopipi, Thabatsukudu, Ntwetwe’s northern reaches, Nata Sanctuary, and Mosu area of Sua Pan (Figure 7).

Figure 6: Botswana Species richness index (From page 62 BSAP, 2003)

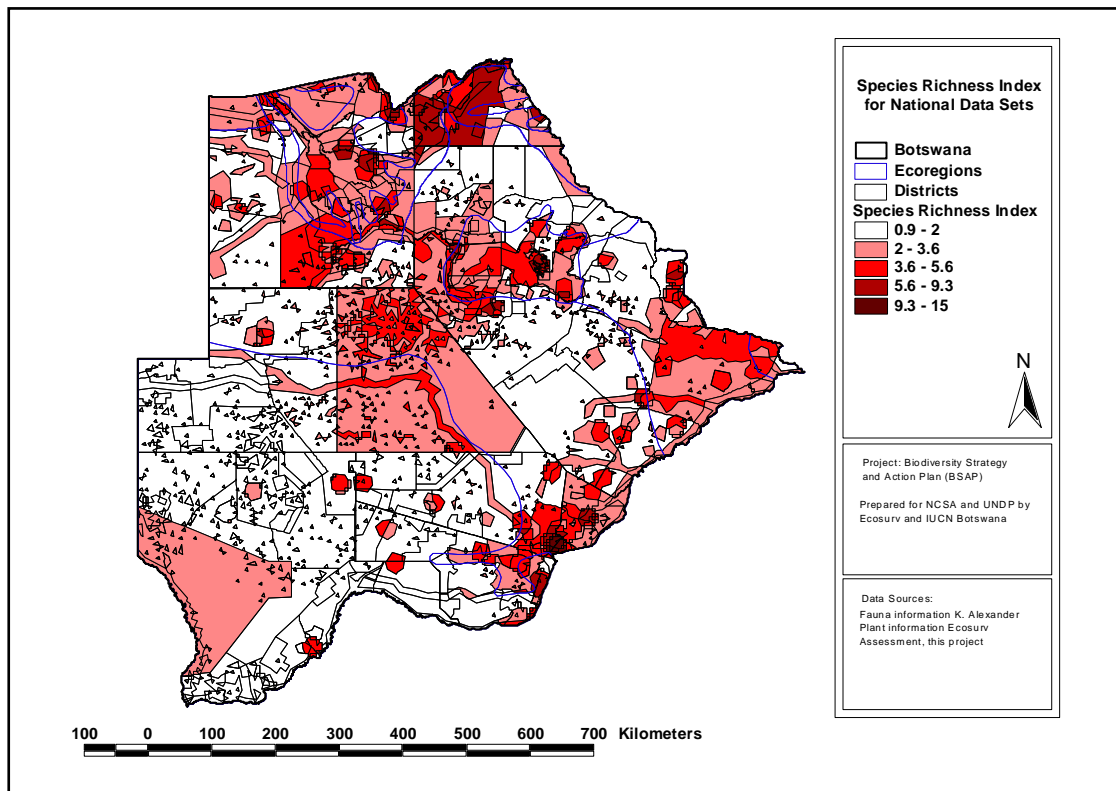
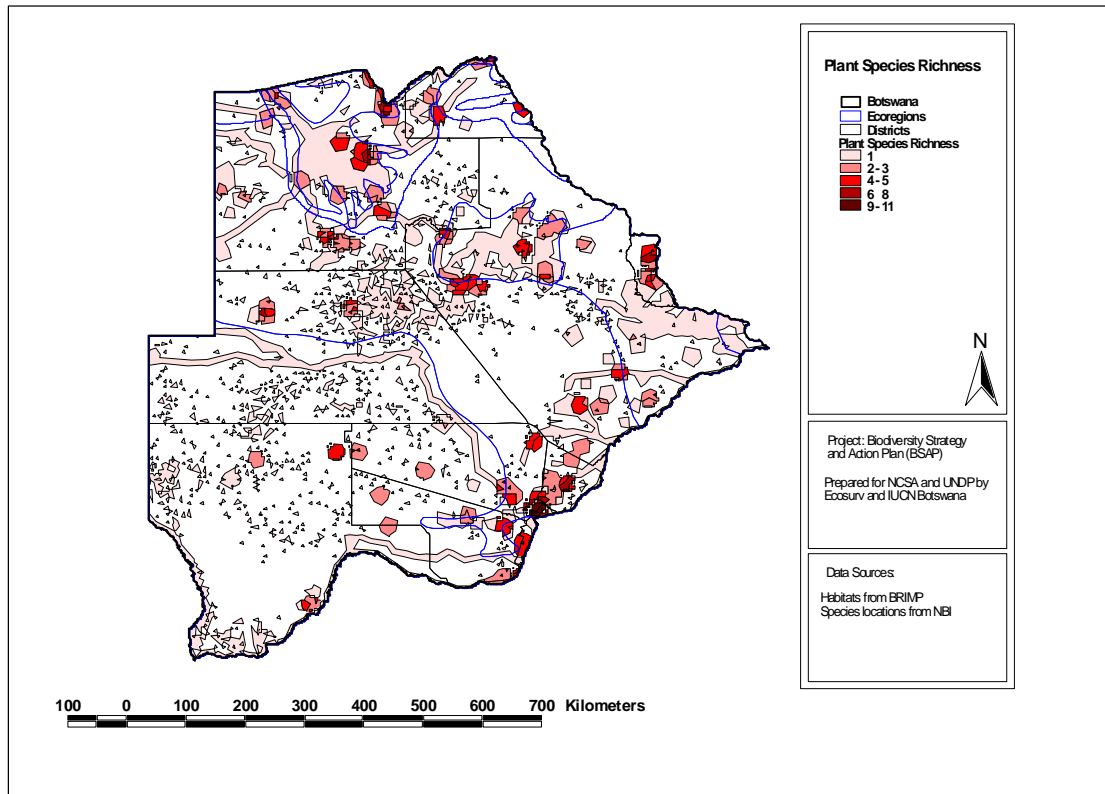


Figure 7: Distribution of Red Data List plant species (From BSAP, 2003; p.40)

As stressed earlier hotspots of native and endemic species richness are of obvious conservation value, but the protection of hotspots alone will not sustain ecological integrity (Fleishman *et al*, 2006). The latter authors emphasise the importance of intact ecosystems, such as much of the boreal forest of Canada and Russia, which are critical carbon sinks and reservoirs of little known biodiversity - yet they are not considered hotspots and have received little conservation attention. Specifying large areas for conservation priority is in itself no guarantee for success. The pattern of surrounding land ownership is also critical and also whether surrounding land users/owners can benefit from existing economic incentives so as to contribute to conservation goals. Moreover, establishing a protected area on paper does not imply the area will be managed in a way that sustains biological diversity and ecological processes (Fleishman *et al*, 2006).

2.3 Dominant vegetation communities

The MFMP vegetation map captures the broad differences in vegetation types that occur within Makgadikgadi Pan National Park (Figure 8), although it is necessarily coarse due to the rapid juxtaposition of different plant communities over short distances (100-200m). This is particularly the case for the shrub and tree savanna areas, where the dominant species can often be identified but the composition of the community itself is highly variable.

Figure 8: Broad (6-class) vegetation map of the MFMP area.

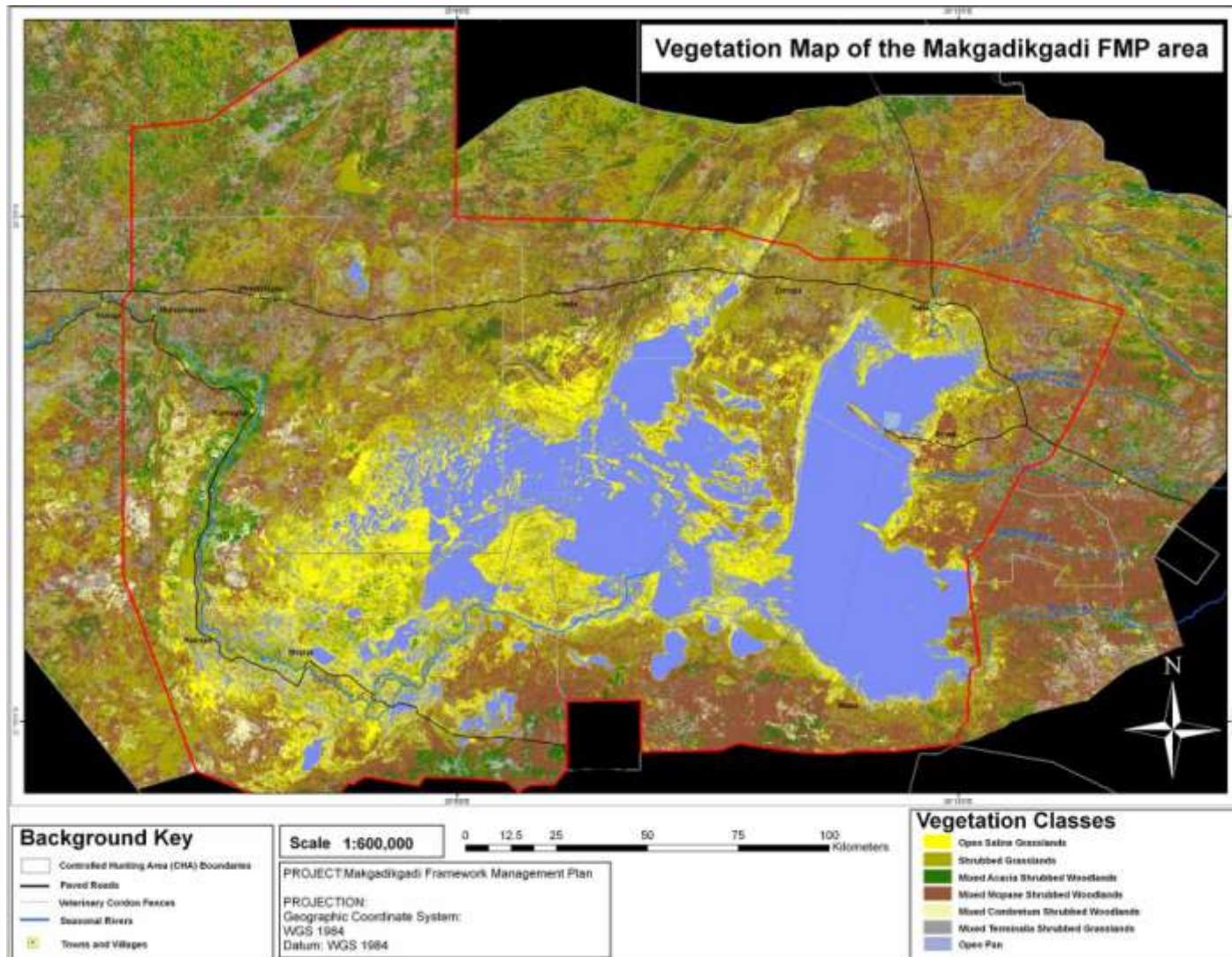


Table 2 lists these vegetation types, together with the equivalent physiographical land system units, on which they occur and a list of herbaceous (grass) and tree species found in each vegetation type. Saline grasslands are relatively species poor and dominated by few grass species, with small numbers of *Acacia tortilis*, *Hyphaene anthelminthica* and *Commiphora Africana*. These grasslands typify the landscape of the Makgadikgadi National Park and elsewhere around the fringes of the Makgadikgadi salt pans.

Table 2: Vegetation classification for the MFMP area

VEGETATION TYPE	LANDSCAPE SYSTEM UNITS	PREDOMINANT SPECIES	
		GRASSES	TREES
1. Saline Grassland	<ul style="list-style-type: none"> ➤ Bare open salt pan ➤ Scattered small salt pans ➤ Low scattered Sand dunes 	<i>Odyssea paucinervis</i> <i>Sporobolus africanus</i> <i>Sporobolus ioclados</i> <i>Sporobolus kentrophyllus</i> <i>Eragrostis echinocloidea</i> <i>Diplachne fusca</i> <i>Shueada (salt plant)</i>	<i>Acacia tortilis</i> <i>Commiphora Africana</i> <i>Hyphaene anthelminthica</i>
2. Shrubby Grassland	<ul style="list-style-type: none"> ➤ Saline sands ➤ Scattered small salt pans ➤ River delta 	<i>Odyssea paucinervis</i> <i>Sporobolus africanus</i> <i>Sporobolus ioclados</i> <i>Diplachne fusca</i> <i>Cenchrus ciliaris</i> <i>Eragrostis echinocloidea</i> <i>Eragrostis rigidior</i> <i>Digiteria eriantha</i> <i>Aristida congesta</i> <i>Schmidtia pappophoroides</i> <i>Stipagrostis uniplumis</i>	<i>Acacia tortilis</i> <i>Acacia mellifera</i> <i>Acacia erioloba</i> <i>Acacia hebiclada</i> <i>Terminalia sericea</i> <i>Grewia spp.</i> <i>Catophractes alexandri</i> <i>Acacia kirkii</i> <i>Commiphora Africana</i> <i>Commiphora pyroanthoides</i>
3. Mixed Mophane	<ul style="list-style-type: none"> ➤ Saline sands ➤ Sand dunes ➤ Old lake terraces (sand) ➤ Deeper sandy soils over duripan ➤ Low shallow clay/sand soils over calcrete 	<i>Odyssea paucinervis</i> <i>Cenchrus ciliaris</i> <i>Stipagrostis hirtiguma</i> <i>Stipagrostis uniplumis</i> <i>Eragrostis echinocloidea</i> <i>Eragrostis trichophora</i> <i>Heteropogon contortus</i> <i>Eragrostis superba</i> <i>Cymbopogon plurinoides</i> <i>Panicum coloratum</i> <i>Aristida congesta</i> <i>barbicollis</i> <i>Cenchrus ciliaris</i> <i>Enneapogon centroides</i>	<i>Colophospermum mopane</i> <i>Terminalia prunoides</i> <i>Acacia tortilis</i> <i>Acacia mellifera</i> <i>Acacia erioloba</i> <i>Combretum hereroense</i> <i>Combretum imberbe</i> <i>Grewia spp.</i> <i>Commiphora Africana</i> <i>Commiphora pyroanthoides</i>
4. Mixed Acacia	<ul style="list-style-type: none"> ➤ Main River distributaries (banks) ➤ River Floodplain ➤ Low-lying Fossil drainage 	<i>Schmidtia kalahariensis</i> <i>Schmidtia pappophoroides</i> <i>Urochloa mossambicensis</i> <i>Stipagrostis uniplumis</i> <i>Digiteria eriantha</i> <i>Eragrostis rigidior</i> <i>Panicum coloratum</i> <i>Cynodont dactylon</i> <i>Eragrostis trichophora</i>	<i>Acacia tortilis</i> <i>Acacia mellifera</i> <i>Acacia erioloba</i> <i>Acacia hebiclada</i> <i>Acacia kirkii</i> <i>Colophospermum mopane</i> <i>Terminalia prunoides</i> <i>Combretum hereroense</i> <i>Grewia spp.</i>

5. Mixed Combretum	<ul style="list-style-type: none"> ➤ Low shallow lacustrine soils over calcrete ➤ Scattered small pans ➤ Fossil Drainage lines 	<i>Cenchrus ciliaris</i> <i>Eragrostis echinochloidea</i> <i>Eragrostis trichophora</i> <i>Eragrostis rigidior</i> <i>Stipagrostis uniplumis</i> <i>Stipagrostis hirtiguma</i> <i>Schmidtia</i> <i>pappophoroides</i> <i>Digitaria eriantha</i>	<i>Combretum imberbe</i> <i>Combretum hereroense</i> <i>Colophospermum mophane</i> <i>Terminalia prunoides</i> <i>Acacia tortilis</i> <i>Commiphora pyrocanthoides</i> <i>Catophractes alexandri</i>
6. Mixed Terminalia	<ul style="list-style-type: none"> ➤ Old lake terraces (sand) ➤ Deeper sandy soils over duripan 	<i>Cenchrus ciliaris</i> <i>Cynodont dactylon</i> <i>Eragrostis trichophora</i> <i>Eragrostis rigidior</i> <i>Stipagrostis uniplumis</i> <i>Aristidia congesta barbicollis</i> <i>Enneapogon centroides</i> <i>Panicum coloratum</i> <i>Schmidtia pappophoroides</i> <i>Digitaria eriantha</i>	<i>Terminalia prunoides</i> <i>Terminalia sericea</i> <i>Colophospermum mopane</i> <i>Acacia tortilis</i> <i>Acacia mellifera</i> <i>Combretum hereroense</i> <i>Commiphora pyrocanthoides</i> <i>Grewia spp.</i>

Within the context of these broad vegetation classifications, a number of key vegetation types can be further defined, according to variations in the dominant vegetative species assemblages within them. For example, the DHV report (1980) identified the following vegetation types:-

- *Odyssea* – *Sporobolus spicatus* short grasslands, dominating species: *Odyssea paucinervis*, *Sporobolus spicatus*, *S.smutsii*, *Panicum sp.*, *Cymbogon sp.* On alkaline calcareous fine sands In Makgadikgadi lacustrine plain and some pan slopes.
- *Sporobolus spicatus* – *acinifolius* short grasslands, dominating species: *Sporobolus acinifolius*, *S.spicatus*, *Panicum sp.* On saline and non-saline calcareous, fine sands associated with small pans within Makgadikgadi lacustrine terrace;
- *Hyphaene* palm tree savanna, dominating species: *Hyphaene benguellensis*, *Acacia arenaria*, *Catophractes alexandrii*. On lacustrine terraces of Makgadikgadi Pans Game Reserve;
- *Digitaria-Antephora* grasslands, dominating species: *Digitaria spp.*, *Eragrostis pallens*, *Antephora pubescens*, *Eragrostis lehmanniana*, *Schmidtia pappophoroides*. Higher parts of lacustrine terrace of Makgadikgadi Pans Game Reserve;
- *Lonchocarpus-Terminalia* broad-leaved bushlands to savannas. Dominating species: *Lonchocarpus nelsii*, *Terminalia sericea*, *Bauhinia petersiana*, *Dichrostachys cinerea*. On Central Kalahari sandveld plains, especially in northern-central Kalahari. Higher parts of Makgadikgadi lacustrine terraces.

Some key characteristic vegetation types have been identified as a sequence of terraces that follows a salinity gradient of broad contrast (DHV report 1980);

- **Makgadikgadi Pan fringes** - Around the pools that form the Makgadikgadi Pan slightly raised hummocks carry a very sparse cover. Only a small number of species are adapted to the conditions of extreme salinity and flooding, among them are the grasses *Sporobolus iocladus*, *Sporobolus spicatus* and *Odyssea paucinervis*, together with the succulent *Suaeda fructicosa*. Because of flooding these areas are largely inaccessible except for a period of few weeks in the year; the amount of vegetation is negligible. This corresponds with the open

pan area on the FMP vegetation map. Due to the extensive bare ground this area is highly susceptible to wind erosion.

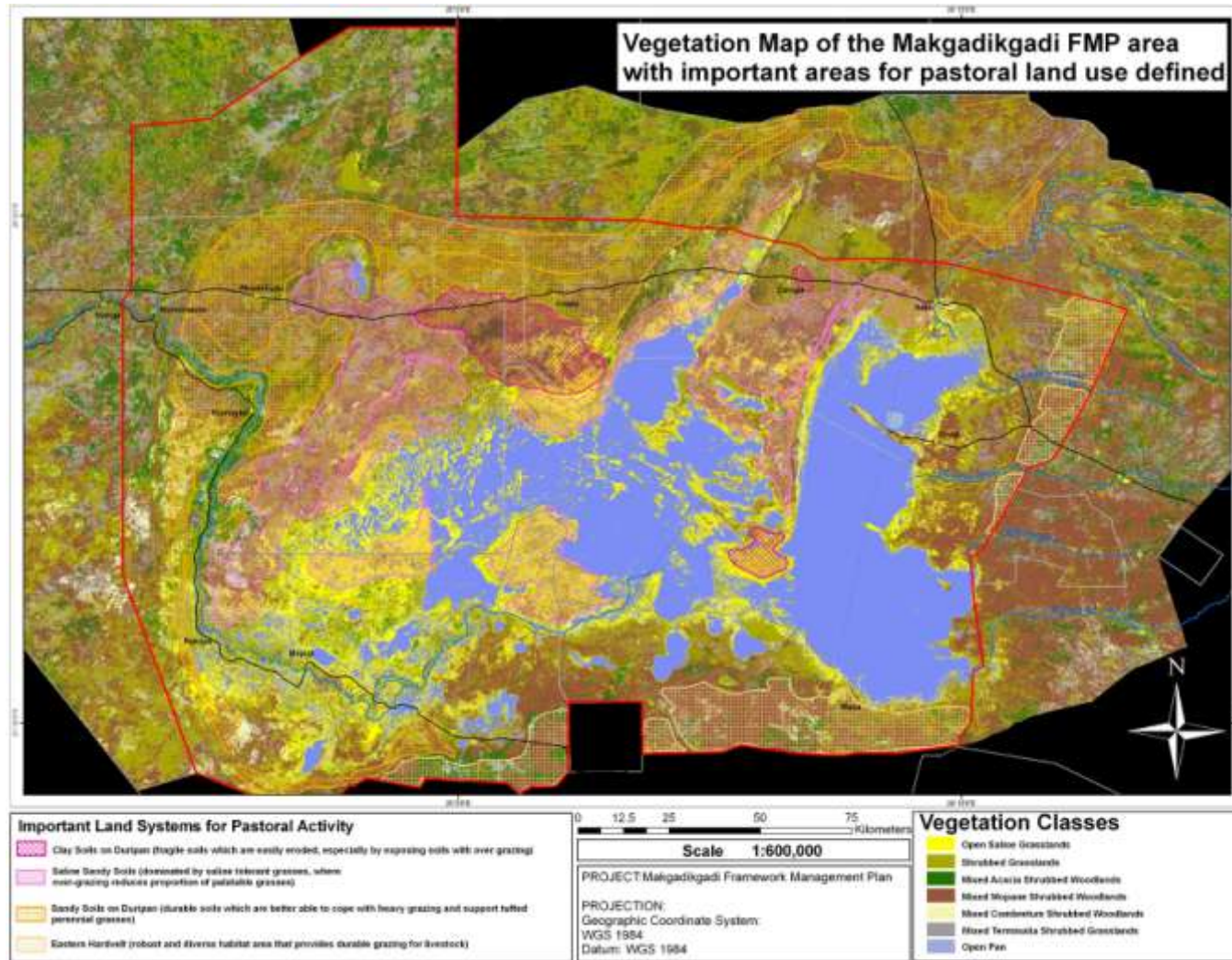
- **Halophytic grassland around Makgadikgadi pan** - Extensive grassland occurs on the slightly higher ground away from the sparse vegetation of the pan fringes. In addition to the seasonally high water table the soils are often both saline and alkaline. Trees and shrubs are absent although there may be scattered or fringing groups of *Hyphaene sp* and *Acacia erioloba*, and on raised hummocks stands of *Albizia antunesiana*, *Terminalia prunioides* and *Acacia spp.* Among the grasses are *Cenchrus ciliaris*, *Panicum coloratum*, *Schmidtia bulbosa*, *Cymbogon sp*, *Eragrostis superba*, *Eragrostis rigidior*, *Eragrostis barbinodis*, *Eragrostis echinochloidea*, *Aristida uniplumis*, *Aristida pilgeri*, *Triraphis fleckii*, *Chrysopogon montanus* and *Odyssea paucinervis*. Some areas are dominated by one or two of these species. The low grey shrub *Catophractes alexandri* and the grasses *Enneapogon scoparius* and *E. cenchroides* occur together on limestone outcrops in this grassland, and these areas are of little or no value. This corresponds with the saline grasslands of the MFMP vegetation map, but also grades into the shrubbed grassland as below. This community is best suited to sporadic grazing under a wildlife or livestock system characterised by mobility and seasonal grazing. Heavy permanent grazing has led *Odyssea paucinervis* to dominate large areas and greatly increased the susceptibility of the fine soils to wind erosion.
- **Halopomorphic grassland associated with sub-desert sands on riverine alluvium** - This unit is similar to that above, with the presence of scattered shrubs and low trees indicating less extreme conditions (in terms of salinity) and a relatively higher level of soil fertility. The Makgadikgadi vegetation map then distinguishes between dominant tree savanna types, which vary from mixed *Acacia*, *Combretum*, *Mophane* and *Terminalia*. *Mophane* dominates the fringes of the project area, particularly around Orapa-Letlhakane, forming a broad contrast with the *Acacia* woodlands along the Boteti, and *Terminalia (prunioides)* and *Combretum* dominated savanna. Meaningful separation of the tree savanna groups is difficult, without detailed fieldwork.
- **Lake Xau** - As an integral part of the Makgadikgadi wetland system, the lack of flows into Lake Xau over the past decades has meant that it has become neglected as an important ecological component of the system. With the same soils as Lake Ngami and the Mababe Depression, Lake Xau is a fertile grassland, containing such species as *Urochloa spp* and *Digitaria spp.* that was until several decades ago seasonally grazed by large herds of migratory antelopes, particularly wildebeest. Following permanent grazing by cattle *Sporobolus spp* and *Odyssea paucinervis* dominate, although species composition can vary over short distances.
- **Boteti Woodlands** - The Boteti River is fringed by a woodland/tree savanna, which generally extends at least several hundred metres outwards from each bank (Figure 9). Dominant species in the tree layer are *Acacia erioloba*, *Combretum imberbe*, *C. hereroense*, *Ziziphus mucronata*, *Acacia mellifera* and *Croton megalobotrys* and although these species may also be found in the shrub layer, *Rhus retinervis*, *Ximenia americana*, *Grewia sp.*, *Maytenus sp.*, *Diospyros lycoides* and *Dichrostachys cinerea* tend to dominate. Ecosurv (1994) report that the herbaceous layer can comprise a significant proportion of weeds, with *Schmidtia pappophoroides* and *Cynodon dactylon* the dominant grasses. The high value grazing and forage along the Boteti riparian corridor, and within the river bed itself, must be emphasised.

Figure 9: Riparian woodland along the Boteti River banks

The underlying geomorphology and soil structure are important drivers of habitat type and it is important to consider the geophysical land system units as well, in order to understand the nature and characteristics of the vegetation type in the MWS. Vegetation types associated with the landscape units were also described in the DHV report (1980). Using the land systems and their sub-units, identified in the ecosystems functions section of the main Ecology and Hydro(geo)logy Component report, we can define habitat suitability and sensitivity to degradation based on their underlying soil and geomorphology and their associated ecological constraints. Four main land systems are thus identified and represent varying suitability to grazing pressure (Figure 10):

- Makgadikgadi clay soils on old palaeolake floor Duripan – these are shallow clay rich soils underlain by calcrete or silcrete layers, on the old palaeolake floors, particularly north of Ntwetwe Pan e.g. area south of Gweta. Overgrazing here leads to reduction in cover, erosion of the hard soil crust and exposure to wind erosion;
- Saline sandy soils– these are saline sandy soils around the perimeter of the contemporary pans that are seasonally nutrient rich and productive, where year round overgrazing leads to a reduction in the proportion of palatable perennial grasses and an overall carrying capacity reduction;
- Saline sandy soils on palaeolake duripan - these are shallow sandy soils over calcrete or silcrete duripan, where the soils are more durable to heavy livestock grazing and that support tufted perennial grasses, and;
- Eastern hardveld on sandy and shallow clay duripan – this is a robust and diverse habitat that provides sufficient woody cover to prevent wind erosion and is more durable to livestock grazing.

Figure 10: Vegetation map of the MFMP area overlain with the main habitat land systems to determine grazing sensitivity.



Other sub-units consist of:

- Makgadikgadi lacustrine terraces, with mixed palm/broad leaved shrub savannas. The herbaceous component comprises the *Digitaria-Antephora* grasslands (above) and the woody component the *Hyphaene-Commiphora* mixed palm/broad-leaved savanna.
- Makgadikgadi lacustrine terraces, with grasslands. *Odyssea-Chrysopogon* grassland plain. Only in relative narrow zone the grassland is wooded with *Hyphaene anthelminthica*, *Commiphora sp*, *Cenchrus ciliaris* and especially herbaceous weeds like *Atriplex sp.*, *Pupalia sp.* due to high densities of shade seeking ungulates.
- Makgadikgadi lacustrine terraces including numerous small calc and clay pans, with grasslands. The grassland plains in between the numerous small pans are of the *Odyssea-Sporobolus* type. The pan slopes and the floor of calc pans carry a different grassland type: *Sporobolus spicatus-acinifolius*. The floors of clay pans are bare.
- Makgadikgadi bare lacustrine floors and terraces with grassland interrupted by relatively large clay pans, As above *Sporobolus spicatus-acinifolius* association. *Commiphora sp.* can occur in the contact zone of the pan slopes and lacustrine terraces.

2.4 Forage value and recommended stocking rates

The entire Makgadikgadi region, with minor exceptions in the north and south, is poorly suited to cattle. The halophytic (salt-tolerant) grass *Odyssea* dominates the pan margins (i.e. within 4kms or so of the pan edge), but can be dangerous to cattle due to its high salt content. The fine silt-clay soils often on calcretes makes it one of the most erodible environments (by wind) in Botswana. For example, in the 1980's drought dust storms enveloped the area for up to 8 months of the year.

KCS (1988) emphasised that the entire area was overstocked and that removal of the pioneer communities on the pan fringe by livestock grazing would make the fine soils prone to wind erosion. They also emphasised the need to destock the pan/calcrete section between the Sua and Ntwetwe pans and keep open a corridor between the pans for wildlife movement.

Even with the relatively 'better' vegetation types forage values are low and mineral deficiencies high. It is striking that one of the earliest known estimates of carrying capacity for pan grasslands and margins by Blair-Rains and Mackay (1968) was 16.5 ha/LSU. Field (1977) placed the 300-400mm/yr annual rainfall zone within the 16ha/LSU range, with that to the north, and including Nxai Pan, slightly higher at 12ha/LSU.

The use of the available 14 years of annual rainfall data from Sua Pan, shows that the average annual rainfall from 1994-95 to 2007-2008 was 457mm. Using 450Kg as one LSU, the carrying capacity is estimated at 16.3 ha/LSU. There is a direct correlation between annual rainfall and primary biomass (Coe et al, 1976) and in rainfall areas of less than 700mm per annum the Large Herbivore Biomass (LHB) the forage can support is calculated as 16.5 ha/LSU.

There is therefore a striking convergence of independently made carrying capacity estimations for the area from 16 – 16.5 ha/LSU. Although it should be noted that a recent report on the assessment of the Boteti Zone Six ranches (Motlogelwa, n.d) within this area, stated the carrying capacity more optimistically to be 9ha/LSU and 13-16ha/LSU, while a Ministry of Agriculture carrying capacity map shows the carrying capacity of the Pan grasslands to be 2-4 ha/LSU. This figure may be achieved for short periods during the wet season, when there is standing (fresh) water after rains, but would not be sustainable on a permanent basis, and creates a misleading impression of the areas potential to carry domestic stock.

2.4.1 Central Kalahari Game Reserve

The direct correlation that exists between annual rainfall and large herbivore biomass (LHB) (Coe *et al.*, 1976) is well established but, even if the low soil nutrient status of the Kalahari sandveld is incorporated (East, 1984), the expected LHB for the Central Kalahari Game Reserve (732 Kg/km²) is well below that actually found (400-439kg/km²) (Murray, 1988).

The latter author attributes this low LHB in the Kalahari to two factors:-

(i) the extreme variability in rainfall, with large herbivore populations adapted to the utilisation of low primary production, and excess production being removed by fire, and;

(ii) a high proportion of the total biomass occurring in the rodentivore and insectivore communities and their prey populations, with termites (*Hodotermes sp.*) particularly significant in both their contribution to total animal biomass, and in plant material removed.

2.4.2 Available Grass Forage

A combined factor called 'edible forage' is typically deducted from the herbaceous peak standing crop to account for grazing efficiency, forage loss and a 'proper use factor' to account for sustainability. Access to forage for water dependent herbivores is limited by the availability of surface water, leading to many farmers desire to increase borehole/well density. A common assumption in dryland ecology is that the peak standing crop at the end of a long rainy season represents the potential amount of forage for the long dry season, of which less than half is available as forage for large grazing herbivores. Forage availability in the long dry season in a dry year limits the maximum number of cattle that can be kept, and it is this dry season forage that is depleted if borehole densities become too high.

2.4.3 Browse

Trees and shrubs survive harsh climatic conditions such as drought and are an important source of browse feed in the arid and semi-arid savannas of Africa. However, although tree leaves have a high protein content, tannins and other secondary compounds may bind this protein, thus rendering it unavailable to the animal. Indeed, tannins and related polyphenolics may have negative effects on palatability and digestibility, and many are also poisonous. Increasing browse cannot therefore be viewed as a simple substitute for declining grass cover. Certainly in grazing areas browse can provide feed in dry seasons to cattle and other domestic stock when the grasses have a low nutritional value, or have all but disappeared. Along the Boteti *Acacia erioloba* pods, dry *Terminalia* leaves and browse were found in the dung deposits of wildebeest (DHV, 1980) suggesting the protein boost provided by such browse when graze values are low or negligible, may be critical.

2.4.4 Makgadikgadi

In contrast to the 400 kg/km² in the Kalahari system, the DHV (1980) report identified a biomass of 6,000 kg/km² for the Makgadikgadi population of zebra and wildebeest, which is equivalent to a stocking rate of about 8 ha/LSU (DHV, 1980). The availability of surface water all year round which resulted from the seasonal migration, from the Boteti (dry season range) and pools (wet season range), were identified as providing a boost to grazing animals.

DHV (1980) point out that wildebeest, when given a choice, favour grasses like *Cynodon dactylon*, *Digitaria spp.*, *Panicum coloratum*, *Sporobolus spp.*, and *Urochloa spp.*, which in the Kalahari are

found mainly on the pan and valley floors. As DHV (1980) point out, wildebeest make every effort, by travelling a great deal, to obtain grasses in the early and nutritious growing stage. They are perhaps the only large wild herbivore in the Kalahari which carries itself through the dry season on a predominantly grass diet.

The key to their existence is mobility, not at a ranch paddock scale, but a regional one, that enables the primary production that follows highly stochastic rainfall and fire events to be effectively utilized. The migratory strategy of wildlife (Sinclair, 1979; McNaughton, 1985) and, that of pastoralists (Western, 1975, 1982, 1986; Homewood and Rodgers, 1987) is well documented as being capable of sustaining much larger populations on semi-arid savannas than is possible under year round residence (Jewell and Nicholson, 1989). Nicholson (1986) describes a three day watering system by the Borana that results in no loss of animal productivity but enables distant pastures to be reached, by breaking the daily watering cycle. Sedentarisation of both domestic and wild ungulates will therefore markedly reduce the carrying capacity of the ecosystem and risk range degradation.

2.5 Groundwater

As emphasised in the above section in semi-arid savannas there is a well established direct correlation between primary biomass and average annual rainfall (Coe *et al*, 1976), with access to this forage dependent upon surface water, and therefore, deep borehole provision. In general there is a gradient of decreasing salinity as one moves outwards from the Pans into the surrounding savanna, with groundwater conditions changing from poor to fair.

As Blair Rains and McKay (1968) point out,

Around the Makarikari fresh water is obtained from wells in areas of exposed calcrete and silcrete; the supply of water in these wells depends on the extent of the catchment area and the rainfall distribution; these supplies are usually small and often fail or become unusable'(p.49).

This perched fresh water is, therefore, an anomaly within what is otherwise a sea of salinity in terms of the groundwater resource. It has however enabled small cattleposts to occupy the area, albeit at little more than subsistence level. Livestock use of the area is therefore more an artefact of the available high water table than a function of the available grazing, which after good rains can be of high biomass, but consistently poor quality.

An important distinction can be made between the rainwater that gathers after storms on the area between the pan and the tree and bush savanna, which is preferred by cattle due to its low salinity, which also enables them to graze the pan fringe. Water salinity is a key factor, but so also is the duration of surface water availability, and it is likely that together these two factors determine livestock's ability to utilise the available grazing. In good rainfall years the animal production is boosted not just by the availability of primary biomass but the access to it that the ephemeral availability of rainwater provides. By contrast in poor rainfall years the utilisation of the grasslands around the pan margins is undoubtedly limited by the salinity of both the forage and available surface water.

Blair Rains and McKay (1968) also point out that:-

'The exploitation of groundwater appears to have often been on an ad hoc basis; little attention has been given to questions of 'carrying capacity' of the surrounding area and the ability to ensure stock limitations. Making water available so that livestock can be kept in an area on a year-round basis, where previously there was only restricted seasonal grazing by wild ungulates, introduces into the system an entirely new factor with far reaching consequences..... the provision of water in

communally-held semi-arid grazing land has invariably resulted in a serious deterioration of the vegetation of the surrounding area in a relatively short time' (p.49).

Blair Rains and McKay (1968) also make the point that,

'Ideally cattle should not have to walk more than two miles to and from water; an area of 1 mile radius is 800 ha and cannot safely carry more than 100 head of stock. Animals should certainly not walk more than a total distance of 5 or 6 miles (8 or 10km) a day for water. Thus if we allow for a radius of 4kms and a grazing area of 5,059 ha then with a carrying capacity of 1 animal per 12ha, the number at each borehole should not exceed 400 adult equivalents or a 500 head herd; because it is normally impossible to ensure that the more distant areas are fully grazed, lower figures than these may be recommended. Watering should be limited to every second day if it is necessary for steers and dry cows to walk more than 5 or 6 miles' (p.53).

2.6 Range degradation

Almost every livestock related study conducted over the past forty years has pointed to the ecological deterioration of the rangeland resource as a direct consequence of keeping excessive numbers of domestic stock. It is a contention that has received substantial support from a number of environmental studies and observations (for example, Campbell and Child, 1971; van Rensburg, 1971; van Vegten, 1981, 1983; Cooke, 1978, 1983, 1985; Carl Bro, 1982; Cooke and Silitshena, 1986; Skarpe, 1983, 1986abc, 1990ab; Arntzen and Veenedaal, 1986; Veenedaal and Opschoor, 1985; MOA, 1995), including also the analysis of satellite imagery (Ringrose *et al*, 1990ab, 1996a).

All the above mentioned studies cite environmental criteria that Abel and Blaikie (1989) term as the 'conventional view' of range degradation, which are narrowed down to the following criteria:

- (i) decreases in palatable and nutritious plant species ('sweet' grasses), and increases in unpalatable and non-nutritious ones ('sour' grasses);
- (ii) decreases in perennial grasses, and increases in annuals;
- (iii) shrub/bush encroachment;
- (iv) changes in soil structure - in particular those affecting available water capacity;
- (v) soil erosion - the loss of mineral particles, organic matter and nutrients;
- (vi) decline in the primary and secondary productivity of rangeland (Abel and Blaikie, 1989: 102).

A sweet grass is one which remains palatable and retains its feeding value after completing its seasonal growth; a sour grass is either unpalatable or its nutritive value declines rapidly during the growing season and is very low in the dry season. A number of grasses are intermediate and their value can be improved by management. Because most pastures are composed of a variety of grasses their value will vary according to the proportions of the components.

Commonly occurring sweet grasses include the following, many of which are perennials, *Antheophora pubescens*, *Brachiara nigropedata*, *Cenchrus ciliaris*, *Chloris gayana*, *Digitaria spp.*, *Eragrostis rigidior*, *E.superba*, *Panicum maximum*, *P.coloratum* and *Schmidtia bulbosa*. In years of adequate rainfall annual *Urochloa spp* produce large amounts of valuable food. Prolonged rains or dry-season showers reduce the value of the standing herbage.

Sour grasses include the aromatic genus *Cymbogon* and tall-growing coarse grasses such as *Andropogon spp.*, *Heteropogon melanocarpus*, *Hyparrhenia spp.*, *Loudetia simplex*, and *Rottboellia exaltata*. *Eragrostis pallens* and many *Aristida spp* are unpalatable and the hard *Odysea paucinervis* also seems to be in this category. *Aristida uniplumis* is widespread and is important in that it may be

utilised to a considerable extent; by skilled management the value of such grasses as *Andropogon gayanus*, *Heteropogon contortus* and *Hyparrhenia spp.* can be enhanced (Blair Rains and McKay, 1968).

It should be emphasised that the certainty that range degradation is occurring rests primarily on factors (i)-(iii) for which there is considerable evidence in Makgadikgadi. Indeed, compositional changes in density and cover as the herbaceous layer shifts from sweet to sour grasses is already evident, together with an increasing dominance of weeds. Bush encroachment has affected large tracts of rangeland in and around Makgadikgadi, particularly around waterpoints or piospheres and along the Boteti River.

2.6.1 Piospheres

The piosphere effect dictates that impacts are greatest at the waterpoint itself and decrease rapidly with increasing distance into the surrounding rangeland (Lange, 1969; Andrew, 1988). Regular patterns of impact therefore emerge over time, and are spatially manifested as distinct zones which surround each borehole and differ significantly in both vegetation composition and structure (Perkins and Thomas, 1993ab).

Three zones are widely recognised as the:-

- (i) Bare ground area or 'sacrifice zone' (Stoddart *et al*, 1975), typically of (0-400m) extent around the borehole, where concentrated trampling and grazing has resulted in the loss of all vegetation cover.
- (ii) Bush encroached zone, typically (400m – 2000m) around the borehole where bush cover exceeds 45 per cent, often forming impenetrable thickets.
- (iii) Grazing reserve, beyond 2000m from the borehole where the typical tufted perennial grasses of the Kalahari dominate.

Vegetation cover after very large rainfall events or following exceptionally wet rainfall periods provide a good indication of the extent of past grazing effects. Indeed, if recovery from grazing does not occur under these exceptional conditions, it is likely to be slow or non-existent in future years under more typical rainfall conditions. In the Kalahari the bare ground area, or sacrifice zone, that immediately surrounds the waterpoint can be expected to be at its minimal extent following a period of good rainfall. Shrub increase and/or increases in unpalatable species can lead to a rapid increase in cover with increasing distance from the borehole (the bush encroached zone), which contrasts markedly with that of the sacrifice zone, and to a lesser extent, that of the surrounding 'grazing reserve'. Herbage response (and total cover) will increase systematically with distance from water as shrub effects diminish.

Consequently in the early 1980s drought it was the lack of grazing around water at Mopipi that resulted in the over ninety per cent wildebeest mortality, rather than the lack of surface water – wildebeest reportedly had to incur a round trip of 100kms in order to reach water and forage.

2.6.2 Water point provision

The expansion of the livestock industry has to a very large extent depended upon the exploitation of underground water by means of boreholes. In the Makgadikgadi the availability of surface water in the Boteti River (when it flows), or from shallow wells in its bed (when it is dry) has placed the River and surrounding vegetation under considerable pressure. In 1997 the 'gaps' in livestock concentrations along the Boteti River were caused by predator pressure, particularly at Moreomaoto and Meno-a-kwena. Xhumaga has always been a hot spot of human-wildlife conflict and provided

considerable justification for the erection of the game proof fence in 2004. The 2004 Game Proof Fence changed this and today, access to grazing has been complicated by the alignment of the Fence and the way in which it criss-crosses the River.

Livestock may compete with wildlife for both water and forage around water points and herders may intentionally or unintentionally scare away wildlife (Leeuw *et al*, 2001). Andrew (1988) suggested that animal species diversity might peak at some intermediate point along the grazing gradient away from waterpoints. Leeuw *et al* (2001) quantified the impacts of water points and livestock on the distribution and diversity of wildlife in the arid pastoral rangelands of northern Kenya. They observed a negative association between livestock and wildlife that they believed to be attributed to the impact of people associated with livestock rather than the impact of livestock itself (Leeuw *et al*, 2001). The same inverse relationship between livestock and game densities is found around Makgadikgadi (cf. Brooks and McCulloch, 2010).

Adverse impacts can be minimised by proper planning and clustering of human activities and spheres. Properly managed rangelands may even serve as a surrogate for wilderness in regions where large blocks of protected areas do not exist. The key to their integrity is the restriction and control of access to humans, namely by limiting the number of tracks and roads, and the maintenance of mobility to wildlife, by keeping such areas open and unfenced. This is particularly important in remote areas that are not protected.

2.6.3 Rangeland degradation in the MFMP area

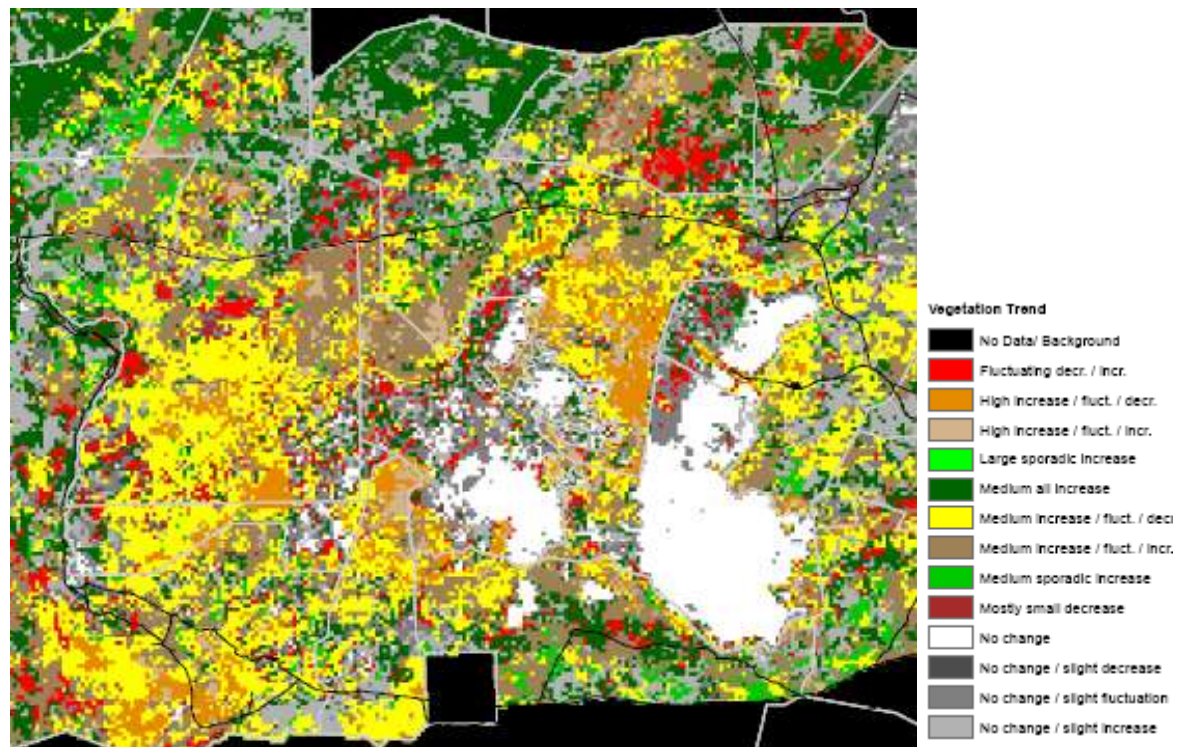
The rangelands around Rakops are widely regarded as degraded (Blair Rains and Mckay, 1968; Arntzen *et al*, 1993) with most studies emphasising the need for reduced stocking rates to allow for recovery of the pastures. The fine lake bed soils are easily picked up by the wind, with the ecosystem best suited to utilisation by large mobile herds of ungulates that grazed the system intensively in the dry season (when the floods arrived) and dispersed into the Kalahari (particularly the Schwelle) in the wet season. Permanent grazing by domestic stock on Lake Xau and the former lake bed around Rakops has therefore radically changed the way in the ecosystem functions and has resulted in a markedly reduced animal biomass and pronounced range degradation (especially soil erosion), and an inter-related loss of livelihood and income generating activities. Blair Rains and Mckay (1968) emphasise that a large area north-east of Rakops has been reduced to a very sparse cover of the hard leaved rhizomatous grass *Odysea paucinervis*, and near Rakops itself *Solanum incanum* is widespread. *Pechuel-loeschea leubnitziae* (Mokodi) or wild sage is common on disturbed areas, particularly road side verges. De Querioz (n.d) points to landscape or ecosystem level degradation due to the loss of the nutrient dispersal (particularly phosphorous) and enrichment mechanism, centring upon pans and depressions, caused by thousands of wild ungulates converging on them in the wet season, and then dispersing throughout the Kalahari in the dry. Certainly, the basic mode of ecosystem functioning has changed radically, following the complete loss of the key wild ungulate species from the area and their replacement with domestic stock, permanently grazing around wells and boreholes (and the Boteti River). This has undoubtedly led to a decline in the average stocking rate that was higher under wildlife than cattle. The latter have however had a pronounced impact on the rangelands within close proximity to water, with areas distant from water actually under or even unutilised.

As a consequence of this change, large areas of rangeland have become bush encroached and almost impenetrable by vehicle, and while the former lake beds (at Lake Xau and Rakops) remain open grasslands, permanent grazing results in severe dust storms for much of the year. The banks of the Boteti River are heavily grazed by livestock, the surrounding pastures bush encroached with *Acacia mellifera* and *Dichrostachys cinerea*, and while after good rains the herbaceous layer appears

to have recovered closer inspection reveals that the cover is dominated entirely by forbs (especially *Tribulus terrestris*). The tall *Acacia erioloba* and *Acacia nigrescens* and *Combretum imberbe* trees are still present, with livestock kraals situated under them and small lands areas adjacent to them, but it is impossible to reach the Boteti River due to impenetrable thorn bushes.

The Enhanced Vegetation Index (EVI) Map of the vegetation recovery trend from 2002 – 2010 (Figure 11) highlights the extent of degradation, particularly around Rakops, Mopipi, west of the Boteti River and around Nata, where very little recovery in the vegetation cover (grey areas) has occurred since the drought period of 2002 owing to overgrazing and habitat degradation.

Figure 11: EVI Map of vegetation recovery trend 2002 – 2010 (From MFMP, 2010)



Access to the River is problematic along much of the area between Sukwane and Rakops as many decades of heavy grazing have resulted in pronounced bush encroachment. Indeed, the aesthetic value of much of this southern or distal section of the Boteti River has been lost. It is an effectively permanent change in the vegetation (60-100 years to reverse – Westoby *et al*, 1986) that offers little or no wildlife/tourism diversification opportunities. At the same time the area has undoubtedly declined in terms of its value to beef cattle, as there is no grazing to be found. There is little to stop this rangeland change scenario progressing up the entire Boteti River, albeit for the effective wildlife enclaves found at Xhumaga and Menoakwena, particularly now predator pressure has been reduced by the Game Proof Fence. The cattleposts on the eastern, western and northern boundaries of the MPNP have also resulted in pronounced bush encroachment, such that the area outside of the immediate waterpoint becomes almost impenetrable. The encroaching species varies widely depending upon the area but the aesthetics and productive value of the land, for livestock or wildlife is greatly reduced.

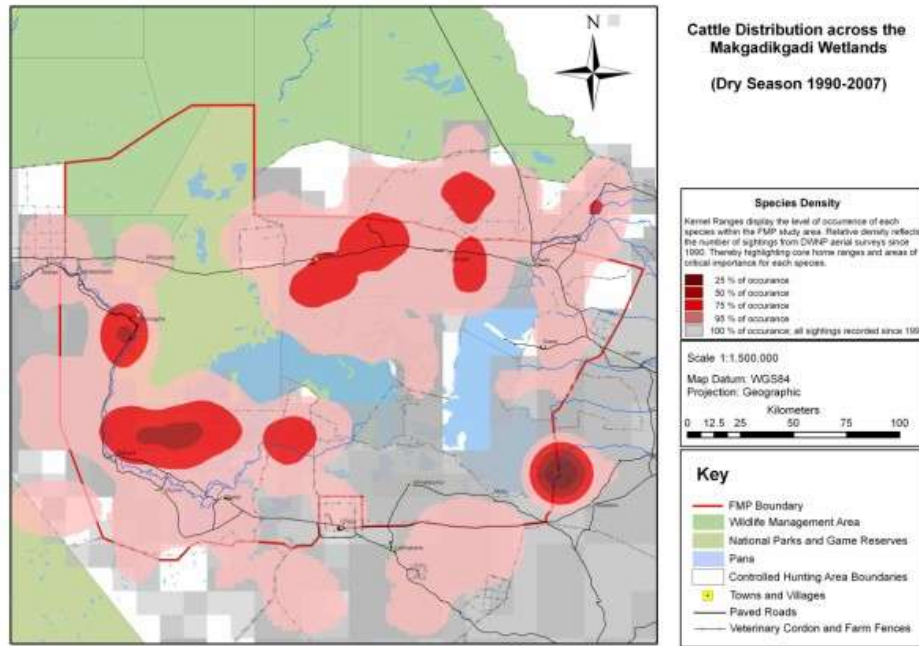
2.6.4 Livestock Distribution within the Makgadikgadi wetland system

The areas under-utilised or not utilised by livestock at all suffer from a lack of groundwater. It can be seen that the Boteti River will rapidly form a hard edge with the National Park, due to the erection of the Game Proof Fence in 2004. Predator pressure was partly responsible for reducing livestock pressure in the northern part of the Boteti system (south of Moreomaoto) (Sefe *et al*, 1997), such that there is today little to prevent livestock expanding all along the western side of the fence.

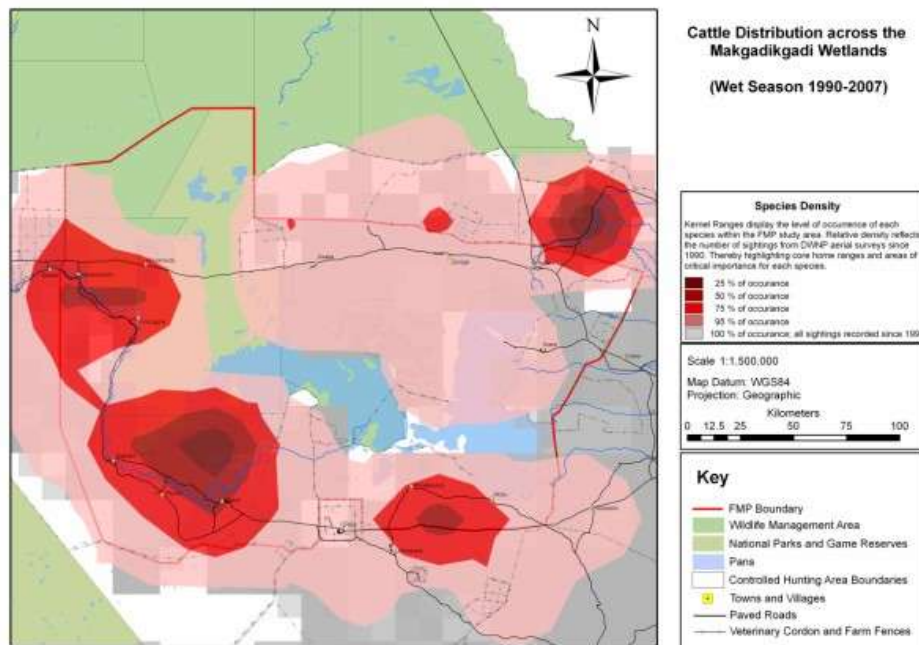
Fire hazard is to a large degree the opposite of the dry season livestock distribution map (Figure 12) – whereby areas that are not grazed heavily by cattle will be prone to veld fires. This is especially the case within the fenced boundary of the National Park – all along the Boteti River, but particularly in the north where the ungulates have been effectively excluded from the river bed by the alignment of the fence. Indeed, with wildebeest and zebra populations at such a low, the biomass that is not grazed along the riparian fringe and surrounding tree savanna will rapidly become a fire hazard – possibly driving the ungulates into the Game Proof fence, with high mortalities. Sefe *et al* (1997) found fire occurrence to be concentrated along the first 0-30kms south of Moreomaoto along the River, and then between 40-46kms. However, livestock encroachment into the Park no longer occurs such that biomass will undoubtedly build up rapidly and accumulate on the eastern side of the fence, resulting in severe fires driven from the east. Management will have to address this issue, through the strategic use of firebreaks, early dry season burns and strategic re-alignments of the fence itself. Otherwise fire will impact heavily upon the riparian zone and remove many of the trees that are undoubtedly over a century old.

Figure 12: Cattle density and distribution within the Makgadikgadi wetland system

i) Dry Season



ii) Wet Season



Source: Brooks and McCulloch, 2010

Grassland areas within Makgadikgadi can also be expected to burn after good rainfall years, simply due to the low large herbivore biomass. Management should seek to break up the fuel load through early dry season burns, so that fire while not eradicated entirely, will burn the grasslands in a patchy manner, so producing a mosaic of habitats and forage. The accumulation of fuel all along the Game Proof Fence, and within its fenced corridor, is also a major concern that will need to be cleared or burnt in the early dry season, in order to avoid a fire hazard to the fence itself. This is shown on the vegetation trend map below (from MFMP, 2010) which shows areas along the Boteti and southern boundary to have increased in biomass.

The EVI map of the vegetation recovery trend from 2002 – 2010 (Figure 11, above) shows the importance of the riparian zone along the Boteti River. The 2004 fence is likely to lead to pronounced contrasts in the condition of the riparian zone. The primary effects of livestock grazing include the removal and trampling of vegetation, compaction of underlying soils, accelerated soil erosion and dispersal of exotic plant species. Zebra and wildebeest can also impact heavily upon the riparian zone, but the effect is seasonal (dry season only) with herds dispersing to the pans in the wet season. Livestock thus have a disproportionate effect on riparian areas because they tend to concentrate in them permanently due to the rich forage and close proximity to water. It seems likely that livestock impacts along the Boteti will become more pronounced and lead to increased bush encroachment and also bare ground. The NDVI will fluctuate with much of the greenness attributable to either thorn bushes or weeds. By contrast the riparian zones dominated by wildlife along much of the Boteti River are likely to rapidly accumulate herbaceous and woody biomass and become ravaged by fire – with pronounced changes to their structure and composition likely.

As in the case of Lake Xau (with its rich grassland) it seems likely that the importance of the riparian zone forage resource to wild ungulates (wildebeest and zebra) has been overlooked in the alignment of the fence. This is likely to greatly reduce the chances of their populations recovering. The Boteti River is also prime habitat for tourism ventures, with the viewing spectacle provided by the River itself and the great diversity of African wildlife, it attracts a major potential source of revenue for local communities via CBNRM ventures – as is the case along the Chobe River in Kasane and the Boro River in Maun. The opportunity to exploit such tourism potential is however fleeting as without a major policy intervention the middle and northern reaches of the Boteti River will come to resemble the habitat south of Xhumaga and have effectively zero tourism potential due to bush encroachment.

2.6.5 Water-point provision for wildlife

The spatial distribution of livestock keeping is primarily determined by the availability of suitable ground, and/or surface water. The latter has led to intense pressure along the Boteti and heavy stocking rates around Rakops and the southern Boteti River. Along the eastern, southern and northern margins of Makgadikgadi it has confined livestock keeping to shallow wells and occasional deep boreholes. The utilisation of available forage by domestic stock is entirely dependent upon the availability of suitable water, which is so poor in both quality and quantity over much of Makgadikgadi that a considerable area of forage remains unutilised by large herbivores. This is simply because wild ungulates have been excluded entirely by the layout of fences, or have been effectively displaced by the combination of people and livestock, albeit it at low densities.

Along with the use of fire, culling and translocation, water provision remains one of the main intervention options available to managers of arid or semi-arid conservation areas supporting high densities of large herbivores (Owen-Smith, 1996). Smit and Grant (2009) clearly document how the scientific and management perception on artificial surface-water provision has swung like a

pendulum from being the 'solution' to the conservation of the herbivore species in the Kruger National Park (KNP) to being the 'cause' of the System changes and associated herbivore problems.

Smit and Grant (2009) point out that initially the supplementation of surface-water through the creation of borehole-associated waterholes had the desired effects in the KNP:

- increasing and stabilising rare antelope populations;
- contributing to the success of rhino re-introductions; and
- providing water and 'year-round habitat' for herbivores that previously migrated to areas outside of the park before their routes were cut-off by fence-lines.

However, the initial euphoria has been replaced by disillusionment with artificial water provision because of:

- the unexpected decline in rare antelopes - ever since about 1986, due to an increase in common grazer populations and a consequent increase in predation pressure on low-density antelope through the increased prey base (r).
- biosphere related degradation of the herbaceous layer,
- increased starvation-induced mortality (Walker et al.1987) and
- for compromising system resilience due to homogenisation (Smit and Grant, 2009).

Warning signs are already evident in the Makgadikgadi System that artificial water points are not addressing the key issues necessary for the conservation and restoration of the key ungulate species (cf Brooks and McCulloch, 2010). The threats of borehole provision in the CKGR was also explicitly made clear by Sweet (1986) and it is noteworthy that wildebeest declined to drink at the pumped boreholes in the north-eastern CKGR in 1992-93 (Lindsay, 1992) but instead perished on the Phefodiafoka Fence – in an attempt to reach Lake Xau/Mopipi.

The idea that artificial water point provision can compensate for the loss of access to the Boteti River, also overlooks the fact that the past die-offs along the Boteti River have been caused by the combination of a lack of drinking water and a lack of grazing around this water. In this respect the Boteti River bed and its banks were important for the floodplain and riparian forage resources that they offered, at a time of drought and/or the peak dry season. The provision of the surface water does not compensate for the lack of grazing. It follows that the large herds of wildebeest and zebra may well not return to either the Kalahari or Makgadikgadi ecosystems, if they become characterised by sedentary and permanent grazing around artificial water points. Livestock cannot utilise the pastures distant from permanent water, such that large areas of land around the Boteti River and the southern MPNP are un-, and/or under utilised by large herbivores.

Borehole provision in the Makgadikgadi should mimic the natural system and so be placed along the river bed and pumped to reflect the natural cycle of water availability (i.e. dry season pumping only along the Boteti River). Realisation of this management rationale will require strategic realignments of the Game Proof Fence – to open up more river bed and riparian grazing to wild ungulates. Permanent water provision runs the risk of increasing predator densities along the River and contributing further to declines of the key wild ungulate species (zebra and wildebeest). Indeed, the key is to maintain the mobility of wild ungulates and their access to key refuge areas. The fact that semi-arid ecosystems managed for the mobility of their ungulate populations can support much higher populations, and carrying capacities, than more sedentary systems is well documented (Western, 1975; Sinclair and Fryxell, 1986). It applies to both livestock and wildlife populations.

Elephants had already started to move down to the waterpoints that were provided along the Boteti River before it started flowing again. They exert a heavy toll upon infrastructure and the riparian woodland and as the Boteti River appears to be entering a renewed cycle of increased flows again,

the elephant population will be a new and powerful dimension to the ecological dynamics of the area. Flooding and elephant impact will undoubtedly damage the Game Proof fence along the Boteti and in turn will compromise the livestock disease control function it has now come to perform. Indeed, it remains to be seen if the return of flows to the Boteti River will lead to a questioning of the sustainability of the current policy of effectively isolating the communities on the western bank of the Boteti River from the wildlife resource, that offers the most realistic and immediate prospect of increasing their incomes and improving their livelihoods. The manipulative form of wildlife management that the Government is currently locked into appears to be both expensive and unsustainable.

2.7 Indicator Species

It is important to be clear about the nature and direction of change that has occurred on the rangelands within and around Makgadikgadi. Historical reports make it clear that Lake Xau and Rakops were marshlands and over the last century a desiccation trend has dominated. As a result many tall *Acacia erioloba*, *Acacia nigrescens* and *Combretum imberbe* trees between Rakops and Mopipi are now standing dead biomass only while the reed beds have disappeared and the palm trees are declining in number.

'Ordinarily the flood-water stops at Rakops, and four months before I was there, the river was a succession of foul stagnant pools, full of crocodiles; Chapman counted fifty-six in one pool..... Up till this year no water had been down to Mopepe since 1905, when a trader Chadwick, came down in mokoros from the Mababe with a freight of otter skins; but before that there was enough water to float boats carrying 6,000 lbs. These barges are still in Ngamiland, and are used locally during flood-time; they will never come down to Mopepe again' (Schwartz, 1926).

'..... and then down to the Botletle to lake Kumadow. The natives told Oswell in 1849 that Lake Ngami was called Noka ea Batlatli, and Andersson records the fact that it was called Noka ea Botletle. Noka is a river, and the Botletle are the Bushmen who live in Lake Kumadow, so the name seems to perpetuate the memory of the conditions when there was a current from Ngami to Kumadow. Chapman states it was probably so thirty years before he was there in 1863, and there is nothing impossible in such a condition of affairs' (Schwartz, 1926).

In 1905 there were crocodiles at Rakops and until the late 1980s they could be found at Xhumaga. Today they are found only in the Thamalakane, near Maun. As the above quote from Schwarz (1926) highlights the Boteti River has been, and remains, entirely unpredictable in its flows. The progressive change in the River System, namely its dominance by livestock is however striking, particularly in the southernmost or distal end of the System (Sukwane – Mopipi). The return of high flows to the Boteti River is not out of keeping with its recent past and the flood waters can be expected to rejuvenate the reed beds and the wetland system – although it remains to be seen if the economic diversification opportunities this water provides, through wildlife based economies, can be seized upon by rural communities through CBNRM initiatives.

Reed beds were still evident in and around Rakops/Mopipi in the late 1980s, and while many large trees (*Acacias*, *Combretums* and *Hyphaene*) have died back, their presence is testament to the unique wetland system that was found there. In the 1980s Mopipi was a fishing village, replete with fishing boats and fish drying racks and a NORAD funded fish harvesting scheme and Orapa had a yacht club on Mopipi Dam, and yacht moorings and a small harbour at the Mopipi Bays Club. Today the yacht shelter bays are used to kraal goats and the quay overlooks the dry pan over which dust devils frequently track across, lifting dust and debris into the sky. The change that Mopipi has

undergone from a wetland fishing village to a dustbowl took only several years as it was driven by an external factor, the lack of flow down the Boteti.

Within this context it is important to emphasise that the area has always been marginal for livestock, even before the Boteti River dried up. 'Molapo' or flood recession arable farming is carried out along the Boteti River bed when conditions allow (Permaculture, 1990). As a result the Boteti River bed contains a complex mosaic of molapo fields, which vary greatly in their extent, but have been in decline over the last two decades due to the lack of flow down the Boteti. However, EcoSurv (1994) report low yields (2 to 3 bags/ha on average) even for years of sufficient rain and flood, with SMEC (1980) reporting a move towards rainfed cultivation on the sandier soils of the older, higher alluvial terraces (from Ecosurv, 1994). Most recently the new phase of Government subsidies within the arable sector has led to some areas between Mopipi and Rakops to be fenced off for cultivation, even though the saline soils are ill-suited to such production.

It seems as though substantial flows have returned to the Boteti River with the 2010 flood predicted to pass Rakops and reach Mopipi Dam, as flooding has already occurred in the upper Boteti at the Boro/Thamalakane River confluence. Mopipi and Lake Xau may well receive water this year, together with Ntwetwe Pan.

The 'Limits of Acceptable Change' (LAC) concept is difficult to apply around the MPNP due to the context within which management occurs. Within the protected area itself there are a number of monitoring activities that can take place with clear management linkages. For example these include:-

- The management of artificial water points linked to a biosphere based monitoring system of the vegetation and in turn linked to changes in animal numbers and distributions – e.g. if rare species are becoming displaced by more common grazers, then it may be necessary to close waterpoints.
- An active fire management scheme linked to the reduction of fuel loads to protect vulnerable habitats (Boteti woodlands and grassland plains); and in turn linked to habitat monitoring and specific objectives such as a reduction in bush density and cover in bush encroached areas; e.g. If only a certain percentage of Makgadikgadi's different habitat types should be allowed to burn in any one year then fire hazard could be assessed and pre-emptive action taken (e.g. maintenance of fire-breaks, early dry season burns etc).
- Problem Animal Control monitoring and activities – linked in turn to active fence monitoring and management.
- The eradication and/or control of exotic plants via an active monitoring system.
- Where tourism/vehicle densities should not exceed certain levels (or rates of encounter) then monitoring and management controls can be put in place to ensure this.

These are all activities that could be undertaken by the DWNP.

However, outside of the Protected Area, management occurs within an effective void with there being little or no incentive for individuals or groups to undertake monitoring - other than for the receipt of some form of payment for collecting such data. This was found to be the case at Kedia in 2007, where there was considerable enthusiasm on the part of the Kedia Development Trust for the use of MOMS, but very few tangible management reasons for them to do so. For example the incentive to collect data on problem animals, a common module within communities located next to conservation areas, was effectively removed by the fact that this was undertaken by DWNP – to which compensation payments to those concerned were directly linked.

A broader criticism of LACs within ecology is that they are implicitly based upon equilibrium theory, or the Range – Succession model, rather than the Multiple Stable States Hypothesis (MSSH) or the state and transition model (Westoby *et al*, 1986). As the latter authors point out bush thickening or

encroachment cannot be reversed by simply reducing or removing livestock, but may take 60-100 years for the coincidence of ecological conditions necessary to revert the savanna back to open grassland. LACs can therefore oversimplify ecosystem functioning and create the impression that the physiognomy, structure and dynamics of the vegetation is up to the Park Manager, when in fact the opposite is true.

However, the linkage between LAC's and 'indicator species is also problematic due to the lack of effective management linkages. Increasing density and cover of such species as *Acacia mellifera*, *Acacia tortilis* and *Dichrostachys cinerea* is symptomatic of bush encroachment and has occurred throughout the southern part of the western Boteti River. Declining cover of sweet perennial grasses and the break-up of mats of *Odysea paucinervis* led Blair Rains and McKay (1968) to call for the immediate destocking of the area east of Rakops, and yet to this day, it has not happened.

According to Blair Rains and McKay (1968): '*Regular burning is the only practical method of controlling woody growth but this necessitates long resting periods to accumulate sufficient combustible material for an effective burn. These long resting periods will reduce the overall carrying capacity to about 1:24 ha and at these stocking rates the provision of water becomes prohibitively expensive*' (p73). As a result, in the absence of destocking and controlled burning the dense woody vegetation will remain, unless it is cleared manually.

There is little to be gained from monitoring this change, by way of indicator species or range condition, for as long as herd sizes are managed opportunistically according to rainfall, and therefore forage availability, these pronounced changes to rangeland structure, composition and functioning will occur. The expansion of kraals and cattleposts along the river could be actively monitored, although collecting information to purely document change is of little but academic value.

The occurrence of exotic species, such as the castor oil plant, *Ricinus communis*, a species of flowering plant in the spurge family, *Euphorbiaceae*, that is evident along the lower banks of the Boteti River, could be monitored and actively eradicated. It is indigenous to the south eastern Mediterranean Basin, Eastern Africa, and India, but is widespread throughout tropical regions (and widely grown elsewhere as an ornamental plant). Its seeds are the source of castor oil, and contain the toxin, ricin, which is also present in lower concentrations throughout the plant. The plant is reportedly the most poisonous in the world with poisoning occurring when animals ingest broken seeds or break the seed by chewing: intact seeds may pass through the digestive tract without releasing the toxin.

Monitoring would be valuable in CBNRM areas if communities had effective control of the area and where there was for example a need to balance the needs and impacts of the livestock sector, with those of wildlife based economies such as tourism. In the Nyae Nyae Conservancy of Namibia Perkins and Stuart-Hill (1996) estimated that stocking rates around water would have to be conservative (of the order of 56ha/LSU) if biosphere related changes were to be avoided – namely aesthetic damage to the rangelands and the loss of veld products. Monitoring could be undertaken to ensure that this was indeed the case. It clearly cannot work where Trusts share the resource base with effectively private and independent cattlepost owners, who will have different management goals to those of the Community Trust. Again this was experienced at Kedia where the grazing management and livestock modules within MOMS were of limited value to the Trust, due to the fact that any improvement in grazing resources would simply be taken up by 'private' cattlepost owners located within the Trust's boundaries. Monitoring within this context can only lead to frustration as the management linkages are fatally flawed.

In the absence of CBNRM Trusts to actively monitor and manage their areas adjacent to Makgadikgadi, the burden of monitoring must therefore fall to the State – namely DWNP (with

respect to (i) –(vii) below; while (vii) is probably only feasible through an independent researcher working with the permission of the Soda Ash mine).

2.7.1 Monitoring recommendations

- (i) Borehole/well densities around the border of MPNP. Active enforcement of livestock free areas.
- (ii) Fire hazard – especially inside the MPNP and along the eastern side of the Boteti. Pre-emptive dry season burns may be required.
- (iii) Exotic species e.g. Castor oil plant – active eradication.
- (iv) Problem animal control activities.
- (v) Fence breakage and livestock incursion into the NP.
- (vi) Vegetation transects that exploit the Fence line contrasts across the Game Proof fence (i.e. livestock versus wildlife land uses).
- (vii) Vegetation monitoring around artificial waterpoints, based on the grazing gradient or piosphere approach.
- (viii) Salt bush encroachment on Sua Pan and the formation of nebkha dunes. The encroachment of *Suaeda merxmulleri* onto Sua Pan, as a result of brine extraction

3 Development Options

The main potential development options are detailed below.

3.1 Fenced ranches

It is important to understand the rationale behind commercial ranching in order to place their provision within the right 'Policy' context. Rangeland rehabilitation has often reflected two prior judgments:

- (i) that removing livestock would reverse the damage that excessive grazing had occasioned; and
- (ii) that the cornerstone of reform would be exclusive grazing leases, which would enable investment in improvements and reward long-term stewardship while maintaining public ownership (Curtin *et al*, 2002). As the latter authors put it leases were advanced in the name of the Jeffersonian ideal of independent, democratic, family-scale producers but afforded a compromise with those who feared the creation of a quasi-aristocratic class of large property owners.

As Curtin *et al* (2002) state these two judgments rested, in turn, on a set of assumptions that went more or less unchallenged in range science for much of the last century that:

- (1) Rangelands would never find a "higher" use than livestock production;
- (2) Spatial and temporal variability in forage production was of secondary importance, as much as it could be abstracted away in carrying capacity calculations and/or mitigated by improvements;
- (3) The intensity of livestock grazing was the principal independent variable determining vegetation response on rangelands; and
- (4) Livestock exclusion would cause vegetation to revert to its earlier composition and density.

The exact origins of these assumptions are obscure, but it is clear that they were imported to desert grasslands from elsewhere (Curtin *et al*, 2005). It is now clear that while these assumptions have shaped policy they are in fact misplaced. Commercial ranching, even when practiced according to a strict rotational grazing system, has not proven the panacea to detrimental changes on the rangelands as many policy makers assumed (Sandford, 1983; Abel and Blaikie, 1989). Teague *et al* (2004) point out that research comparing rotational with continuous grazing has generally concluded that the effect of rotational grazing per se on defoliation patterns is weak or absent.

The strengths of commercial ranching are widely stated to lie in the opportunities it offers for selective breeding and the prevention of straying. However, the former is increasingly controversial as local breeds are particularly important resources because of their superior abilities to resist diseases, poisonous plants, and be productive under heat stress, water restriction and cope with poor quality feed. The loss of traditional breeds could be critical especially in a drier Botswana, as predicted under global climate change.

While commercial ranching remains a cornerstone of Agricultural policy in Botswana it is important to explicitly recognise the mismatch between their provision and current thinking in rangeland ecology. DHV (1980) explicitly stated the belief in the productivity benefits that would supposedly follow the conversion of cattleposts to fenced ranches as 'delusional'. The Protectorate era saw beef ranching as Botswana's only hope of generating income from an export market with the resulting land capability maps dated (for example Debenham, 1965) in the sense that commercial livestock keeping is, but one increasingly less attractive land use option that is now available. Indeed, with the rapid growth of global tourism, the progressive removal of agricultural subsidies, the predicted impact of global climate change and the premium attached to the biodiversity of wilderness areas in

terms of the high value of ecosystem goods and services that they offer, commercial ranching as a universal land use appears distinctly unattractive.

However, should commercial ranches be required to be zoned it follows that they should be located in areas with 'good' quality and quantities of groundwater, and forage, and should serve to deflect wildlife populations into low conflict areas. Ranches can thus be used to rationalise land use around Makgadikgadi, by strategically removing livestock from areas that are critical to wildlife and at the same time reinforce land use and disease control requirements for the beef sector. Development and consolidation of the Nata Ranches on the southern side of the Buffalo fence could thus act to strengthen conservation if they could be used to alleviate pressure along the critical boundary areas of Makgadikgadi (e.g. Ntwetwe Pan and the Boteti). Similarly, the status of the BLDC ranches should be clarified, with those that occur along the boundary of Makgadikgadi appearing to be in a state of disrepair and neglect, as the fences are down and many of the paddocks seemingly ravaged by fire.

Currently out of 25 allocated ranches at Nata, only 8 are properly fenced with viable perimeter fences and paddocks, while 15 have partial or collapsing fences and no paddocks, and appear to be operating like cattleposts, with 2 ranches not developed at all. It is finding that echoes that of the McGow and Associates (1988) report *"the capacity for the National Development Bank to manipulate its models and test alternative approaches to ranch development has increased. However, the basic real world problem of low or negative ranch profitability has not yet been addressed"* (McGowan International and Coopers Lybrand, 1988:8). This is clearly a waste of a valuable resource (grazing land) and it is recommended that such ranches are repossessed and used as a form of compensation for the potential loss of grazing lands in the stateland WMAs – such as CT11.

3.2 Communal rangeland management

Currently, the most effective way of controlling stocking rates on the communal rangelands around eastern and southern Makgadikgadi is to place strict controls on the drilling and use of boreholes/wells for livestock keeping. The perched groundwater on the calcrete ridges of the area have enabled cattleposts to establish, although stocking rates are limited more by the lack of suitable water, than the available grazing – as yields are low and saline. Within these shallow well areas there are also effectively private boreholes where an individual, or syndicate, has drilled a borehole and operates a cattlepost (for example as occurs in CT/10).

Along the Boteti River the dry river bed was characterised by a series of JoJo water tanks and the sound of generators that pumped water up from hand dug wells, before flows returned. Cattle would converge on these watering areas in the late afternoon/early evening before being kraaled, or simply returning to the surrounding grazing areas. There are also some 'private' cattleposts along the Boteti River, with some of the boreholes that were drilled for the construction of the new road between Mopipi and Motopi reverting to cattleposts after the road was built.

Heavy stocking rates on communal rangelands have been much bemoaned within the rangeland management literature and have led to a sustained programme of privatisation and commercialisation of livestock production via the Botswana Government's ranching programme. As a result much of the eastern Kalahari that was formerly open cattlepost country is now fenced ranches, including the area around Kedia. Within this lies the Hima Game Ranch, ostensibly for game farming by Remote Area Dwellers (RADs), but currently without water, game or perimeter fencing.

The prospect of any stocking rate control or limits on communal rangeland is really under-mined by two realities:

- (i) 'Dual grazing rights' – whereby 'private' ranchers graze their livestock on the Commons before retreating to the exclusivity of their fenced ranch as the grazing on the Commons becomes exhausted.
- (ii) Effectively 'private' cattleposts occurring within communal areas around settlements.

Both factors mean that there is no incentive for individuals, or the members of the newly formed Village Trusts to limit grazing in their area, as it will simply be used by stock owned by people who have no interest in the Trust's Management objectives, but nonetheless operate within their area. This is the case around Mopipi/Mokoboxane and Kedia where the Trusts' desires to improve veld condition and generate income from wildlife related economies is fatally flawed due to the presence of private cattleposts within their area. Indeed, a central issue within these tribal land areas is again one of access and rights to the natural resources within them, and the extent to which equity should feature in their management and the distribution of benefits originating within them. As long as livestock keeping remains outside of these critical resource management issues then effective management of natural resources by local communities will remain fatally flawed, and the more powerful individuals within their midst will, perhaps understandably, seek to gain maximal benefit from their livestock by managing them opportunistically and independently of any broader management goals that the Community trust may have (e.g. ecotourism). Within this context the prospect for any meaningful form of livestock management on communal land is also negligible.

If the Trusts in the area (e.g. Mokopi and Kedia) could work together and also have exclusive control over the natural resources within the Trusts' lease area (including the grazing resource), then there is clearly considerable potential to both enhance wildlife-based CBNRM activities and improve the condition of the range by reduced domestic stocking rates and recovery of pastures by a system of enforced 'rotational' grazing – through increased herding. The inequities surrounding the current use of the communal land around Makgadikgadi, and the natural resources they contain, cannot be effectively addressed within the current set up – whereby powerful and effectively private well/borehole owners exploit the communal grazing resource to their own maximal benefit. In this respect it is the semi-privatisation of the Commons by the wealthy that is a tragedy, rather than overstocking by the poor.

The need to diversify the economy of the area through wildlife/tourism based CBNRM activities cannot be overemphasised. Increased use of crop residues, fodder banks, reduced watering and rotational grazing through improved livestock husbandry all have some potential to improve the primary and secondary productivity of the rangelands around Makgadikgadi, but will not overcome the structural constraints, on any form of livestock keeping, that is imposed by poor rainfall and soils. Indeed, the inherent unsuitability of the area for intensive management systems, such as livestock and game ranching, must be emphasised.

In the 1980s demonstration 'communal grazing cells' within the hardveld, sandveld and mopane areas of Botswana sought to demonstrate the benefits of rotational grazing (via a wagon wheel layout) and commercially oriented production (Sweet, 1986). The cells were to be communally owned and operated, and stocked with cattle from the community, with the emphasis placed upon small cattle owners (Sweet, 1986). The latter author reports that despite the poor rains in 1981 and 1983 cattle in the grazing cell performed well, but the project fell behind schedule and was later abandoned, due to the following reasons:

- General lack of interest in the communal grazing scheme;
- Communities were apprehensive about allocating part of an already overcrowded communal area for the exclusive use of a few members of the community;
- Potential beneficiaries did not see sufficient incentives to motivate their acceptance;
- Scheme was based on an alien concept;

- Communities were often motivated by the possibility of securing additional grazing or an additional source of water, rather than a realisation of the need to improve the management of their existing resources;
- In some communities there was reluctance to allow one group exclusive use of part of the commonage and to fence it off;
- No guarantee that cattle coming out of the cells would be sold rather than put back on commonage;
- When they came out of the cell the 'fat' cattle lost more weight than their leaner contemporaries in the commons – leading to reluctance of members to pay for participation; and
- There was little feeling of ownership of the product.

After six years of attempting to establish communal grazing cells, the following factors were felt to be responsible for its failure:-

- the communal grazing cell scheme was badly designed;
- introduced too many alien concepts simultaneously;
- took insufficient cognisance of traditional attitudes to cattle ownership; and
- did not secure active participation of the members.

As Sweet (1986) put it *'Group action to overcome a problem perceived by outsiders can only be expected if that problem is also recognised and considered important by the community.....The issue of grazing control and stock limitation can probably only be successfully tackled when the problems more readily perceived by the communities have been addressed and overcome.'*

3.3 CBNRM

Protected areas in Africa do not provide sufficient space to support the long term viability of large herds of free ranging ungulates (Georgiadis *et al*, 2003), and Makgadikgadi is no exception. Consequently, the remaining option is for wildlife to share rangeland with humans and their livestock (Du Toit and Cumming, 1999) primarily through the promotion of non-consumptive tourism via CBNRM – including also the harvesting of thatching grass and other veld products (fishing, pole and fuel-wood harvesting)cultural services (traditional villages and shows), crafts production, game meat harvesting and live game sale. This model of economic diversification and rural livelihood improvement is proving effective elsewhere in the region, often in areas with strikingly less appealing habitats and wildlife, than Makgadikgadi. Indeed, the aim of CBNRM ventures in large parts of Namibia and South Africa is to try and restore the land and its wildlife populations to its pre livestock ranching condition.

As Ferrar (1995) put it,

"There were no positive sentiments expressed about the Parks or DWNP but, when challenged they generally claimed to have nothing against Parks or DWNP except that they should be elsewhere" (p.25).

And further that,

"There is enthusiasm for projects based upon natural resources but reluctance to face the trade-offs that may be required to make them successful i.e. provision of livestock-free land" (p.25).

IF there could be a more give and take utilisation of the available forage resources on either side of the Makgadikgadi Game Proof Fence, as for example documented around Etosha Pan in Namibia

(Hoole and Berkes, 2009), then the ambitions of both CBNRM related wildlife initiatives and the livestock sector need not be compromised. However, within the current context of an effectively heavily subsidised livestock sector and a dearth of CBNRM initiatives along the River such flexibility would only be to the benefit of the livestock sector – and a return to the situation where livestock graze 40 per cent of the park (Ferrar, 1995) could occur.

3.4 Past Development Scenarios

.... *‘Within the Northern Statelands only limited areas can be recommended for immediate development for grazing. When the large number of factors relating to domestic livestock production have been taken into account the conflict between the interests of the game hunter and those of the cattle producer need not be regarded as irreconcilable’* (Blair Rains and Mckay, 1968; p.64).

Blair Rains and McKay (1968) made a number of recommendations for the development of the then Northern Statelands. It is important to emphasise that at this time livestock development was seen as the only viable development path for the country, with wildlife based economies broached, but little more than remote possibilities. The rangeland carrying capacities suggested by Blair Rains and McKay (1968) are reproduced below (Table 3 and Figure 13).

Table 3: Development potential (From Blair Rains and Mckay, 1968)

Area	Areas suitable for Ranching	Carrying capacity (hectare per animal unit)	Area (sq. Kms)
A	Good potential (mineral deficiencies)	8	606
B	Moderate potential	10	725
C	Moderate potential	12	881
D	Poor – moderate potential water may limit development	12	1,813
E	Poor – moderate potential water may limit development	16	596
F	Moderate potential. Mineral deficiencies; water probably not available	10	207
G	Moderate potential. Mineral deficiencies; water probably not available	10	1,618
H	Immediate destocking: after recovery period moderate potential; mineral deficiencies; water probably not available	12	1,684
I	Low potential; Dichapetulum cymosum occurs frequently on the ridges (dunes)	20	2,512
J	Low potential; Dichapetulum cymosum occurs frequently on the ridges (dunes)	20	492

Area A

North and north east of the fenced Nata ranches, consists of approximately 60,000 ha of open grassland. Special mineral supplements are probably necessary. The estimated carrying capacity is 1:8 ha. Part of this area is within the area known as the Nata Ranch and includes a number of existing boreholes.

Area B

Schmidtia-Urochloa scattered shrub savannas of 72,100 ha; carrying capacity 1:25.

Area C

Lying between Areas A and B and is the Nata River System. Area C consists of 87,600 ha of shrub and tree savanna where the trees are mainly confined to the grassy depressions around the waterholes. The carrying capacity of this area will be far from uniform, but it is estimated to be 1:12 ha overall. The dense mopane scrub and mopane woodland will determine the limit of development in the east.

Area D

Occupying nearly 180,600 ha this area surrounds 20,640 ha of open grassland around the Kudiakam Pan to the east of Area F; a further 77,300 ha would be occupied by the proposed corridor between the Nxai Pan and the Boteti River. The area includes sandveld and mixed grassland and the density of the shrub is variable although mainly open. The woody vegetation tends to be thickest on the loose sand ridges which occur east of the Kudiakam Pan. The Odiakwe veterinary camp is sited in the eastern part of this area. The most serious obstacle to the development of the area is the lack of adequate and reliable supplies of potable water. Many of the boreholes between Gweta and Bushman Pits have yielded highly mineralised water. The carrying capacity will vary from 1:10 ha to 1:16 ha and overall is estimated at 1:12ha.

Area E

In these 59,250 ha between the Makalamabedi Veterinary Quarantine Camp and the old Maun-Francistown Road, any development will depend on the availability of water; the overall carrying capacity is 1:16 ha but will vary according to the density of the scrub. Regular burning will have to be included in the system of management.

Area F

The characteristics of this open grassland, occupying 20,640 ha around the Kudiakam Pan, are similar to those of Area A. The lack of water will probably preclude its development; and mineral deficiencies in the pasture are likely to be serious. Estimated carrying capacity is 1:10 ha.

Area G

Open grassland extends over approximately 161,000 ha immediately north of the south-western arm of the Makgadikgadi Pan. Near Gweta there are herds of cattle which are watered at wells and at seasonal pools, but elsewhere lack of potable water is the most serious obstacle to the introduction of cattle. Mineral deficiencies are probably serious; carrying capacity is estimated to be 1:10 ha.

Area H

Although this is the southerly continuation of area G, a large part of the grassland has been reduced to a sparse cover of the rhizomatous grass *Odyssea paucinervis*. Occasional plants of other grasses suggest that the deterioration is probably due to overgrazing. Wildebeest are common but less numerous than formerly.

There are frequent outbreaks of FMD and the herds of cattle which are kept in the area involve the Veterinary department in a heavy programme of disease control measures. In this area the presence of both cattle and game is clearly unsatisfactory, but no effective utilisation of the area by either cattle or game is possible until the vegetation has recovered from overgrazing.

After a recovery period, provided that adequate quantities of potable water could be supplied, this area of more than 167,000 ha could be developed as a ranching unit, with if necessary the elimination of the game. If enough water cannot be found, and this seems most likely (the existing herds are watered at shallow wells) then the area could be reserved for game with the introduction of some form of game cropping.

Area I

In this area of 249,000 ha of shrub savanna there are alternating belts of fairly dense woody vegetation and more open scattered shrub savanna. The carrying capacity varies according to the density of the shrub cover but is relatively low because of the necessity to include regular burning and is estimated at 1:20 ha. At this stocking rate the cost of providing water may be a serious obstacle to development.

Area J

Shrub savanna occupies 44,500 ha. The carrying capacity is estimated at between 1:16 ha and 1:20 ha. The isolation and size of this area and the cost of providing water appear to be major difficulties affecting any development.

Figure 13: Rangeland carrying capacities suggested by Blair Rains and Mckay (1968)

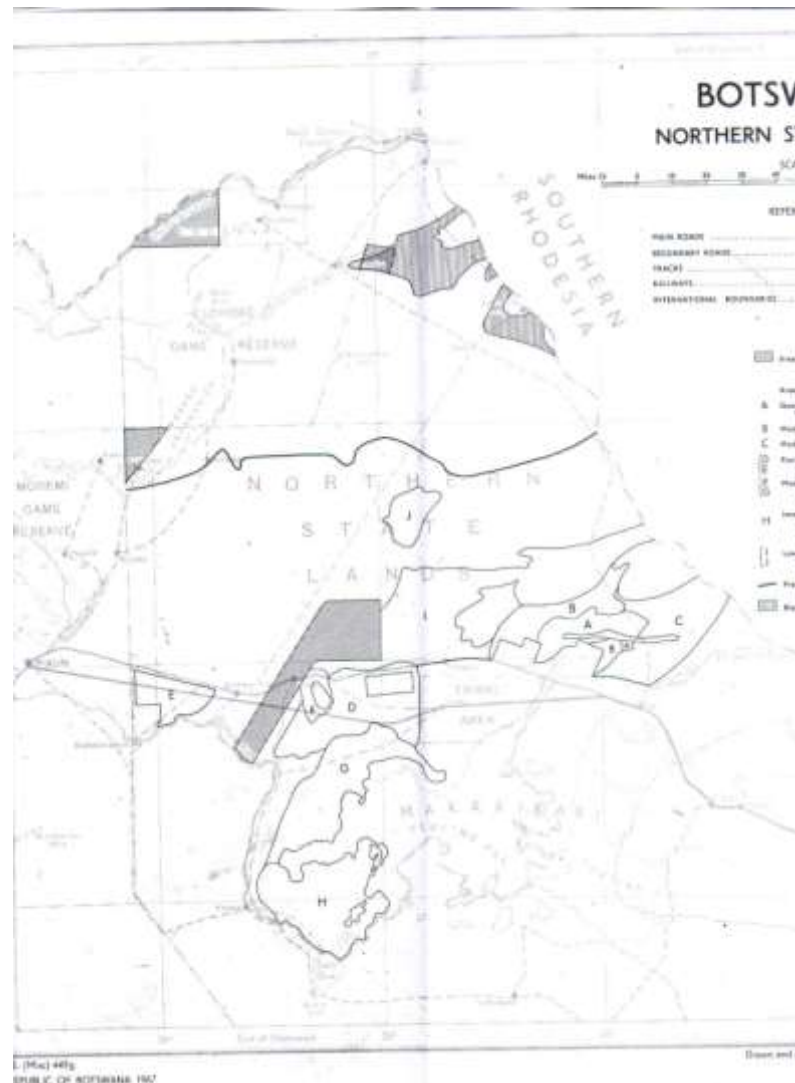
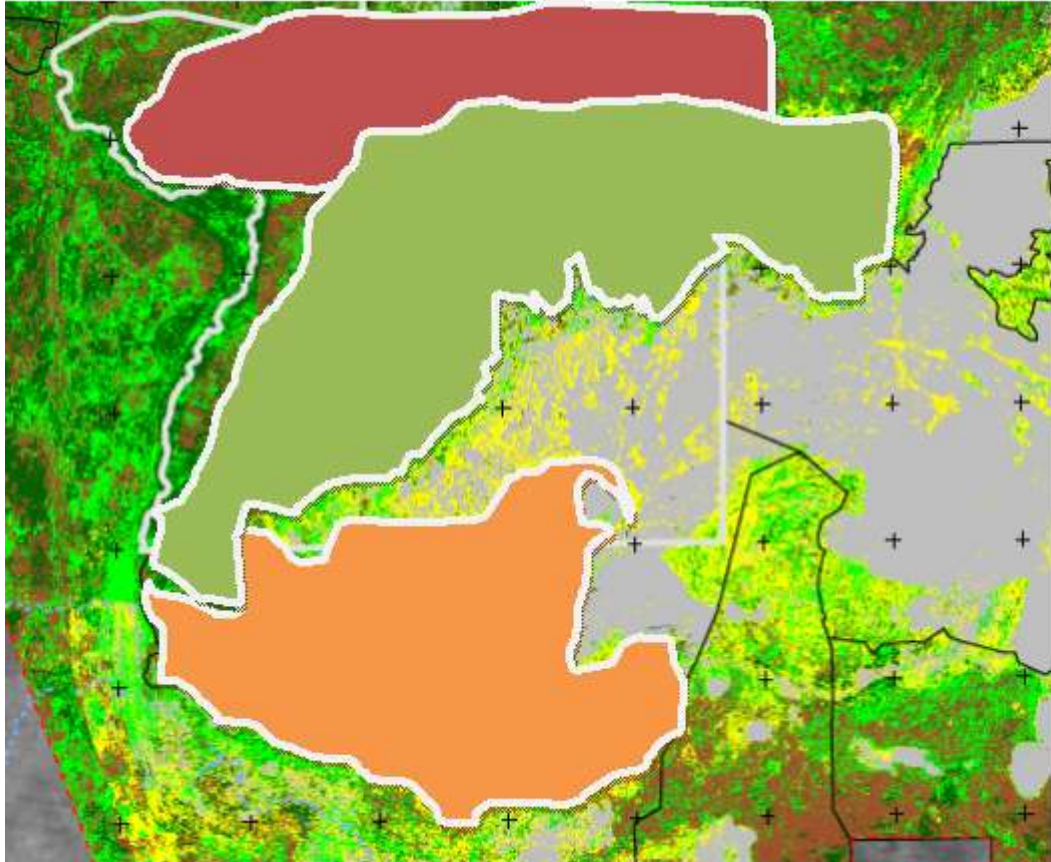


Figure 14: Rangeland carrying capacities suggested by Blair Rains and Mckay (1968) transferred onto the vegetation Map



Source: Blair Rains and Mckay (1968); p.75

Note: Immediate de-stocking was recommended for the area in Orange, An area with a carrying capacity of 10ha/LSU is highlighted in green, and an area of poor to moderate grazing potential (12 ha/LSU) was highlighted in red.

As Blair Rains and Mckay (1968) emphasise in some cases a safe level of stocking will preclude economic success and in others a lack of water will prevent development.

Game in the Northern State Lands

Blair rains and Mckay (1968) also recommended that there should be three new areas where shooting would be prohibited, one of which is of relevance to this study, that being so called Area 1.

Area 1

The largest of these areas is the Nxai Pan which affords exceptional opportunities for viewing large numbers of game animals in open parkland. The protected areas around the Nxai Pan should extend in the west to the Pandamatenga Road to the line of longitude 25°00' east and from 19°45' south to latitude 20°00' south (an alternative boundary could be the old Francistown-Maun road). The preservation of game in this area also requires the provision of a wide corridor to allow access to the Boteti River.

3.5 Summary of development ideas

The *ad hoc* manner in which livestock have expanded, on the basis of suitable groundwater, has compromised optimal land use planning around Makgadikgadi and thus has resulted in:

(i) The excessive concentration of cattle on marginal land with very little gain to the livestock sector and rural livelihoods, while incurring a heavy, if not fatal blow, to the potential to develop wildlife based economies over extensive areas.

(ii) The exclusion of wildlife from key refuge areas, along the Boteti and northern Ntwetwe Pan, by the utilisation of the available water by livestock.

(iii) A dearth of economic diversification potential around the margins of Makgadikgadi Pans National Park due to the polarisation of land uses between wildlife benefits that accrue entirely to the State and livestock benefits that accrue to the individual. Unsurprisingly, much of the marginal land surrounding the MPNP is defended passionately by the rural people found there for, the albeit, small livestock related benefits they can obtain for themselves, rather than the largely non-existent wildlife related benefits that remain only a distant promise.

This state of affairs is limiting rural livelihoods and damaging both the wildlife and livestock sectors. A radical change to this situation is proposed by effective land use planning and zoning, that re-opens dominantly marginal areas of rangeland to wild ungulates and reserves areas with the most potable groundwater and surrounding grazing land exclusively to livestock. Trade-offs are necessarily required from both wildlife and livestock sectors, as the current *ad hoc* expansion of the latter is of little benefit to the majority of rural people and the sustainable development of the area. Wildlife cannot simply fit around the areas utilised by livestock and people and be expected to contribute meaningfully to rural livelihoods. Similarly, the livestock sector should not be developed in a manner that places it in direct competition with wildlife, particularly problem animals such as elephants and predators, and excludes large areas of land from any form of meaningful production (either livestock or wildlife).

3.6 Key Findings

The rangeland ecology study fully endorses the findings of Brooks and McCulloch (2010) and would emphasise the following:-

- Fenced ranch blocks on the grazing areas surrounding potable groundwater should be developed – this includes the current Nata Ranches block which should be fenced and form an effective southern extension of the veterinary cordon fence (encompassing parts of Areas A-C on the Blair Rains and McKay, 1968) map (above). The rationale behind this is that wildlife can find their way around discrete ranch blocks that are adjacent to fences and effectively channel them into low/no conflict zones;
- The alignment of the Game Proof fence along the Boteti River should be altered so as to maximise the returns to both the wildlife and livestock related economies. The Fence should maximise CBNRM opportunities along the River and follow the crest of River Cliffs. Currently prime CBNRM sites for ecotourism have been fenced for livestock access and wildlife has little or no access to the River bed due to the tendency of the Fence to follow the eastern boundary of the riparian zone, rather than the river bed;
- Marginal land currently grazed by livestock around northern Ntwetwe Pan should be vacated for wildlife;

- The situation concerning the BDLC ranches should be rationalised and where possible the land integrated into the MPNP, by re-allocating ranches as a form of compensation for those affected by the potential loss of grazing lands in the stateland WMAs – i.e. CT11.

It is also recommended that a fenced livestock free corridor from the Boteti River to the central Kalahari Game reserve be established.

3.7 Corridor provision to the Central Kalahari Game Reserve

In addition the role that natural grassland/wetland systems like Lake Xau have played in the maintenance of large herds of wild ungulates was unfortunately never quantified, as the die-offs preceded any studies. Today, Lake Xau/Mopipi and the grazing on the former Lake bed around Rakops are dominated by domestic stock. The cattle move from the Boteti River into the former Lake bed, crossing the Rakops-Moreomaoto Road at right angles to it. Typically the cattle return to the River and adjoining kraals in the late afternoon, to be let out and to make their own way to the grazing on the former Lake bed in the following morning, although the presence of livestock in the area at all times of the day and night suggests that the daily rhythm of morning watering and night time kraaling is not as strong as it used to be – presumably due to reduced depredation, especially by lions.

It is striking how even before the erection of the Game Proof Fence wildlife has retreated from this area. In the late 1980s it was possible to see springbok and the occasional wildebeest on the former lake bed, especially its western most edge, together with domestic stock. Today the landscape is dominated entirely by cattle.

The persistence of wildlife at ‘ecologically effective’ densities (sensu Soule’ et al., 2003) is a crucial component of healthy ecosystems and is currently lacking from both the Makgadikgadi and Kalahari ecosystems. Strategic habitat protection of a wildlife migratory corridor linking the two protected areas would strengthen their existing conservation status and help hedge against projected future conditions at relatively modest costs in terms of additional land. Currently, the ability of both protected areas to maintain viable populations of the key ungulates species (wildebeest and zebra) has been greatly diminished by isolating their populations from key resource areas and fragmenting the previous connectivity that existed between the Makgadikgadi and Kalahari ecosystems.

As Blair Rains and McKay (1968) emphasised over four decades ago.....*‘sufficient attention does not appear to have been given to realistic costing of livestock production.‘Free’ water, unpaid herdsmen, subsidised veterinary treatment, and free communal grazing together conceal the true costs of production: costs which would have to be carried by any enterprise’* (Blair Rains and McKay, 1968; p78-79). Indeed, livestock expansion, habitat fragmentation and population declines of the key wild ungulates has been the inevitable result of this reality.

DHV (1980) made this point

“New range will be pioneered by traditional cattle-posts....Game will be greatly reduced and displaced into final refuges defined by the one obstacle the stockman cannot yet overcome: lack of suitable groundwater. Such a process cannot be condemned..... (provided decision makers are)...aware of the consequences. In the context of game management there is no case for planned game use if this is only opportunistic pending its substitution by livestock” (p.38-39).

DHV (1980) also made the point that,

“Enhanced game use is seen as the best way to raise the standard of living of the greatest number of people particularly those who are the poorest”(p.45).

The solution is therefore to connect up the Makgadikgadi Pans NP and the CKGR through a fenced, livestock free, corridor between them and to develop CBNRM wildlife based activities in the area. Currently, often illegally acquired boreholes are blocking any such development, (for example, as happened at Kedia in the 1980s), and so is effectively locking the entire area into poverty. It is a necessarily political issue, but the extent to which a more diverse, sustainable and equitable use of the natural resources in the area for the majority of rural dwellers is being compromised by the presence of large herds of cattle owned by a few individuals is striking.

It is recommended that a separate study is commissioned to look into the most viable option for the location of this fenced, livestock free migratory corridor. The options appear to be:

- (i) The route the wildebeest are known to have taken in the early 1980s, from the north-eastern CKGR to Mopipi/Lake Xau – except this area is now full of fenced livestock ranches;
- (ii) The shortest route to the Boteti from the NE corner of the CKGR, i.e. from CKGR to Rakops – except this area is now quite densely settled with people and livestock;
- (iii) A longer route from the northern CKGR through the Hainaveld farms to an area around Xhumaga – except this requires the consent of the affected Hainaveld Farms and the creation of a livestock free corridor to the river.

Within the current context of a dearth of CBNRM activities along the Boteti and the potentially affected corridor areas, it is difficult to see how local communities/livestock owners could be expected to buy into such a migratory corridor. Indeed as Jones and Weaver (2003) put it, *'In both Namibia and in Botswana and in other southern African countries, a certain combination of circumstances creates one of the a major constraints facing CBNRM: financial benefits from wildlife and tourism to individual households remain low, cost of living with wildlife remain high and community proprietorship over wildlife continues to be weak. The current enthusiasm of rural communities could wane if household benefits do not increase and proprietorship over wildlife is not strengthened (from CAR, 2003; p.44)'*.

4 Conclusion

It is becoming increasingly clear that there can be no provision for wildlife except on livestock free land. An active drive for the promotion of CBNRM with an emphasis upon wildlife related economies could rapidly change this situation, but currently it appears that the boundaries of the protected areas in general, and Makgadikgadi in particular, are increasingly forming hard edges, where the livelihoods of communities are tied to subsistence agriculture and the fate of wildlife populations outside of the protected areas is at best uncertain. Within this context, porous boundaries can do little more than increase problem animal control activities and harden already dominantly hostile, community attitudes to wildlife. It is recommended on the one hand that key refuge areas are secured for wildlife to enable the recovery of their populations and that on the other fenced ranches are consolidated around Nata and on the southern side of the buffalo fence.

The urgent need to promote CBNRM around the Makgadikgadi wetland system is emphasised, within which the renewed flows down the Boteti and probably in the 2010 flood year to Mopipi/Lake Xau should be used to provide some impetus and a more visionary look at sustainable livelihood options, beyond those provided by cattle and crops. Stocking rate estimates, made independently from a diverse array of authors, all indicate that the rangelands are marginal for livestock keeping due to poor forage on halomorphic soils and dominantly saline groundwater.

The management of natural resources through community-based trusts has considerable potential to address the key problems afflicting the region; structural poverty and poor management of communal resources. Security of tenure is however essential if such initiatives are to succeed requiring the issues of effectively private cattleposts on communal land, and dual grazing rights, to be addressed.

Problem animal control activities are unlikely to decline unless animal husbandry is improved around the margins of the protected areas, with livestock expansion along the western side of the Boteti likely as a result of the erection of the Game Proof Fence. With zebra and wildebeest populations at historic low, large parts of the MPNP will remain ungrazed, creating a fire hazard to wildlife populations within the MPNP – as the prevailing winds will drive the fire towards the fence. Active management will be required if extensive areas of riparian woodland and pan grasslands are to be protected from fire. Livestock populations dying on the western side of the fence despite a large standing biomass of forage within the protected area, remains a distinct possibility in the future – i.e. during the next drought, and in the absence of meaningful CBNRM activities will undoubtedly harden attitudes to wildlife conservation and put pressure on the Game Proof Fence itself. The latter, through strategic realignments should be used to promote CBNRM and provide for economic diversification within the area.

Management within the Makgadikgadi wetland system itself should seek to re-instate the natural variability of the ecosystem, with the provision of artificial waterpoints managed within this context. Climate change presents a potentially severe threat to biodiversity, with the phyto-chorology of the area suggesting that the linkage between the Boteti River and the Kalahari system may well be critical in order for species to disperse rapidly through fragmented and keep pace with the changing climate. Current management of the Makgadikgadi wetland system runs the risk of creating spatially and temporally varying environmental conditions that bear little resemblance to historic patterns and are ill-suited to the conservation of the key wildlife resources under predicted climate change scenarios. These changes can be mitigated by the protection of ecosystem integrity and functioning and the strategic incorporation of key wildlife refuge areas into the protected area system, including the provision of a livestock free migratory corridor to the CKGR. The changes recommended within this report, when coupled with the strategic development of fenced livestock (or game) ranches will

serve to strengthen the livestock production and disease control aspirations of the Ministry of Agriculture on the one hand and the promotion of wildlife conservation and sustainable rural livelihoods on the other.

Summary of recommendations:

<p>1. Promotion of CBNRM wildlife/tourism based activities around the boundaries of Makgadikgadi Pans wetland system:-</p> <ul style="list-style-type: none"> • Strategic realignment of the Game Proof fence to allow for CBNRM activities and to rationalise livestock and wildlife access to the Boteti River and other key refuge areas – in particular by fencing the top of river cliffs on the bank on which they occur, rather than on the opposite bank. • Secure prime ecotourism sites for CBNRM activities before they become bush encroached due to livestock related impacts.
<p>2. Increase wildlife access to 'natural' waterpoints and grazing within the Boteti River through strategic realignment of the Game Proof fence to allow wildlife more strategic access to the River bed and riparian grazing resource.</p>
<p>3. Develop a fenced wildlife migratory corridor from the Boteti River to the Central Kalahari Game Reserve.</p>
<p>4. Decrease livestock pressure on the marginal rangelands around Makgadikgadi Pans by consolidating the Nata Ranch Block and strategically relocating cattlepost owners to it.</p>
<p>5. Active fire management within the Makgadikgadi Pans NP to prevent its most vulnerable habitats (Boteti woodlands and plains grasslands) being ravaged by fire.</p>
<p>6. Active maintenance of the Game Proof Fence</p>
<p>7. Improvements to animal husbandry (herding and kraaling) through the formation of CBNRM Trusts and diversification of the rural economy through tourism related ventures.</p>
<p>8. Management of the artificial waterpoints within the MPNP so as to mimic the natural system (i.e. dry season pumping only along the Boteti River) and wet season pumping in the Pans.</p>
<p>9. Actively monitor and manage exotic species within the Makgadikgadi wetland system</p>
<p>10. Maximise CBNRM activities following the renewed floods down the Boteti River and the rejuvenation of the wetland system – including the new opportunities for fishing and veld product harvesting</p>
<p>11. Rationalise the BLDC ranches and where possible incorporate them into the protected area.</p>

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