Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module Specialist Report Country: Namibia Discipline: Wildlife

K. Roberts

June 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

BIOPHYSICAL SERIES

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module

Specialist Report

Country: Namibia

Discipline: Wildlife

Author: K. Roberts

Date: June 2009

EXECUTIVE SUMMARY

The Namibian wildlife assessment is a first attempt at trying to understand the flow related water needs of wildlife living along the Namibian section of the Okavango River. The EFA process can then make predictions of the effects on the abundance of river associated wildlife, of flow pattern changes in the river, caused by a range of development scenarios. Similar wildlife assessments were made by Angola and Botswana for their river sections. The river was divided into units of analysis during a EFA team exercise with all three countries. (Project Report No 2: Delineation of the Okavango Basin).

The two Namibian integrated units of analysis for the assessment were "main channel with floodplain", which was represented by a site on the floodplain at Kapako 30km to the west of Rundu; and the "rocky island and braided channel" unit of analysis which was represented by a site at the Popa Rapids.

The Namibian wetlands associated wildlife that were considered for this assessment of their water-flow requirements, included vertebrate taxa other than fish and birds (the latter two groups were assessed separately). In practice, bats were also excluded because of the lack of water flow related information on this group.

The "Wildlife Indicators" were those species thought to show relationships with water flow conditions. These later became the main species dependent on particular flow related habitats. Seven flow related habitats were identified as indicator habitats for wildlife for all three countries. As similar habitats had different species in the different countries, the main wildlife species occupying these habitats in each country became the country representative species for that indicator. Later some of the habitats and their representative species were combined and five wildlife indicator groups remained.

Wildlife Indicator 1
Name: Main Channel Dwellers. Representative species: Hippo, Crocodile, Otters, Terrapins. Water Monitor
Water needs: sufficient channel depth and width for daily living space and protection and concealment during low water flows. Sufficient high water flows are needed to maintain sand bars, channel islands and floodplain vegetation, papyrus and reed beds. Enough water depth / flow during low flow season for some islands to remain as islands. Islands used for nesting reptiles at the end of the dry season. Islands that become joined to the bank during low flow seasons will have greater resource use and predator pressures e.g. from humans, livestock, dogs etc. Sufficient water levels are needed to sustain papyrus and reedbeds. Sufficient periodic high flows are needed for sandbar maintenance. Early high floods can inundate nests.

Wildlife Indicator 2
Name: Frogs and river snakes,
Representative taxa:- Frogs, Snakes and Musk shrews.
Known water needs: Periodic high floods are needed to scour out floodplain depressions and annual floods are needed to fill these. Sufficient low season water levels are needed to maintain backwaters connected to the channel. Other backwaters and floodplain pools depend on low season river related groundwater levels. Non groundwater-fed pool water depth should be at least 50cm at the start of the season for frog lifecycles to complete before pools dry. Water is needed in backwaters and pools to maintain aquatic invertebrates, fish and frogs which also form the food of many reptiles, especially juveniles. Low water flow rates in backwaters. Usually wet but reed beds and water-lilies can survive limited drying-out. Sufficient low flow water levels needed to maintain fringe vegetation.

High floods can remove vegetation. Early floods can inundate reptile and small mammal nests. Sufficient water is needed for direct access to the vegetation i.e. a barren drawdown zone would be detrimental.

Wildlife Indicator 3
Name :- Middle floodplain grazers.
Representative species: Elephant, Buffalo, Tsesebe, Warthog.
Known water needs: Annual flooding for from two to six months needed to allow for vegetation growth. Sufficient flood flows needed to provide sand, silts and nutrients. Slow flooding and slow receding allows for more vegetation growth.

Wildlife Indicator 4
Name:- Outer floodplain grazers
Representative species: Wildebeest, Zebra, Impala, Duiker, Aardvark, Mice
Known water needs: Occasionally flooded grasslands maintained by a flood frequency sufficient to maintain tree-line. Grasslands are still available during normal flood peaks. On higher banks river associated groundwater is available all year to maintain riperian forests.

Wildlife Indicator 5
Name: Lower floodplain grazers
Lechwe, Sitatunga, Reedbuck, Waterbuck. Mice.
Known water needs: Primary floodplain habitat needs seasonal flooding for four to six months to maintain vegetation. Wildlife use flooded areas and denser floodplain vegetation during dry season for feeding and protection.

Workshops with wildlife experts from all three countries produced response curves for each indicator for a range of water flow conditions. These data were then fed into the DSS by the Environmental Flow Assessment consultants and along with data from the other disciplines will predict the overall environmental effects for a range of future development scenarios.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
NNF	Namibia Nature Foundation
MET	Ministry of Environment and Tourism

ACKNOWLEDGEMENTS

Thanks to Shirley Bethune, Polytechnic of Namibia and Joshua Ndeliimona - Intern Polytechnic of Namibia, for help with the boat and trapping and Celeste Espach from the Ministry of Agriculture, Water and Forestry for the site maps.
Mark Paxton is thanked for the great Spotted-necked Otter and snake photographs.

INTRODUCTION

Background

An Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project is being implemented under the auspices of the Food and Agriculture Organization of the United Nations (UN-FAO). One of the activities is to complete a transboundary diagnostic assessment (TDA) for the purpose of developing a Strategic Action Plan for the basin. The TDA is an analysis of current and future possible causes of transboundary issues between the three countries of the basin: Angola, Namibia and Botswana. The Okavango Basin Steering Committee (OBSC) of the Okavango River Basin Water Commission (OKACOM) noted during a March 2008 meeting in Windhoek, Namibia, that future transboundary issues within the Okavango River basin are likely to occur due to developments that would modify flow regimes. The OBSC also noted that there was inadequate information about the physico-chemical, ecological and socio-economic effects of such possible developments. OBSC recommended at this meeting that a preliminary Environmental Flow Assessment (EFA) be carried out to predict possible development-driven changes in the flow regime of the Okavango River system, the related ecosystem changes, and the consequent impacts on people using the river's resources.

This preliminary EFA is a joint project of EPSMO and the Biokavango Project. One component of the preliminary EFA is a series of country-specific specialist studies, of which this is the Wildlife Report for Namibia.

Okavango River Basin EFA Objectives and Work-plan

Project objectives

The goals of the preliminary EFA are:
To summarize all relevant information on the Okavango River system and its users, and collect new data as appropriate within the constraints of this preliminary EFA
to use these to provide scenarios of possible development pathways into the future for consideration by decision makers, enabling them to discuss and negotiate on sustainable development of the Okavango River Basin;
to include in each scenario the major positive and negative ecological, resource-economic and social impacts of the relevant developments;
to complete this suite of activities as a preliminary EFA, due to time constraints, as input to the TDA and to a future comprehensive EFA.

The specific objectives at a preliminary level are:
to ascertain at different points along the Okavango River system, including the Delta, the existing relationships between the flow regime and the ecological nature and functioning of the river ecosystem;
to ascertain the existing relationships between the river ecosystem and peoples' livelihoods;
to predict possible development-driven changes to the flow regime and thus to the river ecosystem;
to predict the impacts of such river ecosystem changes on people's livelihoods.
To use these preliminary EFA outputs to enhance biodiversity management of the Delta.
To develop skills for conducting EFAs in Angola, Botswana, and Namibia.

Layout of this report

Chapter 1 gives a brief introduction, to the background of the project and lists project objectives. Chapter 2 describes the broad study area of the Okavango River Basin and gives more detail on the two specific sites chosen for this preliminary EFA within the Namibian section of the river- Kapako floodplain and Popa rapids. In Chapter 3, the agreed wildlife indicators and flow categories are highlighted. Literature review pertinent to wildlife work in the Okavango River and other similar systems is given in Chapter 4; full indicators are listed. The field survey work undertaken for the wildlife investigation within Namibia in both the dry season (October 2008) and wet season (February 2009); together with data collection, and results are outlined in Chapter 5. Chapter 6 is a first attempt to link wildlife to water flows and to provide information on the flow-response relationships for use in the Okavango EF-DSS. References are found in Chapter 7 and the appendix gives site maps and a species list.

2 STUDY AREA

2.1 Description of the Okavango Basin

The Okavango River Basin consists of the areas drained by the Cubango, Cutato, Cuchi, Cuelei, Cuebe, and Cuito rivers in Angola, the Okavango River in Namibia and Botswana, and the Okavango Delta (**Error! Reference source not found.**). This basin topographically includes the inactive drainage are of the Omatako Omuramba. Although this ephemeral river still regularly floods along its southern portion, it has not contributed any flow to the Okavango River. Outflows from the Okavango Delta are drained through the Thamalakane and then Boteti Rivers, the latter eventually joining the Makgadikgadi Pans. The Nata River, which drains the western part of Zimbabwe, also joins the Makgadikgadi Pans. On the basis of topography, the Okavango River Basin thus includes the Makgadikgadi Pans and Nata River Basin (**Error! Reference source not found.**). This study, however, focuses on the active drainage parts of the basin in Angola and Namibia, and the Okavango delta in Botswana. The Omatako Omuramba, Makgadikgadi Pans and Nata River are not included.

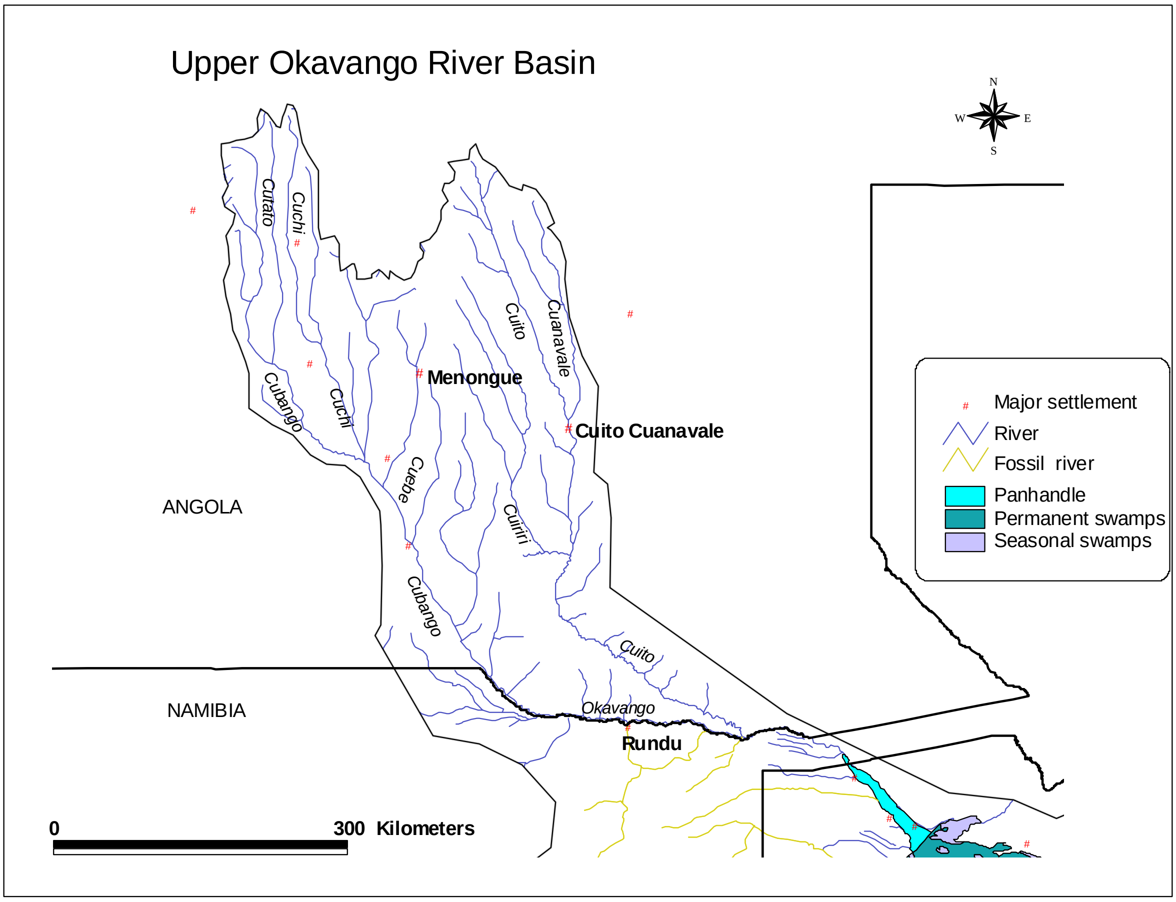


Figure 1 Upper Okavango River Basin from sources to the northern end of the Delta

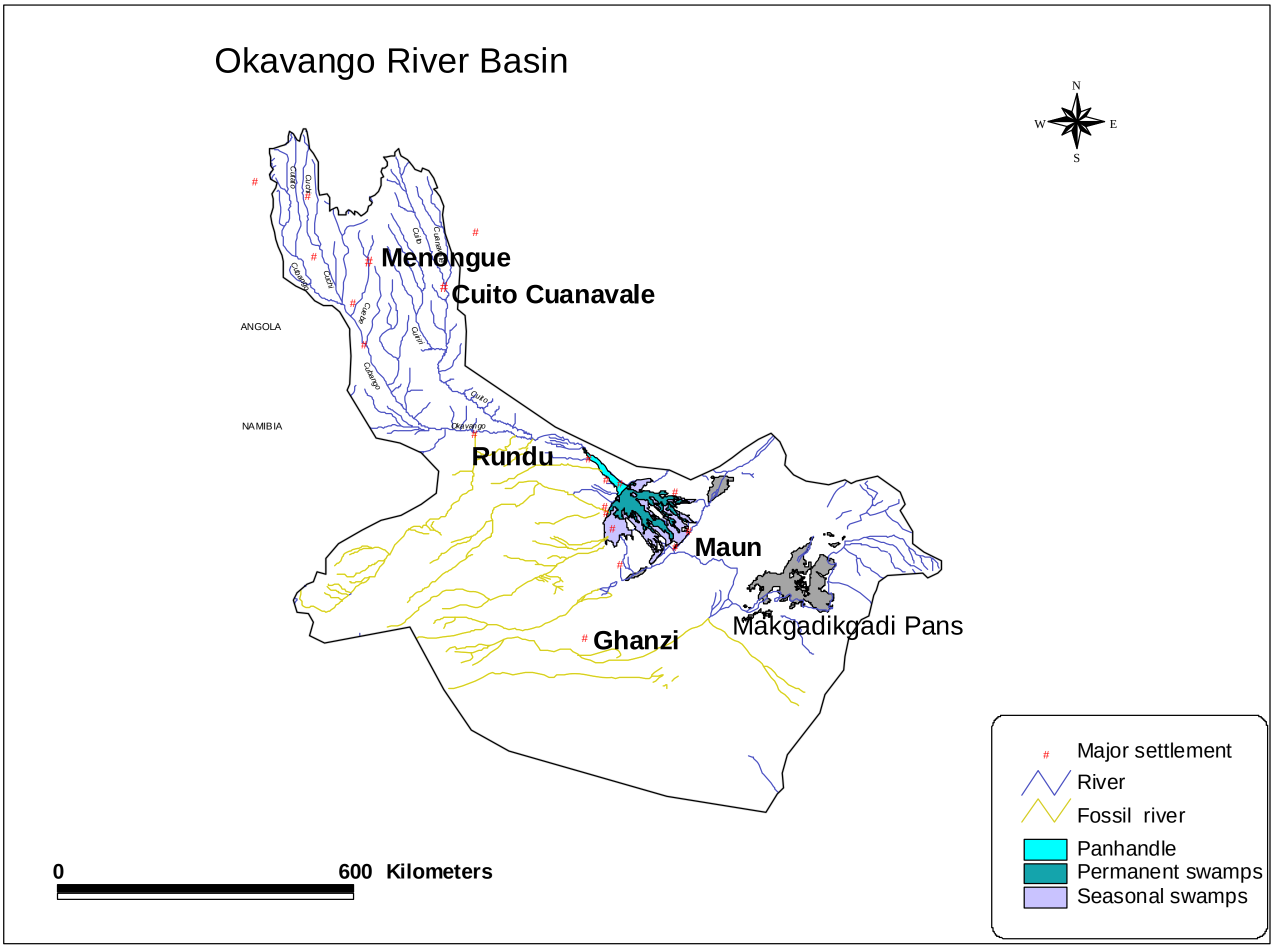


Figure 2 **The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans**

2. 2 Delineation of the Okavango Basin into Integrated Units of Analysis

Within the Okavango River Basin, no study could address every kilometre stretch of the river, or every person living within the area, particularly a pilot study such as this one. These representative areas that are reasonably homogeneous in their ecological characteristics and can be delineated and used to choose several sites in which focus for data-collection and monitoring can be done. The results from each representative site can then be extrapolated over the respective wider areas.

Using this approach, the Basin was delineated into Integrated Units of Analysis (EPSMO/Biokavango Report Number 2; Delineation Report) by:
dividing the river into relatively homogeneous longitudinal zones in terms of:

- hydrology;
- geomorphology;
- water chemistry;
- fish;
- aquatic macroinvertebrates;
- vegetation;
- wildlife

harmonizing the results from each discipline into one set of biophysical river zones;

dividing the basin into relatively homogeneous areas in terms of social systems; harmonizing the biophysical river zones and the social areas into one set of Integrated Units of Analysis (IUAs). See delineation report for details

The 19 recognised IUAs were then considered by each national team as candidates for the location of the allocated number of study sites:

Angola: three sites
Namibia: two sites
Botswana: three sites.

The sites chosen by the national teams are given in **Error! Reference source not found.**.

Table 1 Location of the eight EFA sites

EFA Site No	Country	River	Location
1	Angola	Cuebe	Capico
2	Angola	Cubango	Mucundi
3	Angola	Cuito	Cuito Cuanavale
4	Namibia	Okavango	Kapako
5	Namibia	Okavango	Popa Rapids
6	Botswana	Okavango	Upper Panhandle around Shakawe
7	Botswana	Xakanaka lagoon and Khwai River	Xakanaka in Delta
8	Botswana	Boteti Rivers	Maun and Chanoga

2.3 Overview of sites

In the Namibian section of the Okavango River, the majority of the human population lives along the river and the main road, with several hot spots such as Rundu, Divundu and Nkurenkuru which have a high population density. The river can be divided into four clear units of analysis, the longest section that extends from where the river enters Namibia at Katwitwi to the Cuito confluence that is typified by the meandering mainstream and large seasonally-flooded floodplains on either side to the river (Kapako site 4, was chosen as a typical floodplain and mainstream site within this section); the section immediately downstream of the Cuito confluence that has permanently swamped areas and large islands (not included in the preliminary survey but essential to include in a later more detailed EFA study); the southward flowing rocky, braided section from Mukwe to just below the Popa Rapids where the river is largely confined to the mainstream and flows around several sand and rock based islands (Popa rapids Site 5, was chosen as a typical rocky river site within this section) and the protected section of the river downstream of Popa to the border with Botswana at Mohembo that lies within the newly declared Bwabwata National Park which as two of its core conservation areas on either side of the river, the Buffalo core area on the west bank and the Muhango core area on the east bank.

2.3.1 Site 4: Kapako

The main focus point for socio-economic work at the Kapako floodplain site 4 is Kapako village: S-17.94 E– 19.56, situated some distance inland from the river on the other side of the main road.

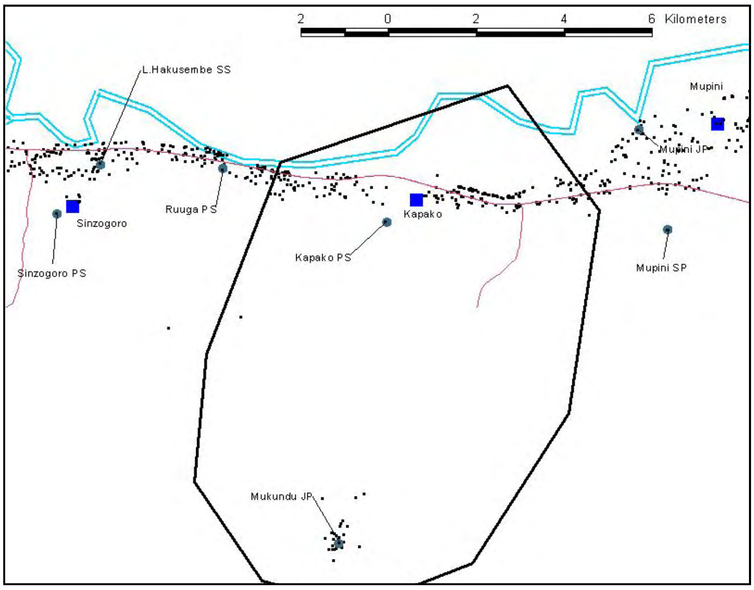
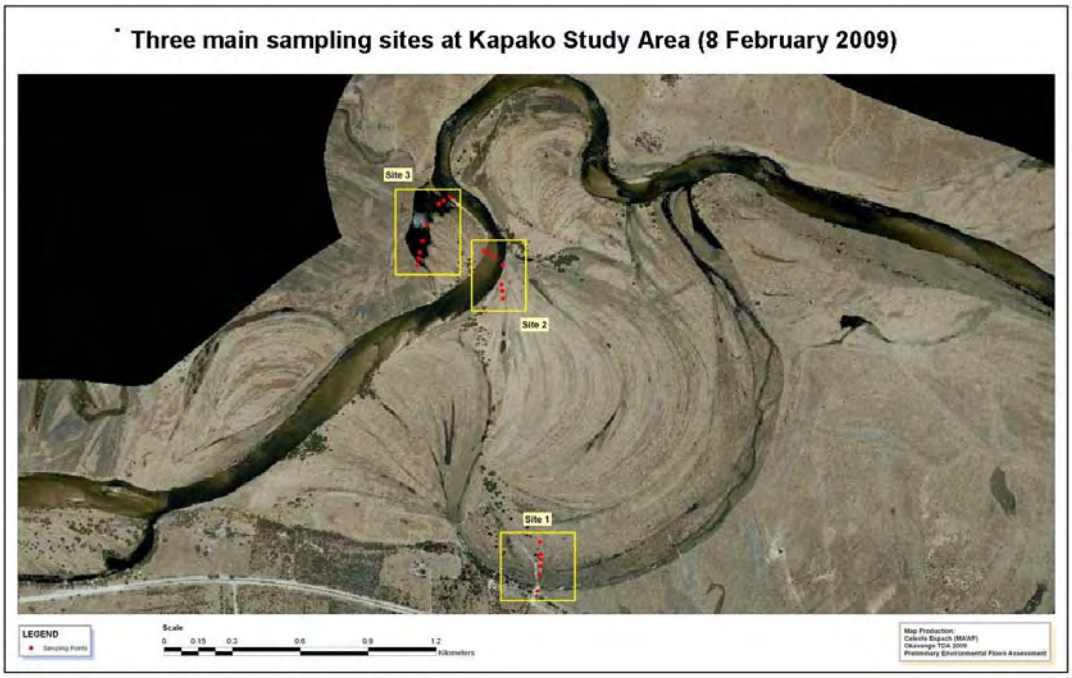


Figure 3. Site 4: Kapako showing the village of Kapako, the surrounding town and the position of the main road and the villages in relation to the river. Most of the area between the road and the river is floodplain. The border shows the area covered by the socio-economics team. Map by Socio-economics team.

The main villages close to Kapako village are Mupini to the east (downstream), Mukundu to the south, Ruugua and Sinzogoro to the weat (upstream).

The floodplain site itself is situated on the Okavango River and three main sites on the floodplain and the mainstream were used for sampling. They were:
Kapako site 1 S-17.87775 E- 19.58200 (south bank) S- 17.87850 E-19.58211 (end of site 1)

Kapako site 2 S- 17.86557 E-19.58057 Kapako site 3 S- 17.86209 E-19.57855



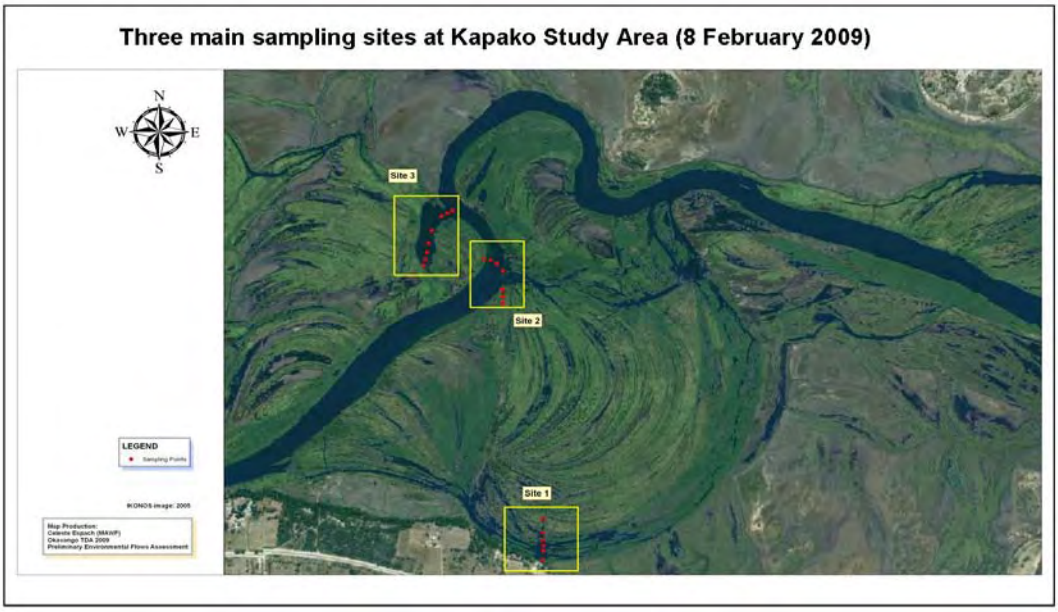


Figure 4. shows two satellite images of the Kapako floodplain site 4, one in the dry season and one in the wet or flood season. Maps by Celeste Espach.

The riverine landscape includes the main Okavango River channel or mainstream, the annually flooded floodplains with several braided side channels and deeper pools or backwaters, as well as the higher fluvial terrace with alluvial deposits are very seldom flooded. There is a steep, well vegetated bank at the edge of the floodplain close to the main road that rises to several meters above the floodplain.

Kapako area has a population of approximately 2,500 people within 10 km of Kapako village. The greatest density of people (over 100 per km^2) live alongside the river in the area just west of the Kapako study site whilst at the site itself the density varies from no people on the floodplain, 6 – 25 / km^2 at the Ebenezer mission, to a density of 25 – 50 /km^2 closer to the road and 51 – 100 /km^2 on the other side of the main road, rapidly decreasing again with distance inland. (See Map 3 in Populations Demographics Report prepared by Celeste Espach). We can assume that some of these people make some use of the floodplain site at Kapako and elsewhere along this stretch of river.

During the focus group discussion held at Kapako village, the basin residents mentioned that, the flooding starts when the rising river and channel waters push out over flat surrounding ground and the biggest floodplains form in years when river levels are highest. They said that the most important feature of the flooded areas is that they are rich in nutrients. The floodplains also offer the young fish refuge from larger, predatory species and thus offer the greatest survival of young fish. They had noted that an overall increase in fish population occurs in years when water levels are high and flooding lasts longest. Local people have recognised that water quality and fish resources are decreasing in the Okavango River. Fish and fishing remain significant features in the lives of people at Kapako, who fish for food or to earn incomes by selling their catches. In addition some earn money by providing trips for tourists. They estimate fish stocks in the floodplains to be four times higher than in the main channel.

About 47% of households at Kapako catch fish, and each person consumes an average of 10-20 kilograms of fish per year. September to December is the peak fishing period at Kapako when the river is at its lowest and fish are concentrated in the mainstream. The kinds of traps or gear used to catch fish are separated into traditional and modern methods. The most used traditional gear are fish funnels, kraal traps, scoop baskets, push baskets, bows and arrows, set fish hooks and spears.
Modern gear consists of line and hooks, wire mesh fykes, illegal mosquito nets, and gill and seine nets. The use of fish for recreational angling forms part of the tourism value associated with the river. Biophysical response curves for the angling species would feed into the tourism values for the river reducing them partially. Only a small part of tourism value is attributable to angling.

At Kapako, as elsewhere along the Namibian section of the river, the ever -increasing human population and clearing for crops and livestock has put increasing pressure on the natural resources along the main channel. The vegetation along the river bank is overgrazed and in some areas depleted, thus at Kapako the residents graze their livestock across the river on the Angolan floodplain. Cattle were routinely seen being swam across the river at this site during fieldwork.

Associated with this population growth, has been an increase in livestock, fire frequency as well as the area of land cleared for crops and fuel. These associated land use changes are an undeniable factor of increasing settlement and development at a Kapako and indeed all along the Okavango.

The road westwards from Rundu has been upgraded and is currently being tarred. It runs parallel to the Okavango River all the way to the border post with Angola at Katwitwi.
This has opened up the region allowing people to exploit the land alongside the road. As expected highest densities are alongside the road parallel to the river. As the population continues to increase, exploitation of the land that new roads have opened up should disperse the pressure on the Okavango River floodplains and its resources to land further inland from the river, although the river will always remain the main source of water even for livestock watering.

The extent of erosion and clearing and thus of bare ground has also increased; yet the people perceive the overall water quality not to have declined substantially. The only exceptions mentioned were an increase in phosphate concentrations, a decrease in water clarity and a related increase in suspended sediments. There are more short term, seasonal variations in water quality particularly in the floodplain pools, than any long term water quality change. So far there does not seem to have been an excessive exploitation of the water resources in the main channel, although the basin further inland has some serious water shortages at times and a lack of deep boreholes. The Kalahari sands that overlay the area are deep.

2.3.2 Site 5: Popa rapids

The main focus for the socio-economic work at the Popa rapids Site 5 was the village of Popa and the Popa Falls Rest Camp run by Namibia Wildlife Resorts. The main transect used for the physical and biological field survey work was a transect across the river immediately above the Popa Rapids from the irrigation water drawoff point used by the Prison Services on the eastern ban (West Caprivi) where the gauge plate was put up to the protected section close to the Popa Falls Rest Camp on the western bank. Popa rapids: S- 18.15316 E- 21.6045 (Popa Falls rest camp)
Popa falls (gauge plate) S- 18.11603 E- 21.57900. Figure 5. below shows the main villages.

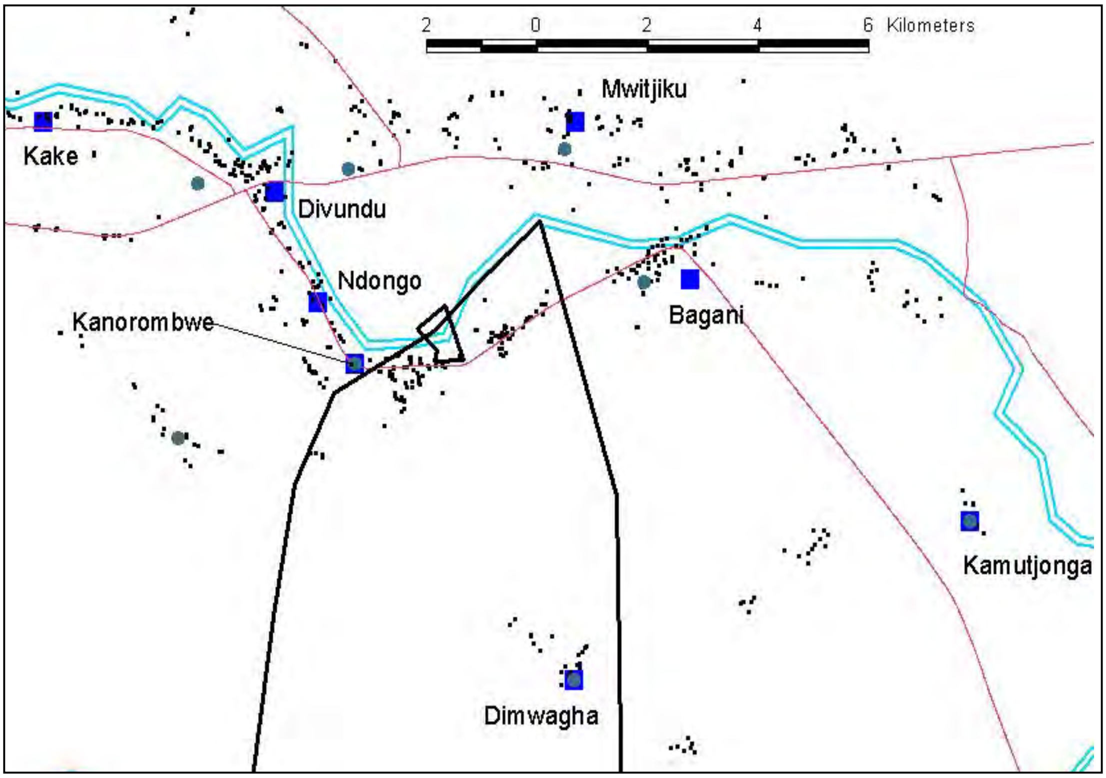


Figure 5. Site two, Popa rapids is shown in the map above; The majority of population lives along the river and the main road. Map from the socio-economic team.

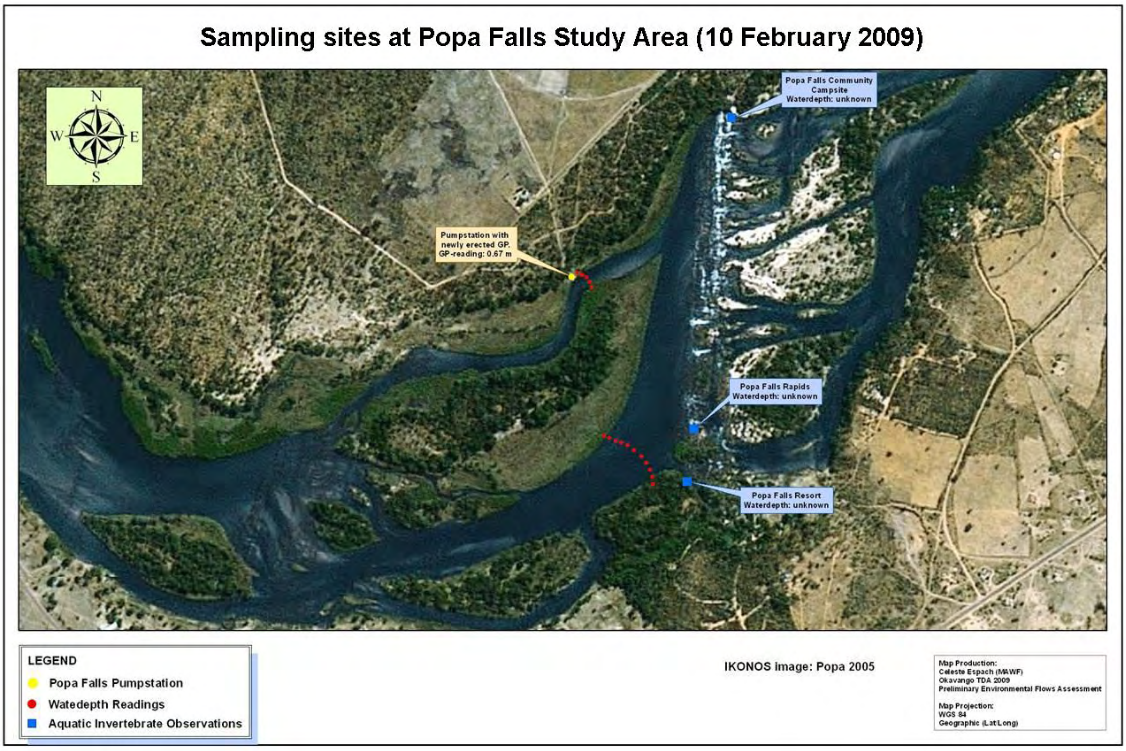


Figure 6. below shows the Popa rapids site five in both the dry and the wet season and indicates the main field survey transect and team sampling sites. The Wildlife survey maps are shown in the appendix.

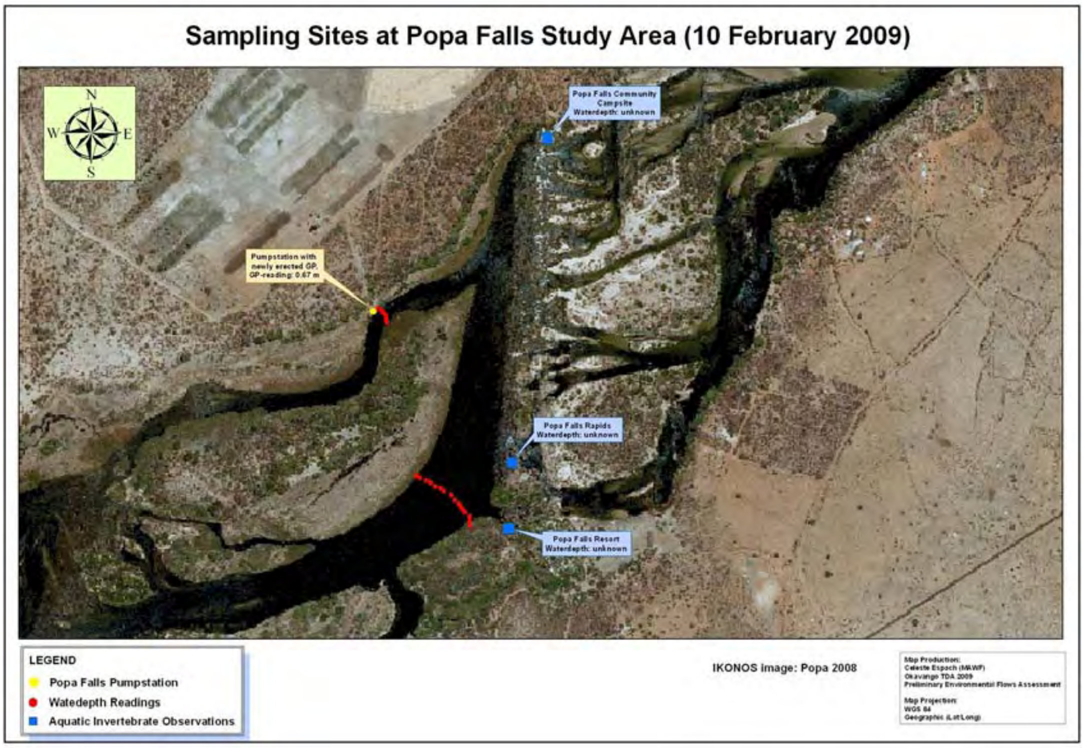


Figure 6. Satellite images of the wet and dry season for Popa rapids here showing transect and sampling sites. Maps prepared by Celeste Espach.

About 3,000 people live in the area surrounding Popa. The highest population density in the area is immediately upstream of the Popa rapids at the Bagani/Divundu settlement, within an area of over 12 km^2 . At the Popa rapids site itself the population density is much lower at 6 – 25 people/km^2 and it must be remembered that the Popa camp is within an 8 km^2 park, the islands are uninhabited and the opposite bank supports a community campsite reserved for tourists. Immediately downstream of Popa camp the riverside population increases to 26-50 people/km^2 and includes several lodges. See Map 3 in the Population Demographics report prepared by Celeste Espach for the TDA.

At the Popa rapids, the entire width of the river cascades down several meters before resuming its normal slow and leisurely flow. The quartzite rocks were formed from sediments deposited in rift valleys about 900 million years ago, (*el Obeid, S., Mendelsohn* 2004).

During the focus group discussion, it was mentioned that due to the Popa rapids and rocky areas, it's difficult for the local fishermen to catch fish as desired. Therefore, only a few individuals that own local mukoros, hook and line, and gill fish nets have access to fish catches in the main channel. Thus fishing is a secondary activity for most people at the Popa area, contributing little to the overall cash or in-kind incomes of the majority of households. People also pay much less attention to fishing than to farming and business activities. Each household depends on a different mix of incomes derives from wages, business earnings, pensions and remittances

Papyrus cyperus, papyrus, dominates the deepest water margins alongside the main channels. Water can seep through the walls of papyrus to the reedbeds behind the papyrus and in places where they exits into backwaters and side channels. The sandy sediments are confined to the channels. These are flanked by reed beds of *Phragmites*, *Typha capensis* or bulrushes and the sedge *Miscanthus junceus* in the shallower waters. The residents do not experience floods as there are no floodplains in this area. They depend in the main channel for most of their water and wetland resources. Most houses at Popa village are thatched with grass and reeds, while reeds are used extensively to make sleeping mats, walls, palisades, courtyards and fences.

Farming activity is an important source of income; households are engaged in both crop and livestock farming. Planting is staggered through the raining reason and is initiated only after a good rainfall event. This increases the chance of crop survival during the hot dry periods. Livestock farming is dominated by cattle and goats, not kept within fields but are moved for grazing and between water sources, mainly the Okavango River.

Tourism is a major source of income to the Popa resident; most of them are employed within the lodges around the Popa area. They value tourism as their major source of income.

2.4 Discipline-specific description of Namibian sites

2.4.1 Site 4: Kapako

The Namibian, "main channel with floodplain ecosystem", representative of this integrated unit of analysis was the floodplain at Kapako that is located 30km to the west of Rundu Town. The site consists of a meandering main river channel that forms a loop to the north. Inside the loop on the Namibian side and the west side in Angola there are floodplains formed by previous progressive meanders of the river. These consist of a series of banks of different heights interspersed with level areas and depressions. On the southern edge of the floodplain there is a riparian fringe or dry-bank. The site has varied vegetation that is associated with the large range of geomorphological features of the main channel, river bank, floodplain and dry bank. The characteristics of the vegetation in any particular location depend on the water inundation periodicity during present and historic flood and dry seasonal cycles. (See the Vegetation report and Appendix A for a site image) The varied vegetation of the site provides a range of habitats for wildlife for most parts of the year. These are the main channel fringe vegetation, primary (lower) floodplain vegetation, secondary (middle), floodplain vegetation, tertiary (Upper) floodplain (tree islands and bank). During all but small floods most habitats apart from the upper floodplains, tree islands and riparian zone are inundated and this restricts the available living space for terrestrial wildlife. During high floods only the dry bank and emergent trees remain unsubmerged. Human pressures have reduced the wildlife component of the floodplains in this unit. The larger grazing mammals no longer occur in the unit except Hippo and possibly Duiker because all have been hunted to local extinction. The flood season alternative habitats normally used by wetland wildlife i.e. the riperian zone and inland forest savanna is now largely used for stock-grazing or farmland.

2.4.2 Site 5: Popa Falls

The Namibian “rocky island and braided channel” unit of analysis was represented by a site at the Popa Rapids. The site consists of deep channels contained within rocky, riparian tree covered banks. The channel has vegetated islands and a bedrock bar that crosses the river width resulting in many small bedrock rapids with a fall of between two and three meters. Because there are no floodplains at this site and the river is confined, the vegetation and terrestrial wetland wildlife habitats vary over short distances that reflect the different water levels of the annual flood cycle. For instance the downstream edges of the islands often have circling fringes of Papyrus, Reeds and Sedges that form 2-20m wide bands parallel to the water. The larger island interiors consist of riparian forest. Downstream of the rapids there are sandbars and further small reed-fringed islands.

3. IDENTIFICATION OF INDICATORS AND FLOW CATEGORIES

3.1. Indicators

Introduction

Biophysical indicators are discipline-specific attributes of the river system that respond to a change in river flow by changing their:
abundance;
concentration; or
extent (area).

Social indicators are attributes of the social structures linked to the river that respond to changes in the availability of riverine resources (as described by the biophysical indicators).

The indicators are used to characterise the current situation and changes that could occur with development-driven flow changes.

Within any one biophysical discipline, key attributes can be grouped if they are expected to respond in the same way to the flow regime of the river. By example, fish species that all move on to floodplains at about the same time and for the same kinds of breeding or feeding reasons could be grouped as Fish Guild X.

3.1.2 Indicator list for Wildlife

In order to cover the major characteristics of the river system and its users many indicators may be deemed necessary. For any one EF site, however, the number of indicators is limited to ten (or fewer) in order to make the process manageable. The list of indicators was developed collaboratively by the country representatives for the discipline (for the wildlife component these were Mr. Kevin Roberts – Namibia, Dr. Carmen Van-Dúnem – Angola, and Dr. Casper Bonyongo – Botswana). The representative species are given in Appendix B and discussed fully in Chapter 0.

The “Wildlife Indicators” were those species thought to show relationships with water flow conditions. These later became the main species dependent on particular flow related habitats. Seven flow related habitats were identified as indicator habitats for wildlife for all three countries. As similar habitats had different species in the different countries, the main wildlife species occupying these habitats in each country became the country representative species for that indicator. Because some species depended on more than one habitat some of the habitats and their representative species were combined so as to make the indicator species groups unique. Five wildlife/habitat indicator groups were finally used to assess responses to changing water flow conditions in the river.

The Wildlife that were considered for the wildlife assessment included vertebrate taxa other than fish and birds which were assessed separately. In practice, bats were excluded because of the lack of flow related information.

Table 2 List of indicators for Namibian wildlife and those chosen to represent each site

Indicator Number	*Indicator name* and representative species	Sites represented							
		1	2	3	4	5	6	7	8
1	*Channel Dwellers* . Including Channel island, sand and rock bar dwellers. Hippo, Crocodile. Water Monitor, Otters, Terrapins				x	x			
2	*Frogs and river snakes*. Backwater , floodplain pool emergent vegetation and permanent swamp dwellers. Snakes, Frogs, Musk Shrews				x				
3	*Middle Floodplain grazers* Secondary seasonally flooded floodplain dependant species Elephant, buffalo, Tsesebe, Warthog				x				
4	*Outer floodplain grazers* Tertiary floodplain channel riparian zone and Delta island grassland dependant species. Wildebeest, Zebra, Impala, Duiker, Aardvark, mice.				x	x			
5	*Lower floodplain grazers* Primary seasonally flooded floodplain dependant species, Lechwe, Sitatunga, Reedbuck, Waterbuck, ,				x				

3.1.3 Brief description and location of indicators - Namibia

Wildlife Indicator 1

Name: Channel Dwellers

Description: Main channel dwellers. These species need sufficient low flow channel width and depth for daily living space, for protection from disturbance and to obtain food. Includes vegetated islands and sand bars in main channel, that provide protection, feeding and breeding sites.

Representative species: Hippo, Crocodile. Otters. Water Monitor, Terrapins.

Flow-related location: Main channel and pools during low flow periods and channel sandbars and upstream and downstream of islands during higher flows.

Water needs: >1.5m depth and >80m channel width for protection and concealment during low flow. Sufficient high flows to maintain sand bars, floodplain vegetation and papyrus and reed beds.

Vegetated islands and sand bars in main channel need enough water depth / flow during low flow season for some islands to remain as islands. Islands used for nesting for reptiles at the end of the dry season. Islands that become bank will have greater resource use and predator pressures e.g. from humans, livestock, dogs etc. Need sufficient periodic high flows for sandbar maintenance. Early high floods can inundate nests.

Wildlife Indicator 2

Name: Frogs and river snakes

Description: Backwaters and floodplain pools used for protection, feeding and breeding sites. Includes emergent vegetation and permanent swamp.
Representative species: Frogs, snakes, Musk shrews

Flow-related location: After floodplain inundation recedes, floodplain depressions and backwater pools remain filled. Water levels reduce during the following dry season until the next flood. Pools and backwaters are characterized by still water or slow currents with emergent and floating vegetation such as water lilies. Some pools are dependent on river related groundwater during the dry season and remain wet all year. Backwaters have low currents and emergent and floating vegetation but are linked to the river for part or most of the year. Vegetation along water margins and in backwaters and side channels provide protection, feeding and breeding sites for many riverine wildlife species.

Known water needs: Periodic floods to scour out and annual floods to fill the floodplain depressions. Floodplain groundwater levels above pool floors. Non groundwater-fed pool water depth at least 50cm at start of dry season for frog lifecycles to complete.

Sufficient dry season water levels for backwaters.

Usually wet but reed beds and water-lilies can survive limited drying-out. Sufficient low flow water levels are needed to maintain fringe vegetation.

Wildlife Indicator 3

Name: Middle floodplain grazers.

Description: Floodplain areas that flood later and are inundated only over the flood peak. Normally un-inundated and the vegetation is available to terrestrial wildlife for longer during normal floods except during flood peaks.

Representative species:, Elephant, buffalo, Tsesebe, Warthog

Flow-related location: Secondary floodplain areas (higher lying) and banks along main channel and margins to smaller islands.

Known water needs: Flooding during high-flow season for two to six months.

Wildlife Indicator 4

Name: Outer floodplain grazers.

Description: Grasslands and riparian zone along floodplain and channel margins and on larger / higher islands. This vegetation zone is occasionally flooded during very high floods but is normally dependent on river associated groundwater (Trees) or local rainfall (grasses). Provides non-aquatic and floodplain wildlife with cover and food especially during high flows.

Representative species: Wildebeest, Zebra, Impala, Duiker, Aardvark, Mice

Flow-related location: Riverine margins and islands only occasionally flooded.

Known water needs: Periodic flooding needed to maintain floodplain margin tree-lines. River associated groundwater is available all year to maintain riparian forests. Grazing areas important for wildlife during and after floods.

Wildlife Indicator 5

Name: Lower floodplain grazers

Description: Seasonally inundated channel floodplains and seasonal swamps. New vegetation available during and after inundation. Floodplain pools and backwaters filled.

Representative species: Lechwe, Sitatunga, Reedbuck, Waterbuck,

Flow-related location: Primary floodplains along margins of main river channel and backwaters.

Known water needs: Annual flooding for four to six months over flood period. Sufficient flood flows needed to provide sand, silts and nutrients and duration for vegetation growth. Slow flooding and slow receding allows for more vegetation growth. These wildlife species use the inundated floodplains for feeding and protection from predators.

3.2 Flow categories – river sites

One of the main assumptions underlying the EF process to be used in the TDA is that it is possible to identify parts of the flow regime that are ecologically relevant in different ways and to describe their nature using the historical hydrological record. Thus, one of the first steps in the EFA process, for any river, is to consult with local river ecologists to identify these ecologically most important flow categories. This process was followed at the Preparation Workshop in September 2008 and four flow categories were agreed on for the Okavango Basin river sites:

Dry season
Transitional Season 1
Flood Season
Transitional Season 2.

Tentative seasonal divisions for river Sites 1-5 are shown in Figure 7.1 to Figure 7.5. These seasonal divisions will be formalised by the project hydrological team in the form of hydrological rules in the hydrological model. In the interim they provide useful insights into the flow regime of the river system suggesting a higher within-year flow variability of the Cuebe River and a higher year-on-year variability of the Cubango River.

It is planned to use similar flow seasons for the remaining river sites: 6 and 8.

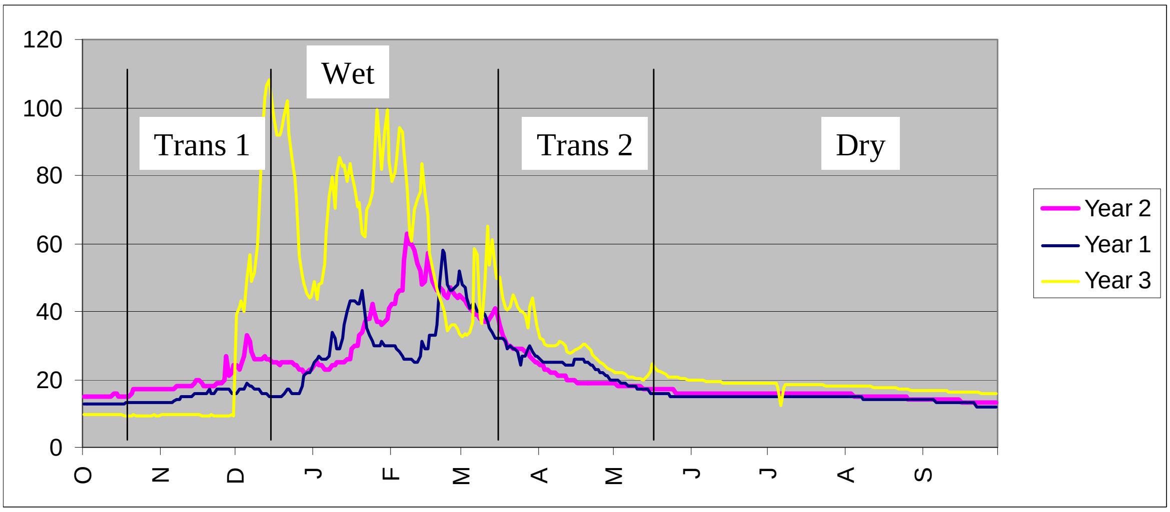


Figure 7.1 Three representative years for Site 1: Cuebe River @ Capico, illustrating the approximate division of the flow regime into four flow seasons

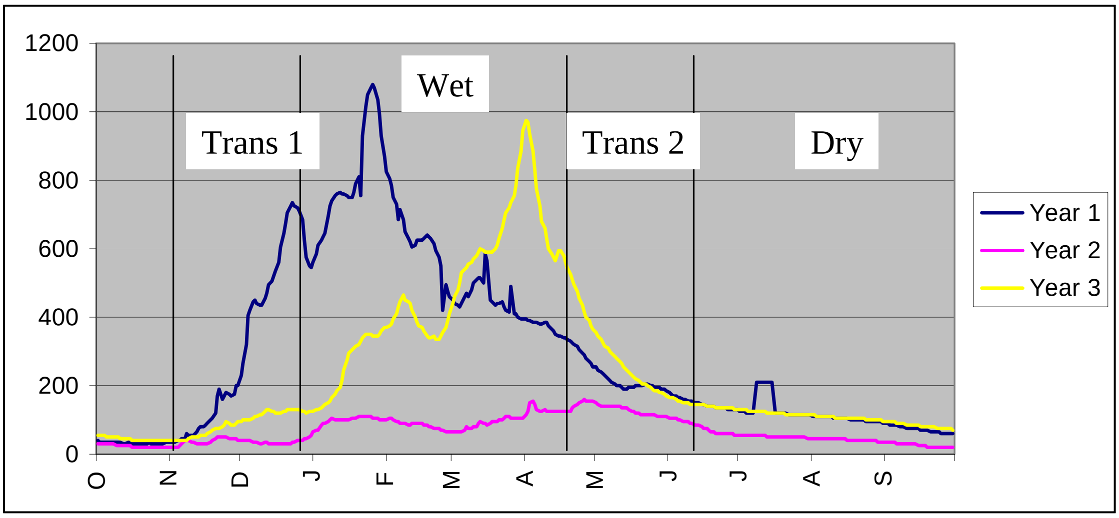


Figure 7.2 Three representative years for Site 2: Cubango River @ Mucindi, illustrating the approximate division of the flow regime into four flow seasons

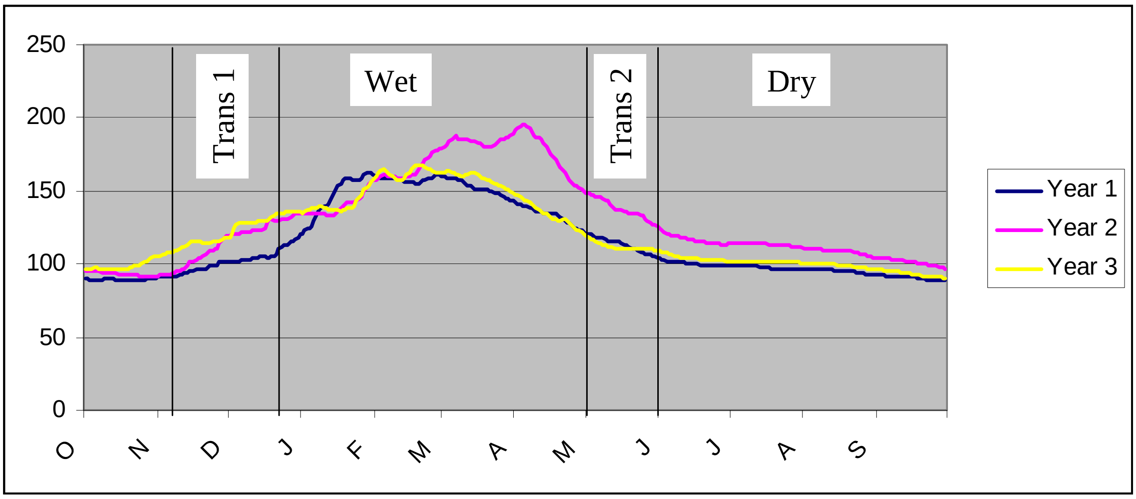


Figure 7.3 **Three representative years for Site 3 Cuito River @ Cuito Cuanavale, illustrating the approximate division of the flow regime into four flow seasons**

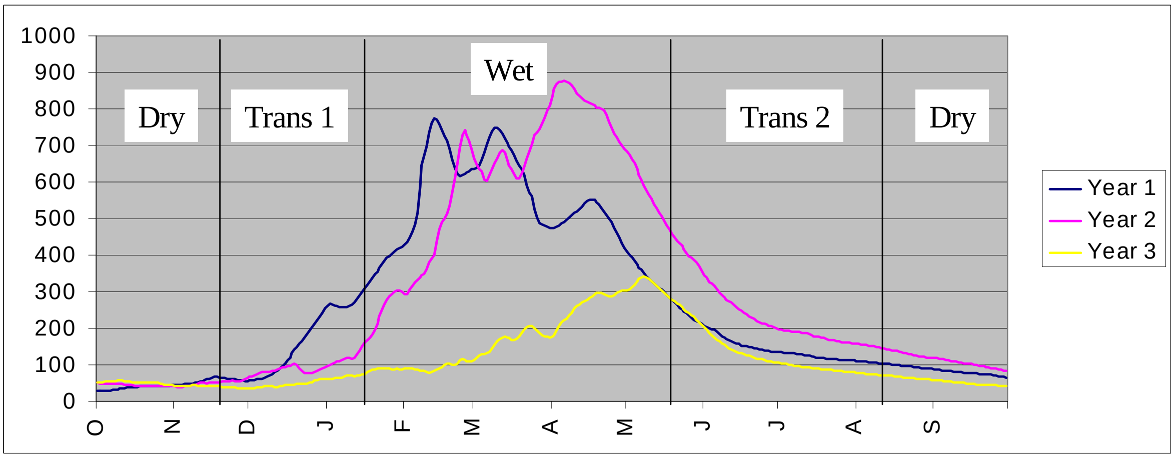


Figure 7.4 **Three representative years for Site 4: Okavango River @ Kapoko (hydrological data from Rundu), illustrating the approximate division of the flow regime into four flow seasons**

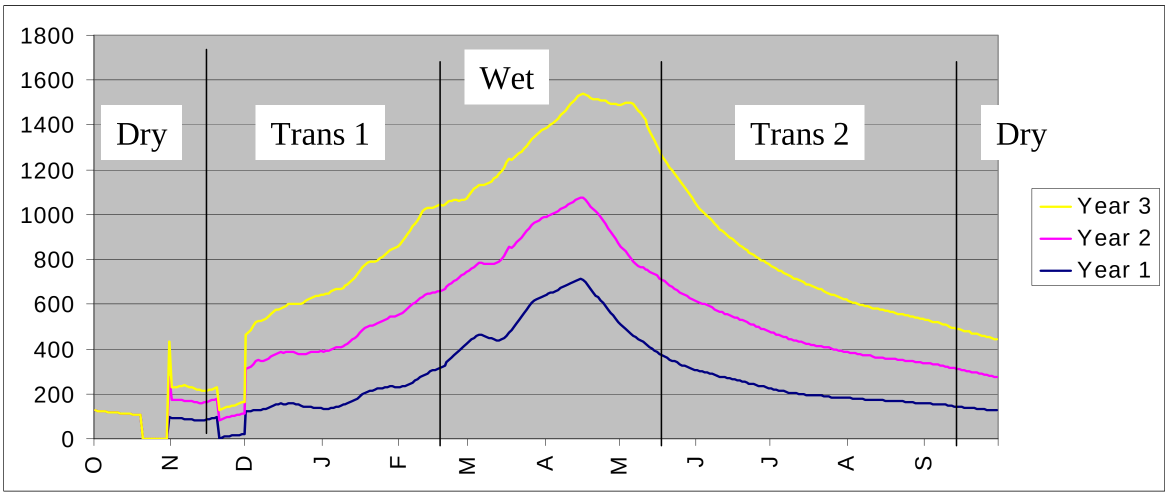


Figure 7.5 Three representative years for Site 5: Okavango River @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

The literature review (Chapter 0) and data collection (Chapter 0) are focused on addressing what is initially expected to be nine main questions related to these flow seasons (Table).

Table 3 Questions to be addressed at the Knowledge Capture Workshop, per indicator per site. In all cases, 'natural' embraces the full range of natural variability

Question number	Season	Response of indicator if:
1	Dry Season	Onset is earlier or later than natural mode/average
2		Water levels are higher or lower than natural mode/average
3		Extends longer than natural mode/average
4	Transition 1	Duration is longer or shorter than natural mode/average - i.e. hydrograph is steeper or shallower
5		Flows are more or less variable than natural mode/average and range
6	Flood season	Onset is earlier or later than natural mode/average – synchronisation with rain may be changed
7		Natural proportion of different types of flood year changed
8	Transition 2	Onset is earlier or later than natural mode/average
9		Duration is longer or shorter than natural mode/average – i.e. hydrograph is steeper or shallower

3.3 Inundation categories – delta sites

The recognised river flow categories are not relevant in the Delta, where inundation is the major driver of ecosystem form and functioning. The main inundation categories recognised by the inundation model developed by the Harry Oppenheimer Okavango Research Centre (HOORC) are used here (Table 4). These categories do not apply to the Namibian sites but the table is included for completeness.

Table 4 Inundation categories for the Okavango Delta as recognised by the HOORC inundation model

Inundation category number	Inundation category name
Delta 1	Channel in permanent swamp
Delta 2	Lagoons in permanent swamp
Delta 3	Backswamp in permanent swamp
Delta 4	Seasonal pools in seasonally flooded zones
Delta 5	Seasonal sedgelands in seasonally flooded zones
Delta 6	Seasonal grasslands in seasonally flooded zones
Delta 7	Savannah – dried floodplain in seasonally flooded zones
Boteti 1	

Boteti 2	Disconnected pools
Boteti 3	Dry

LITERATURE REVIEW

4.1 Introduction Wildlife Indicators

The review concentrates on the representative wildlife species for the flow related indicators (Table 3.)

The first unit of analysis In Namibia (represented by site 4), Main channel with floodplains, has few protected areas on the Namibian bank and an increasing human population. The Angolan bank was largely uninhabited between 1966 and 2002 due to war. Since Namibian independence and especially since 2002 when civil war ended in Angola, some people have returned but landmines remain a restraint to development on the northern bank of the river. (Mendelsohn and el Obeid 2004). The resources of the northern river bank in Angola, such as reeds and grazing are often used by Namibians when the Namibian side becomes depleted.

In Namibia, clearing natural vegetation for subsistence agriculture and livestock production as well as government irrigation schemes are the chief land uses. The river is seen by some in government as providing water that can be used for irrigation or other use elsewhere in Namibia, and by the people as providing free water, reeds, fish and livestock grazing areas (Mendelsohn and el Obeid 2004). Because of the above pressures, few of the larger natural floodplain associated mammals now remain in this unit (van Aarde and Ferreira 1997).

In contrast, the conservation of natural habitats is also being promoted by some government departments and NGOs that support the establishment of conservancies and protected areas of different types in the region. Some of the floodplain species, Lechwe, reedbuck and waterbuck, could potentially be reintroduced into existing or new conservancies if there is continued support for this type of land use in the future. The Namibian populations of these species are low and declining but there are long term management plans to increase them and reintroduce them into suitable areas in Caprivi and Okavango (Martin 2004).

The smaller wildlife taxa in this unit are also threatened by increasing human pressure on the river resources but can still be found associated with the river margins and floodplains because here human habitation and land clearing for agriculture is prevented or reduced by regular flooding. Literature on the wildlife of this unit was chiefly from general Namibian wetland research eg Simmons, Brown and Griffin (1991), Namibian species occurrence lists such as in Bethune (1990), Curtis *et al* (1998), Griffin and Grobler (1991), Griffin (2003), Griffin and Coetzee (2005), as well as distribution maps and species descriptions from Southern African wildlife books eg Mammals: Smithers (1983), Apps (2000), Reptiles: Branch (1988), Rodents: De Graff (1981), Snakes: Broadly (1983), Bats: Taylor (2000), and Frogs: Carruthers (2001)., Specialist reports contained in environmental impact studies were another source of information. e.g. van Aarde and Ferreira (1997) and Jacobsen (1997).

The second Namibian unit of analysis (represented by site 5) is characterized by channel islands and rapids. It includes the protected areas of the western core conservation areas of Bwabwata National Park, (Popa Falls, Mahangu and Buffalo). Apart from the above literature, information on the wildlife in this unit includes Namibian literature associated with the management of these protected areas, such as aerial surveys and game counts (eg Brown, Stander, Meyer-Rust, and Mayes, 2005; Chase, 2007; Rodwell, Tagg and Grobler, 1995). Reports produced during the environmental assessment of a proposed hydroelectric scheme near Popa Rapids (eg Griffin, 2003; Bethune, 2003) were another source of information of the river-associated wildlife occurring in this unit. Good details and excellent accounts of the Namibian distributions, biology and aspects of management of several larger wetland associated mammals are available, (e.g. Martin 2004), as part of the transboundary mammal project of MET which was facilitated by the Namibia Nature Foundation (NNF) and is available on their website. The information was also made available as a series of booklets on:- Southern Savanna Buffalo, Savanna Elephant, Hippopotamus, Roan, Sable and Tsessebe and Southern Reedbuck, Common Waterbuck, Red Lechwe and Puku. E.g. Martin (2008).

Web based searches for particular taxa and Okavango River usually produced references to literature on the wildlife of the Okavango Delta system in Botswana. These were useful for habitat use and lifecycle information on particular species such as Crocodile (e.g. Wallace and Leslie, 2008) and Sititunga (Games 1983).

Even so, there was surprisingly little on Okavango amphibians, rodents or most reptiles. Most web hits referred to tourism and the larger mammals found in the Okavango Delta. Many of these species are not wetland species and are associated with the river system particularly for water and forage during the dry season or simply because the location of the various protected areas include wetlands or the river.

Southern African literature was available to varying degrees on most of the species, see below. General worldwide links between particular taxa and riverine wetlands were also searched for using combined keywords such as floodplain, pool, frog, amphibian, otter, *Varanus* etc.

There are increasing numbers of websites attached to organizations and specialist groups that provide status and research reports on wildlife species or ecosystems and with links to other groups and literature. Some relevant ones are included in the References.

The current Namibian checklist of wildlife species for frogs, reptiles and mammals (Griffin and Coetzee 2005) lists 38 frog species, 75 reptile species and 124 mammal species that are known or expected to occur in the area of the Okavango River in Namibia. Of these, ten frog species, eight reptile species and 18 mammal species are thought to be dependent on the Okavango River wetland habitats in Namibia. Over 90% are classed as being of national conservation concern. (Griffin 2004).

4.2 Wildlife Indicator 1 : Channel Dwellers

Main characteristics of the habitat

The main Okavango River channel is well defined in both Namibian sites. Associated main channel river habitats include the Namibian seasonal floodplains which are relatively narrow and discrete and short sections where the channel is braided around small islands. The main channel habitat is typically from 50-150m wide, gently meandering with clear water, a sandy substratum. The banks are typically defined by reed or papyrus beds. Sandbars, rocks, small islands and rapids add structure in some sections.

Species dependent on this habitat.

Nile Crocodile, *Crocodilus niloticus* Laurenti, 1768. Hippopotamus, *Hippopotamus amphibius* Linnaeus, 1758. Spotted-necked Otter, *Lutra maculicollis* Lichtenstein, 1835.

These semi-aquatic keystone species use the channel as their main daily habitat for protection from human disturbance, to travel along, for social interaction and for finding or obtaining access to food. The characteristics of the main channel in any particular reach are especially important for the occurrence of the representative species during the low flow season when the channel width and depth decreases. These characteristics determine the time and use of the habitat by the different species. The Namibian Okavango population of Hippo was about 351 or 3.9/km² (of surveyed area) in 2007, mainly in protected areas (Chase 2007), and Crocodile about 35 or 0.48/ km² (Chase 2007) compared with corrected counts in 2004 of 66 individuals greater than 2m and 38 less than 2m (Brown *et al* 2005). The highest densities of both species are found in the protected areas in Namibia.

Life cycle attributes of Indicator 1 representative species.

Hippo mate, are born and suckle in water where they also spend the day largely submerged in groups. They repeatedly use the same locations, returning after nocturnal foraging trips. They leave the water at night to graze individually on land.

Crocodile sub-adults and adults use the main channel for moving and finding food, which is primarily fish with the occasional mammal. Juveniles frequent vegetation and backwaters and feed mainly on aquatic invertebrates and amphibia with the occasional small mammal. (Wallace and Leslie 2008). Nests are made on island and main banks, often in clearings in reed and papyrus beds where about 60 eggs are laid at the end of the dry season (Blomberg 1976). Nest temperatures determine the sex ratio of hatchlings. The water monitor is a chief crocodile egg predator (Blomberg 1976): 33% of nests in the Okavango were predated chiefly by monitors during one survey (Leslie 2005). Humans, fishermen and reed-cutters have deliberately destroyed nests in the panhandle (Leslie 2005) and can be a principal threat to breeding success (Wallace and Leslie 2008).

Links to flow

Hippos use the main channel as daytime living space where they rest in pods. Lie up sites are located on shelving banks where there is a range of water depths (in protected areas) or on sandbars or pools in midstream if the river is wide enough for protection from human disturbance outside protected areas or inside pools in vegetation such as Papyrus or reedbeds in some places if these are available. Hippo prefer a water depth of about 1.5m (Bruton 1978) which is deep enough to submerge by kneeling or have their backs out of the water by standing (Scotcher 1974). During low water flows the number of available sites is reduced and pod sizes can increase.

Crocodile can use all water depths and lie on sand bars and banks where there is access to deep water.

Water depth and distance from suitable grazing sites from the river banks are important factors that determine hippo occurrence in the Namibian sites. Main river channel use by hippo and crocodile in the protected areas of the Namibian sites varies markedly from that where the banks are populated by humans (e.g. Chase 2007). In protected areas hippo are frequently out of the water during the cooler parts of the day and both species rest on the banks or in water close to the banks. In populated areas hippo and crocodile are often absent from the main channel during the day or are restricted to wide river reaches where they have some protection from human disturbance. Day time refuge sites for both species in populated reaches are often inside reed or papyrus beds rather than in open water.

The representative species need sufficient low flow water levels to maintain channel depth, and reed and papyrus beds. They need high flow water flows to maintain sandbanks and floodplain vegetation. Early high floods can kill the eggs in lower lying crocodile nests.

Vegetated islands, sand bars and rocks in the main river channel provide protection, feeding and breeding sites for some channel dependant wildlife. In Namibia Okavango River islands are protected to some extent from human disturbance and their vegetation tends to be in better condition than that on the bank. Water Monitor *Varanus niloticus* , African Clawless Otter *Aonyx capensis*, Spotted-necked Otter *Lutra maculicollis* Okavango Hinged Terrapin *Pelusios bechuanicus*

Crocodile and Terrapins lay eggs in nests in soil towards the end of the dry-season / start of summer (Branch 1988) (Leslie 2005). Water Monitors dig nests in termite mounds where the eggs hatch after rain the following year (Branch 1988). Otters nest in hollows under riparian trees or rocks eg Rowe-Rowe (1992), Perrin (2000). Young reptiles need protection from predators amongst island and bank aquatic vegetation which is protected from terrestrial predators. Hatchlings need access to emergent and fringe vegetation around islands, along channel fringes and in inundated floodplains and pools. Here they have protection and can find their largely invertebrate and amphibian food (e.g. Leslie 2005; Broardley 1983; Branch 1988.)

Links to flow

1. Nest sites are vulnerable to flooding from early floods.
2. Sandbanks formed during exceptionally high floods can be used during following years.
3. Lower low flows make islands part of the bank or more accessible to terrestrial predators, humans and livestock that can eat or destroy eggs, remove vegetation and trample banks.

4.3 Wildlife Indicator 2: Frogs and River snakes

Description: Amphibians, snakes and small mammals such as Musk shrews inhabit floodplain pools, backwaters and emergent vegetation.

Main characteristics of Indicator habitat

Still or low current conditions. Emergent aquatic vegetation provides cover and food. Backwaters , floodplain pools and emergent vegetation and permanent swamp dwellers. Channel emergent / floating vegetation stands such as papyrus, reed beds and, lily-pad beds, along water margins and in backwaters and side channels provide protection, feeding and breeding sites for many riverine wildlife species. (Eg, Branch 1988; Broadley 1983; Smithers 1983;, Skinner and Smithers 1990).

Species dependent on this indicator.

Frogs, Snakes, Musk Shrews. Swamp musk shrew *Crocidura mariquensis shortridgei,* Tiny musk shrew *Crocidura fuscomurina woosnami* , Giant musk shrew *Crocidura occidentalis zuleika and* Lesser Red musk shrew *Crocidura hirta deserti* .

Life cycle attributes of Indicator

Juvenile reptiles hunt for food and find protection in backwaters and floodplain pools. These habitats are the living space of frogs, aquatic invertebrates, birds, breeding fish and small mammals that also form the food of juvenile and sub-adult aquatic reptiles. (Eg Leslie 2005, Branch 1988, Broardley 1983)

Musk shrews need semi aquatic vegetation of dense grasses and reed beds Smithers (1983). *C.hirta* also occurs away from wetlands Smithers (1983). They are largely insectivorous but may be carnivorous, for instance feeding on frogs, and are active at intervals throughout the day and night. They breed all year apart from the winter months. They nest in thick grass or flood deposited debris Smithers (1983).

Links to flow

Occasional very high flows scour out floodplain depressions and form new backwaters.
Seasonal floods fill floodplain pools and maintain floodplain groundwater levels.
Seasonal floods provide fish, aquatic plants and aquatic invertebrates.

Channel flows maintain backwater water levels during dry season. Water levels vary through the structure of emergent vegetation with the seasonal flood cycle. Floating vegetation such as papyrus and water lilies move or grow with changing water levels At low water there is less of this indicator habitat available whereas during floods vegetation on the floodplains are also available.

Amphibian and aquatic invertebrate lifecycles are dependant on a minimum inundation period of 1-2 months (Carruthers 2001).
Annual floods are needed to maintain vegetation and habitat for invertebrates and amphibians. Fast rises in water level or unseasonal high flows may flood Musk shrew nest sites.

4.4 Wildlife Indicator 3: Middle Floodplain grazers

Species dependent on this indicator. Secondary seasonally flooded floodplain species such as , Elephant *Loxodonta africana*,, Buffalo *Syncerus caffer*, Tsessebe *Damaliscus lunatus* and Warthog.

Description of habitat: Flooded vegetation during seasonal floods, new growth of aquatic grasses, as the flood recedes the resources become available to terrestrial grazers as well as small mammals Middle (secondary) floodplain is inundated for a shorter time over the flood peak, than lower (primary) floodplain and is available for non aquatic floodplain species when the seasonal floodplain is inundated. Vegetation here is denser and taller and is also used by species such as reedbuck and small mammals.

Information on Namibian Floodplain grazing Species :

Floodplain Grazers occurring in the Namibian UOA include Hippopotamus *Hippopotamus amphibius* , Red Lechwe *Kobus leche*, Southern Waterbuck *Kobus ellipsiprymnus*, Common reedbuck *Redunca arundinum* and Buffalo *Syncerus caffer*. A Namibian hypermedia document, http://www.nnf.org.na/RARESPECIES/InfoSys/Index.htm is available on the Namibia Nature Conservation website, as part of the Transboundary Mammal Project of the

Ministry of Environment and Tourism. This hypermedia network of information gives details of the numbers, distribution, habitats, behaviour, limiting factors and population dynamics of some of the larger wetland associated mammals of the Caprivi and Okavango in Namibia, together with management plans. Presently the species covered include Buffalo *Syncerus caffer,* Elephant *Loxodonta africana*, Hippo, *Hippopotamus amphibious*, Roan *Hippotragus equinus,* Sable *Hippotragus niger* , Tsessebe *Damaliscus lunatus*, Reedbuck *Redunca arundium*, Waterbuck *Kobus ellipsiprymnus*, Red lechwe *Kobus leche*,and Puku *Kobus vardoni.*

The Namibian Okavango Buffalo population occurs in the western core areas of the Bwabwata National Park and is effectively isolated from other buffalo by lack of water in the central part of the park and from Botswana by the veterinary fence. Buffalo are regulated by their food supply – a decline in quality and quantity of available food during the dry season limits the population (Sinclair 1975). Perennial Panicum grass species preferred by buffalo (*P. coloratum, P. maximum, P. repens*) are present in the northern areas of Namibia and *P.coloratum* was reported in Curtis's vegetation report as part of this study.

During the dry season the buffalo occurring in UAO 5 frequent the floodplains of the Okavango in large herds that disperse during the wet season.

Links to flow: For all floodplain grazers, regular floods are needed to maintain the primary and secondary floodplain vegetation. In any one flood cycle the proportion of seasonal to secondary floodplain may influence the distribution of floodplain grazers and small mammals. Un-inundated floodplain vegetation is normally available to wildlife during flood periods except during flood peaks. Middle floodplains are maintained by large floods and seasonal flood peaks and are inundated for two to six months.

4.5 Wildlife Indicator 4: Outer floodplain grazers

Representative species: Tertiary floodplain channel riparian zone and Delta island grassland species such as Wildebeest, Zebra, Impala, Duiker, Aardvark, and mice.

Main characteristics of Indicator habitat The riparian zone along floodplain and channel margins and on larger / higher islands. This vegetation zone is occasionally flooded during very high floods but is normally dependent on river associated groundwater (Trees) or local rainfall (grasses). Provides non-aquatic and floodplain wildlife with cover and grazing especially during flood periods when other floodplain types are inundated. Riparian trees / forest with species such as *Garcinia livingstonei ,Albizia versicolor and Diospyros mespiliformis.*

Links to flow: Ground water linked to river water sustains the riparian zone during the dry season. The grasslands and lower riparian tree line margin is maintained by periodic high floods. A longer flood interval will allow encroachment of trees onto the floodplain. In Namibia the riparian zone forests are more dependant on the extent of human caused deforestation than any changes in flow regime.

4.6 Wildlife indicator 5: Lower floodplain grazers

Primary seasonally flooded floodplain dependant species such as Reedbuck *Redunca arundium*, Waterbuck *Kobus ellipsiprymnus*, Red lechwe *Kobus leche* and Sitatunga *Tragelaphus spekei*

Main characteristics of Indicator habitat

.

Other species dependent on this indicator habitat.

and non aquatic species such as the small mammals. This dependency is chiefly over the flood peak of high floods when the other riverine habitats are inundated. Otters and monitors lie up in bank thickets and tree roots during the floods season for protection and basking. Some bats are also dependant on riparian forests but no flow related information could be found. They are probably dependent on wetland associated invertebrates such as mosquitoes, mayflies and cyronomids *

Reedbuck are chiefly nocturnal. require tall grass or reedbeds for daytime cover (Smithers 1983). They seem to do well on poor grassland as long as cover and water are available. They prefer open areas and avoid woodland and bush encroached areas. Clear burning causes them to vacate habitat. They do not seem to be attracted to fresh sprouting grasses after fire as much as other grazers (Howard 1987). Poaching and dogs threaten reintroduced animals (Rowe-Rowe 1991)

Red Lechwe are water-loving antelope that frequent shallow inundated floodplains and will feed in water up to 0.5m deep. They seldom drink in the cool, dry season.

Martin (2004) compiled a list of plant species eaten by reedbuck, waterbuck, lechwe and puku based on the feeding studies by Jungius (1971) and Child and von Richter (1969):

4.9 Summary

The literature on the distribution and ecology of the larger wildlife, the floodplain grazers such as Red Lechwe, Waterbuck and Reedbuck, as well as Hippo, Otters and Crocodile are good and sufficient for the purposes of this initial water flows assessment. Most species are Southern African rather than Namibian Okavango River dwellers and there are more data on the Okavango Delta in Botswana than on the Namibian section of the river. There are new studies (Hippo) and studies in progress (Crocodile, Otter, Elephant) in the Okavango system. These should produce new information on the particular ecology of these species in the Okavango system and especially their relationships with river flows, which may be used for a future full flows assessment. The literature giving details of habitat requirements of the other taxa are generally Southern African rather than on the Okavango in particular. For these taxa water-flow related habitat needs had to be inferred from reported breeding seasons, food preferences etc.

Major knowledge gaps are information on particular water flow needs of most of the smaller indicator representative species including Namibian amphibians, small mammals and bats. Even the taxonomy and biogeography of many Namibian amphibian and some rodent groups is still deficient.

There are increasing numbers of specialized web sites where information and literature on wildlife can be found together with links to other aspects such as conservation, human interactions, community based management, studies and specialist groups. Some of these are given after the references.

DATA COLLECTION AND ANALYSIS

5.1 Methods for data collection and analysis

The representative sites for each of the Namibian units of analysis were visited once in the dry and twice in the wet season.

The objectives of the field visits were to gain impressions of the UOAs and their habitats so that flow related indicators could be suggested that would reflect the effects of changes in water flows on representative wildlife species. Sightings or signs of wildlife were looked for to confirm the presence of representative species.

Kapako floodplain site was visited three times, in October 2008, January 2009 and in February 2009. During the second visit the water was much higher than normal for January and most of the floodplain was inundated.

Visit 1. Walks over the dry floodplain and along the river bank produced some wildlife occurrence information. (See Appendix A Map, Wildlife 1. Site 3)
Visit 2. Floodplain was flooded; walks in the riparian zone and on small floodplain islands produced some wildlife occurrence information for the site. (See Appendix A Map, Wildlife 1. Site 4)

Visit 3. The floodplain was flooded. To see if small mammals still frequented the remaining small floodplain islands, two small-mammal trap lines were setup on small islands that were located on the main channel edge of the floodplain. One was about 150m from the dry bank and the other about one km. Both islands were about 80m long and 30m wide with a line of River Rhus *Searsia quartiniana*. The dry areas were covered by terrestrial grass clumps and sedges merging into flooded hippo grass *Vossia cuspidata* on the floodplain side, with some reeds fringing the open water along the side of the main river channel. Sherman live traps were placed 10m apart along the spine of each island (six and eight) in the evening and collected the next morning. (See Appendix A Map, Wildlife 1. Sites 1and 2)

Popa rapids site was visited on in October 2008, and January and February 2009
Visit 1. Walks over the rapids, on the islands and along the banks produced some wildlife occurrence information.
Visit 2. Ditto.
Visit 3. Sherman live traps for small mammals were placed on two of the islands and along the north river bank. (See Appendix B for site map.) Site 1, north bank trap line, site 2 north island trap line and site 3 south island trap line.

5.2 Results

Kapako visit 1. The quite varied topography of the floodplain which is composed of a series of banks interspersed with lower areas and floodplain pools was noted. Because of this the floodplain vegetation and hence wildlife habitats was also varied. Cattle grazing on the floodplain had depleted the vegetation cover in some areas, especially around the floodplain pools and along the river bank where there was also some erosion. Some pools appeared to have been recently netted by people as the water was turbid and aquatic vegetation was pulled onto the banks.
Signs of wildlife were:- Crocodile 2, Water monitor 2, Otter sign, Hippo sign. Duiker sign. unidentified rodent sign, Cattle 30+.

Kapako visit 2. All the habitats for the indicators were present except indicator two, Channel Island, sand and rock bars. Wildlife or wildlife sign was:- Water monitor 2, Spotted necked Otter 2, Mole rat sign, Hippo sign, Ridged-frogs *Ptychadena spp*, Duiker sign, unidentified rodent sign, Cattle 30+, Goats, dog.

Kapako visit 3. The trap lines on the small floodplain islands, sightings and sign was:- Swamp musk shrew *Crocidura mariquensis shortridgei* trapped, 1(Site 1), Spotted Necked Otter 1, Hippo sign, Multimamate mouse *Mastomys natalensis ovambiensis* Trapped 1 (site 1), cattle, goats, dog.

Popa Rapids visit 1. Wildlife sightings or sign were:- Hippo 6, Otter spraints. Frogs *

Popa Rapids visit 2. Wildlife sightings or sign were:- Cane rat sign, Hippo 1, Hippo sign, Terrapin sign, small spotted genet, Puddle frog *Phrynobatrachus natalensis*,

Popa Rapids visit 3. The trap lines on the channel islands, sightings and sign was:- Hippo sign, Otter sign, Swamp Musk Shrew *Crocidura mariquensis shortridgei* trapped,1 (site 2). Frog* trapped, 1 (Site 2), Serval, *Felis serval* midden, Multimamate mouse *Mastomys natalensis ovambiensis* Trapped 1 (site 3) Boomslang, Chobe Dwarf Gecko *Lygodactylus capensis and* Puddle frog *Phrynobatrachus natalensis* at Popa camp.

5.3 A summary of present understanding of the predicted responses of all wildlife indicators to potential changes in the flow regime

The following tables give a broad idea of how changes to flow patterns may impact the habitats and hence the wildlife indicators linked to those habitats.

5.3.1 Indicator 1. Main channel dwellers. (Hippo, Crocodile, Otters)

Table 5.1 Predicted response to possible changes in the flow regime of main channel dwellers in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence
1	Dry Season	Onset is earlier or later than natural	Earlier = nil Later = Channel deeper for longer so islands are protected, good for reptile pops.	Medium
2		Water levels are higher or lower than natural	Higher = deeper channel, more living space for both hippo and crocodile, perhaps fewer dry sand breeding sites for crocodile. Lower = shallower channel ,fewer safe locations,	Medium
3		Extends longer than natural	Lower channel depth at season end and so fewer safe locations	
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer =more time for nesting of crocodile Shorter= less time for nesting of crocodile	
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier = Breeding of some crocodile maybe disrupted by flooding of nests Later = Breeding of some crocodile maybe disrupted. Juveniles need access to floodplains and backwaters.	
7		Natural proportion of different types of flood year changed	Higher high-flows = good for sandbank development, good for pool scouring. Lower high-flows = less flow for channel maintenance as above	
8	Transition 2	Onset is earlier or later than natural	Earlier = floodplains dry out sooner=Juvenile crocodile have to return to main channels where there is less food and protection. Later = more habitat for juvenile Crocodile.	
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

5.3.2 Indicator 2 Frogs and snakes (Frogs snakes and musk shrews))

Table 5.2 Predicted response to possible changes in the flow regime of Channel island, sand-bar and rock-bar dwellers in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator	Confidence
1	Dry Season	Onset is earlier or later than natural	Earlier=emergent vegetation dries out sooner, reedbeds dryer sooner =. Later =backwaters deeper for longer = reedbeds watered for longer.	medium
2		Water levels are higher or lower than natural	Higher =Better marginal and emergent vegetation = more habitat = increased survival. Lower = reedbeds and marginal vegetation drier = less habitat = decreased survival.	
3		Extends longer than natural	Fewer safe locations and resources	
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier = marginal vegetation and reedbeds flooded earlier. Less habitat available. May flood nests before hatching Later = Habitat available for longer, but hatchlings need inundated floodplain resources.	
7		Natural proportion of different types of flood year changed	Populations may increase if this habitat is available for longer and reduce if it is inundated or dries out sooner than normal	
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

5.3.3 Indicator Middle Floodplain grazers.

Table 5.3 Predicted response to possible changes in the flow regime of middle floodpain grazers in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator	Confidence
1	Dry Season	Onset is earlier or later than natural	Earlier= pools may dry out sooner =reduced breeding time for amphibians Later =Pools and backwaters available for longer =increased breeding time for amphibians	Medium
2		Water levels are higher or lower than natural	Higher =, more pools, less competition for resources= reduced mortality Juvenile reptiles. Lower = fewer pools, more competition for resources= increased mortality.	
3		Extends longer than natural	fewer pools, backwaters reduce or dry up= Fewer resources available for adults and young.	
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer =floodplains flood later = pool habitat available later and for shorter time. Shorter= Floodplains flood earlier=pool habitats available sooner and for longer.	
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier = Earlier access to floodplain pools and backwaters =good for juveniles. Later = competition for resources greater if onset is delayed. =Food for Juvenile reptiles reduced.	
7		Natural proportion of different types of flood year changed	Higher high-flows = good for pool scouring=Deeper pools next dry season Lower high-flows = less flow for channel maintenance as above	
8	Transition 2	Onset is earlier or later than natural	Earlier= pools may dry out sooner =reduced breeding time for amphibians , habitat for juveniles. Later =Pools and backwaters available for longer =increased breeding time for amphibians	
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

5.3.4 Indicator 4. Species Using outer floodplains.

Table 5.4 **Predicted response to possible changes in the flow regime of species dependent on outer floodplains in the Okavango River ecosystem.**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence
1	Dry Season	Onset is earlier or later than natural	Earlier= River linked groundwater may reduce – vegetation water stress before next flood. Later = nil	medium
2		Water levels are higher or lower than natural	Higher = nil Lower = Ditto groundwater effects	
3		Extends longer than natural	River linked groundwater dependant trees may be stressed	
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier = Non aquatic species move into riparian zone earlier -reduced resources. Later = nil	
7		Natural proportion of different types of flood year changed	Higher high-flows = habitat may be flooded-fewer resources available. less habitat available if inter-flood interval is reduced too much. Lower high-flows = less flooding of riparian zone = more habitat available but may become depleted if inter-flood interval is extended for too long	
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

5.3.5 *Indicator 5. Lower Floodplain dependant species.*

Table 5.5 Predicted response to possible changes in the flow regime of Lower Floodplain dependant species in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator	Confidence
1	Dry Season	Onset is earlier or later than natural	Earlier= Floodplains will be drier reduced availability of resources e.g. grazing, pools Later =Floodplains will provide good resources for longer	medium
2		Water levels are higher or lower than natural	Higher = same as later Lower =same as earlier, Floodplain pools may dry out.	
3		Extends longer than natural	Resources may become depleted for floodplain grazers	
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer = slower flooding = aquatic vegetation has time to grow and be available to grazers Shorter = Faster flooding = water deeper which excludes some floodplain grazers from new vegetation.	
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier = inundated floodplain resources available sooner = earlier breeding for frogs and better survival of juvenile reptiles. Later =	
7		Natural proportion of different types of flood year changed	Higher high-flows = good for sandbank development, good for pool scouring Lower high-flows = less flow for channel maintenance as above	
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

5.4 Conclusions

Linking the ecological needs of particular species to different water flows in the Okavango River in Namibia was an interesting exercise that highlighted the following aspects:-

- The lack of basic information on all but the larger species, especially the Namibian populations.
- The changing water flows in the river and their extent and periodicity affect a whole chain of morphological and chemical factors that define the vegetation and hence the riverine habitats available to wildlife, These interactions were known but never thought about in detail.
- The distributions of the larger wildlife in the Namibian sites has much more to do with a particular reach's protected status than the availability of flow linked indicator habitat (presumably because of direct human pressures).
- The above means that along the Okavango in Namibia, the larger wetland associated species are threatened with local extinction. The small existing protected areas are vital for the biodiversity of the river in Namibia and should be increased at every opportunity through, for instance, conservancies that include special habitats such as rapids, islands and floodplains, together with their wildlife species.
- Outside protected areas this assessment of what effects changes to the flow regime will have on the larger wildlife, such as floodplain grazers, is relevant to future potential, e.g. for reintroducing species, rather than the present distributions of these species.
- There are several ongoing and new research projects on some of the larger representative indicator species. These studies will provide new information on relationships with and dependence on, particular flow stages of the Okavango River that will be available for the proposed comprehensive flows assessment.
- More work will need to be done on how details of the Okavango River hydrogragh impact the ecology and lifecycle of the smaller wetland associated species in Namibia.

6. Flow-response relationships for use in the Okavango EF-DSS

Response curves for the wildlife indicators were constructed together with the wildlife experts from Angola and Botswana during a workshop in Windhoek in April 2009. The response curves were fed into the Okavango Environmental Flow Assessment Decision Support System for use during the Scenario Workshop in CapeTown in July 2009 but will be provided on a CD linked to the final report.

7. References (*) and limited Bibliography.

General

Special wetlands biodiversity issue of the AQUATIC SCIENCES JOURNAL, featuring the Okavango: *Aquatic Sciences* Vol 68, No 3, 239-414.

*Bethune .S, 2003. Impacts on aquatic ecosystems in: Popa falls (Divundu) pre-feasibility study. Preliminary environmental assessment. NamPower.

*Bethune, S. 1990. Kavango River wetlands. *Madoqua* 17 **2** : 77 – 112

*Bethune, S. 1992 Unpublished. An updated review of the limnological baseline survey of the Okavango River in Namibia 1984 – 1992. Internal report RR/92/3 of the Research Division , Department of Water Affairs, Namibia.

*Branch, B. 1988. Field Guide to the Snakes and Other Reptiles of Southern Africa. Struik Publishers CapeTown.

*Broadley, D.G. 1983. FizSimons Snakes of Southern Africa. Delta Books

Bonyongo, M.C. and Harris, S. 2007. Grazers species -packing in the Okavango Delta, Botswana. *African Journal of Ecology*, (4), 527–534.

*Channing, A. and M. Griffin. 1993 An annotated checklist of the frogs of Namibia. *Madoqua* 18:101-116.,

*Carruthers.V. 2001 Frogs and Frogging in Southern Africa. Struik Publishers. CapeTown.

*Curtis, B.A., Roberts, K.S., Griffin, M., Bethune, S., Hay, C.J., and H. Kolberg. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation* 7 **4** : 447 – 466.

el Obied, S. and J. Mendelsohn. 2000. A preliminary profile of the Kavango Region in Namibia. Every River has its People project. Sida, DRFN.

*Games, I. 1983. Observations of sitatunga (*Tragelaphus spekei selousi*) in the Okavango Delta of Botswana. *Biological Conservation* 27:157–70.

*Griffin, M. 2003. Annotated checklist and provisional national conservation status of Namibian reptiles. Namibia. Wissenschaftliche Gesellschaft. Windhoek, Namibia.

*Griffin, M. and C.G. Coetzee. 2005 Annotated checklist and provisional national conservation status of Namibian mammals. Technical report 4. Directorate Scientific services Ministry of Environment and Tourism. Windhoek.

*Griffin, M. 2003. Impacts on mammals, reptiles and amphibians: Popa falls (Divundu) pre-feasibility study. Preliminary environmental assessment. NamPower.

Griffin, M. 1989. The species diversity, distribution and conservation of Namibian mammals. *Biodiversity and Conservation*, 7 (4): 484-494.

Griffin, M. 2005. Diagnostic key to the identification of Namibian chiroptera. Technical report of scientific services Ministry of Environment and Tourism.

*Griffin, M. & Grobler, H.J.W. (1991). Wetland-associated mammals of Namibia - a national review. *Madoqua*, Vol 17, Issue 2. p.233-237. ISSN: 1010-2299.

Høberg, P., Lindholm, M., Ramberg, L. & Hessen, D. O. 2002. Aquatic Food Web Dynamics on a Floodplain in the Okavango Delta, Botswana. *Hydrobiologia*, 470, 23-30.

Lindholm, M., Hessen, D.O., Mosepele, K. and Wolski, P., 2007. Food webs and energy fluxes on a seasonal floodplain: The influence of flood size. *Wetlands*, 27(4):

*Murray-Hudson,M., Wolski,P. and Ringrose,S. 2006. Scenarios of the impact of local and upstream changes in climate and water use on hydro-ecology in the Okavango Delta, Botswana. *Journal of Hydrology*, 331, 73-84.

Ramberg,L., Hancock,P., Lindholm,M., Meyer,T., Ringrose,S., Sliva,J., Van As,J. and Vanderpost,C. 2006. Species diversity of the Okavango Delta, Botswana. *Aquatic Sciences*, 68, 3, 310-337.

Ramberg, L., Wolski, P., Krah, M., 2006. Water balance and infiltration in a seasonal floodplain in the Okavango Delta, Botswana. *Wetlands*, 26, 3, 677-690.

*Rodwell T.C.,Tagg.J,and Grobler.M. 1995. Wildlife resources of the Caprivi, Namibia: The results of an aerial census in 1994 and comparisons with past surveys. Research Discussion Paper 9. Ministry of Environment and Tourism.

*Taylor, P.J. 2000. Bats of Southern Africa. Guide to Biology, Identification and Conservation. University of Natal Press Pietermaritzburg.

dos Sontos Leile, F.A. 1997. Specialist report on: Fauna and flora of the Okavango River Basin (Angolan Sector) in: Okacom Diagnostic Assessment. GEF Project Brief compiled by S Crerar for Okacom

Martin, R,B. 2008. Background Information and species Management Guidelines for Namibia's rare and Valuable Wildlife. Transboundary Mammal Project of Ministry of Environment and Tourism, Namibia facilitated by The Namibia Nature Foundation and the World Wildlife Fund LIFE Programme.

*Martin, R.B. (2004). The Wetland Grazers: Species Report for Reedbuck, Waterbuck, Red Lechwe and Puku. Study conducted for The Transboundary Mammal Project of the Ministry of Environment and Tourism, Namibia facilitated by The Namibia Nature Foundation and the World Wildlife Fund LIFE Programme

Mendelsohn, John & Carole Roberts (1997). An Environmental Profile and Atlas of Caprivi. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Republic of Namibia. 45pp

*Mendelsohn, John & Selma el Obeid (2004). Okavango River – The flow of a lifeline. Publ. RAISON (Research and Information Services of Namibia) & Struik Publishers, Capetown. 176pp

*Simmons, R.E., C.J. Brown and M Griffin Eds (1991). The Status and Conservation of Wetlands in Namibia, Special Wetlands Edition . Proceedings of a Wetlands workshop held on 22 November 1988 in Windhoek Namibia. *Madoqua* 17 2.

*Skinner,J.D. and R.H.N. Smithers. (1990). The Mammals of the Southern African Subregion. University of Pretoria, Pretoria, RSA. +771pp.

*Smithers, R H.N. (1983). The Mammals of the Southern African Subregion. University of Pretoria, Pretoria, RSA. 736pp

*Van Aarde R.J. & S.M. Ferreira. 1997. Mammals of the Okavango River system in Namibia and the Okavango Delta in Botswana. In:- Feasibility study on the Okavango River to Grootfontein link of the Eastern National Water Carrier. Report for Department of Water Affairs.

Wager, V.A. 1986. Frogs of South Africa: Their fascinating life stories. Johannesburg. Delta Books.

*Wallace K.M. and A. J. Leslie 2008. Diet of the Nile Crocodile *Crocodylus niloticus* in the Okavango Delta, Botswana. *Journal of Herpetology* **42(2**):361-368.

OTTERS

Perrin, M.R. & d'Inzillo Carranza, I. (1999) Capture, Immobilization and Measurements of the Spotted-Necked Otter in the Natal Drakensberg, *South Africa. S. Afr. J. Wildl. Res*. 29: 52 – 53

Perrin, M.R. & d'Inzillo Carranza, I. (2000a) Activity Patterns of Spotted-Necked Otters in the Natal Drakensberg, South Africa. *S. Afr. J. Wildl. Res*. 30: 1 – 7

*Perrin, M.R. & d'Inzillo Carranza, I. (2000b) Habitat Use by Spotted-Necked Otters in the KwaZulu-Natal Drakensberg, South Africa. *S. Afr. J. Wildl. Res*. 30: 8 - 14

Perrin, M.R. & d'Inzillo Carranza, I. & Linn, I. J. (2000c) Use of Space by the Spotted-Necked Otter in the KwaZulu-Natal Drakenberg, South Africa. *S. Afr. J. Wildl. Res*. 30: 15 – 21

Perrin, M. R. & Carugati, C. (2000d). Food habits of coexisting Cape clawless otter and spotted-necked otter in the KwaZulu-Natal Drakensberg, South Africa. *South African J. of Wildl. Research* 30(2):85-92.

Perrin, M. R. & Carugati, C.. (2000e). Habitat use by the Cape clawless otter and spotted-necked otter in the KwaZulu-Natal Drakensberg, South Africa. *South African J. of Wildl. Research* 30(3):103-113.

Rowe-Rowe, D. T. (1977a). Food ecology of otters in Natal, South Africa. Oikos 28:210-219.
Rowe-Rowe, D. T. (1977b). Prey capture and feeding behaviour of South African otters. *The Lammergeyer* 23:13-21.

*Rowe-Rowe, D. T. (1992). Survey of South African otters in a fresh-water habitat, using sign. *South African J. of Wildl. Research* 22:49-55.

Rowe-Rowe, D. T. & Somers, M. J. (1998). *Diet, foraging behaviour and coexist*ence of African otters and the water mongoose. *Symposia of the Zool. Soc. of London* 71:216-227.

Van Niekerk, C. H., Somers, M. J. & Nel, J. A. J. (1998). Fresh-water availability and distribution of Cape Clawless otter spraints and resting places along the south-west coast of South Africa. *South African J. of Wildl. Research* 28:68-72.

Purves, M. G., Kruuk, H. & Nel, J. A. J. (1994). Crabs Potamonautes perlatus in the diet of otter Aonyx capensis and water mongoose Atilax Paludinosus in a freshwater habitat in South Africa. *Zeitschrift für Säugetierkunde* 59:332-341.

HIPPO

Ellery, W.N., Dahlberg, A.C., Strydom, R., Neal, M.J., and Jackson, J. (2003 May) Diversion of water flow from a floodplain wetland stream: an analysis of geomorphological setting and

hydrological and ecological consequences, *Journal of Environmental Management*, 68(1), pp. 51-71.
HSG (2004). Country-by-country assessment of the status of common hippo. Report from the web-site of the Hippo Specialist Subgroup of the IUCN/SSC Pigs, Peccaries and Hippo Specialist Group. http://moray.ml.duke.edu/projects/hippos.

Lewison, R. (2007) Population responses to environmental and human-mediated distrubances: Assessing the vulnerability of the common hippopotamus (Hippopotamus amphibius), *African Journal of Ecology*.

Lewison, R. and Carter, J. (2004 Jan 1) Exploring behavior of an unusual megaherbivore: a spatially explicit foraging model of the hippopotamus, *Ecological Modelling*, 171(1-2); pp. 127-138.

Marshall, P.J. & Sayer, J.A. (1976) Population ecology and response to cropping of a hippopotomus population in eastern Zambia. *Journal of Applied Ecology* 13 (2): 391-404.
McCarthy, T.S., Ellery, W.N., and Bloem, A. (1998 Mar) Some observations on the geomorphological impact of hippopotamus (Hippopotamus amphibius l) in the Okavango Delta, Botswana. *African Journal of Ecology*, 36(1); pp. 44-56.

Mugangu T.E. & Hunter M. L. (1992). Aquatic foraging by hippopotamus in Zaire - Response to a food shortage. *Mammalia* 56 (3):345-349.

O'Connor, T.G. & Campbell, B.M. (1986). Hippopotamus habitat relationships on the Lundi River, Ghonarezhou National Park, Zimbabwe. *African Journal of Ecology* 24:7-26.

Scotcher, J.S.B. (1978). Hippopotamus numbers and movements in Ndumu Game Reserve. *Lammergeyer* 24: 5-12.

*Scotcher, J.S.B., Stewart, D.R.M. & Breen, C.M. (1978). The diet of the hippopotamus in Ndumu Game Reserve, Natal, as determined by faecal analysis. *South African Journal of Wildlife Research* 8(1): 1-11.

Van Hoven, W. (1974) Ciliate protozoa and aspects of the nutrition of the hippopotamus in the Kruger National Park. *South African Journal of Science* 70: 107-109.

Van Hoven, W. (1977). Stomach fermentation rate in the hippopotamus. *South African Journal of Science* 73: 216.

Van Hoven, W. (1978). Digestion physiology in the stomach complex and hindgut of the hippopotamus (Hippopotamus amphibius). *South African Journal of Wildlife Research* 8 (2): 59-64.

Viljoen, P. C., & H. C. Biggs. (1998). Population trends of hippopotami in the rivers of Kruger National Park, South Africa. Pages 251-279 in Behavior and Ecology of Riparian Mammals, N. Dunstone and M. L. Gorman, editors. Symposia of the Zoological Society of London, Cambridge Press, London, UK.

Viljoen, P.C. (1980). Distribution and numbers of the hippopotamus in the Olifants and Blyde Rivers. *South African Journal of Wildlife Research* 10: 129-132.

Wright, P.G. (1987). Thermoregulation in the hippopotamus on land. *South African Journal of Zoology* 22(3):237-242.

The IUCN/SSC Hippo Specialist Sub-Group website. Promotes scientifically-based action for the conservation of common and pygmy hippos. Becca Lewison

Crocodile

Aust,P.   Research proposal: Conservation of Nile Crocodiles in north-eastern Namibia: ecology, socioeconomics and sustainable utilization. NNF

Crocodile Conservation Website: http://academic.sun.ac.za/consecol/okavango

*Brown, C.J., Stander, P., Meyer-Rust, R., Mayes, S. 2005. Results of a Crocodile Crocodylus niloticus survey in the river systems of north-east Namibia during August 2004. CoP13 Inf. 26 CITES Proceedings of the Thirteenth meeting of the Conference of the Parties in Bangkok, Thailand. [pdf 1,621kb]

Gans, C. Pooley, A.C. 1976. Research on Crocodiles. *Ecology* 57 (5): 839-840 1976

Hutton, J. M. 1992. The CITES Nile Crocodile project. A publication of the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Lausanna, Switzerland.

Ligomeka, B. 2000. Malawi Plans Crocodile Management Programme. Environment News Service,

*Leslie A.J. 2005. Crocodiles of the Okavango. Earthwatch Institute Field Report.

Revol, B.1995. Crocodile Farming and Conservation, the example of Zimbabwe. *Biodiversity Conservation* 4 (3): 299-305 APR 1995

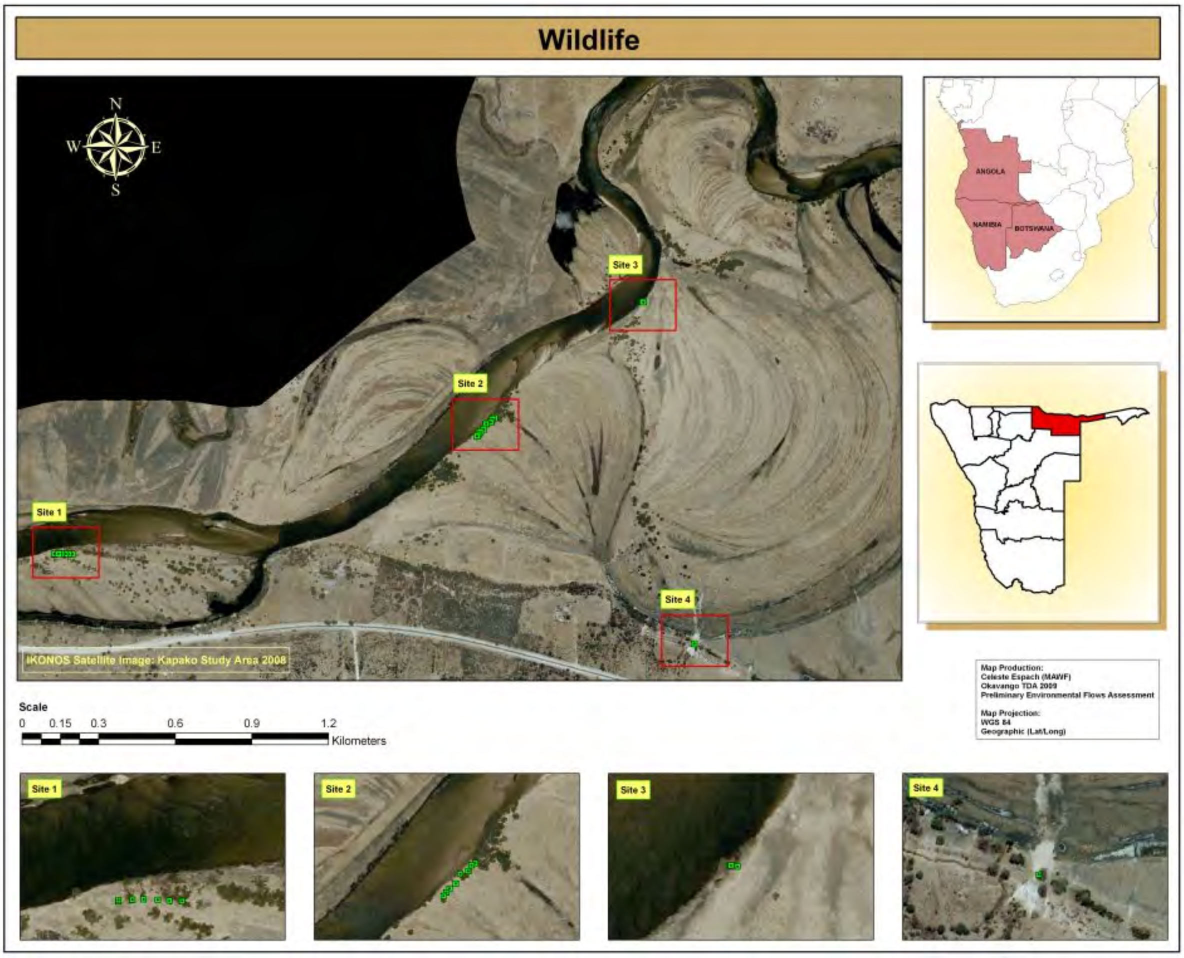
Thorbjarnarson, J.1999. Crocodile Tears and Skins: International Trade, Economic Constraints, and Limits to the Sustainable Use of Crocodilians. *Conservation Biology*, Pages 465-470 Volume 13 No. 3

*Wallace K.M. and A. J. Leslie1 2008. Diet of the Nile Crocodile (*Crocodylus niloticus*) in the Okavango Delta, *Botswana Journal of Herpetology* 42(2):361-368.

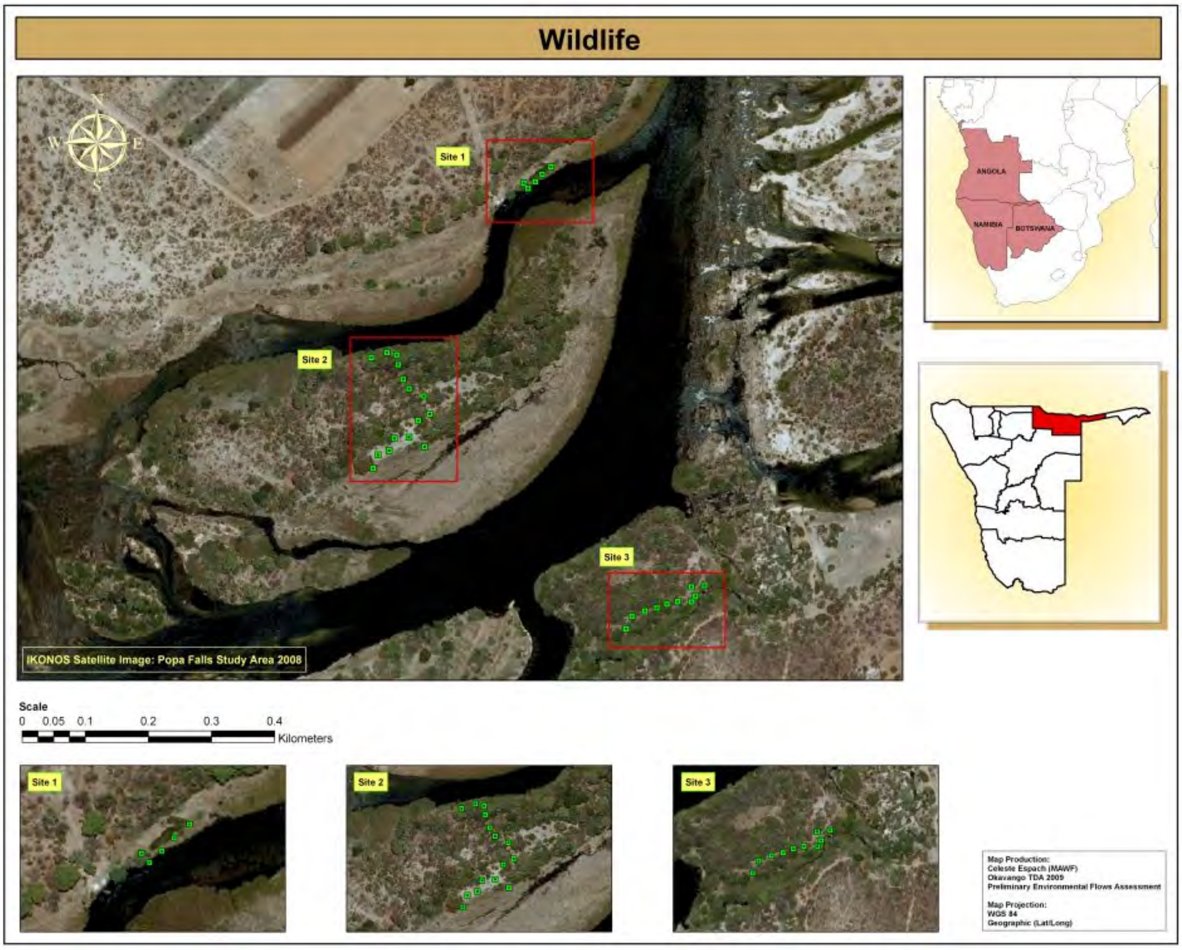
Useful Websites

Namibia Nature Foundation: Home
Harry Oppenheimer OKAVANGO RESEARCH CENTRE: http://www.orc.ub.bw/
http://www.biodiversity.org.na/dbase/database.php
Aquatic biodiversity (Darwin project)
Okavango Research Group www.wits.ac.za
Ramsar Convention Secretariat (www.ramsar.org).

Appendix A Site Maps



APPENDIX 1: Figure 1: Kapako study site in the dry season showing position of small mammal traplines sites 1 and 2 and and bases for general examinations of the floodplains for wildlife sites 3 (dry season) and 4 (wet season).



.

APPENDIX 2: Figure 2: Wildlife study sites at Popa Falls in the dry season showing the position of small mammal traplines on both banks and on the vegetated island.

Appendix B. Species list.

Frogs

Flat-backed Toad *Bufo maculatus* Hollowell,1854

Sharp-nosed (long) reed frog *Hyperolius nasutus* Gunther,1864

Snoring Puddle frog *Phrynobatrachus natalensis* (A. Smith, 1849)

Guttural toad *Bufo gutturalis* Power, 1927

Kavango dwarf toad *Bufo kavangensis* Poynton & Broadley, 1988

Painted reed frog *Hyperolius marmoratus* angolensis Rapp, 1842.

Ridged (grass) frogs Ptychadena ssp.

Reptiles

Nile Crocodile *Crocodilus niloticus* Laurenti, 1768

Water Monitor *Varanus niloticus* (Linnaeus, 1766)

Chobe Dwarf Gecko *Lygodactylus chobiensis* FitzSimons, 1932

Snakes

Green water snake *Philothamnus hoplogaster* (Günther, 1863)

Northern green bush snake *Philothamnus irregularis*

Western green snake *Philothamnus angolensis* Bocage,1882

Ornate water snake *Philothamnus ornatus* Bocage, 1872

Striped swamp snake *Limnophis bicolor*

Olive marsh snake *Natriciteres olivacea* (Peters, 1854)

Southern African Python *Python natalensis* (A. Smith, 1840)

Terrapins

Okavango Hinged Terrapin *Pelusios bechuanicus* Fitzsimons 1932

Helmeted terrapin *Pelomedusa subrufa* (Lacépède, 1789).

. Zambian swamp terrapin *Pelusios rhodesianus* Hewitt,1927

Mammals

Rodents

Giant Vlei rat *Otymys maximus* Roberts 1924

Greater Canerat *Thryonomys swinderianus* (Temminck, 1827)

Vlei multimammate mouse *Mastomys shortridgei* (St.Leger,1933)

Natal multimamate mouse *Mastomys natalensis ovambiensis* Roberts 1926

Fat mouse *Steatomys pratensis* Peters, 1846

Damara Mole Rat *Cryptomys damarensis* (Ogilby, 1838)

Bushvelt Gerbil *Tatera leucogaster*(Peters, 1852)

Groove-toothed Mouse *Pellomys fallax rhodesiae* Roberts,1929

Water Rat *Dasymys nudipes* (Peters 1870)

Bush squirrel *Paraxerus cepapi* Roberts 1932

Mustelids

African Clawless Otter *Aonyx capensis* (Schinz, 1821)

Spotted-necked Otter *Lutra maculicollis* Lichtenstein, 1835

Viverrids

Civet *Vivera civetta volkmanni* Lundholm 1955

Rusty-spotted genet *Genetta maculate* (Grey,1830)

Genet *Genetta genetta* (Linnaeus,1758)

Water Mongoose *Atilax paludinosus* G.Cuvier,1829

Shrews

Swamp musk shrew *Crocidura mariquensis shortridgei* St Leger, 1932

Tiny musk shrew *Crocidura fuscomurina woosnami* Dollman 1915

Giant musk shrew *Crocidura occidentalis zuleika* Dollman 1915

Lesser red musk shrew *Crocidura hirta deserti* Schwann 1906

Floodplain grazers

Hippopotamus *Hippopotamus amphibius* Linnaeus, 1758

Red lechwe *Kobus leche* (Gray, 1850)

Southern Waterbuck *Kobus ellipsiprymnus* (Ogilby, 1833)

Common Duiker *Sylvicapra grimmia* (Linnaeus, 1758)

Common reedbuck *Redunca arundinum* (Boddaert, 1785)

Sitatunga *Tragelaphus spekei*

Buffalo *Syncerus caffer*

Other Mammals

Aardvark *Orycteropus afer* (Pallas, 1766)

Bats

Ruppell's Bat *Pipistellus rueppellii*

Damara wooly Bat *Kerivoula argentata* (Tomes 1961)

Angola Free_Tailed Bat *Mops condylurus* (A.Smith, 1833)

Rendall's Serotine Bat *Neoromicia rendalli* (Thomas)

Egyptian tomb Bat *Taphozous perforatus* E.Geoffroy

APPENDIX B: RAW DATA

The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

In 1994, the three riparian countries of the Okavango River Basin – Angola, Botswana and Namibia – agreed to plan for collaborative management of the natural resources of the Okavango, forming the Permanent Okavango River Basin Water Commission (OKACOM). In 2003, with funding from the Global Environment Facility, OKACOM launched the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project to coordinate development and to anticipate and address threats to the river and the associated communities and environment. Implemented by the United Nations Development Program and executed by the United Nations Food and Agriculture Organization, the project produced the Transboundary Diagnostic Analysis to establish a base of available scientific evidence to guide future decision making. The study, created from inputs from multi-disciplinary teams in each country, with specialists in hydrology, hydraulics, channel form, water quality, vegetation, aquatic invertebrates, fish, birds, river-dependent terrestrial wildlife, resource economics and socio-cultural issues, was coordinated and managed by a group of specialists from the southern African region in 2008 and 2009.

The following specialist technical reports were produced as part of this process and form substantive background content for the Okavango River Basin Transboundary Diagnostic Analysis

Final Study Reports	***Reports integrating findings from all country and background reports, and covering the entire basin.***		
		Aylward, B.	*Economic Valuation of Basin Resources: Final Report to EPSMO Project of the UN Food & Agriculture Organization as an Input to the Okavango River Basin Transboundary Diagnostic Analysis*
		Barnes, J. et al.	*Okavango River Basin Transboundary Diagnostic Analysis: Socio-Economic Assessment Final Report*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Project Initiation Report (Report No: 01/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009)*
		Bethune, S. Mazvimavi, D. and Quintino, M.	*Okavango River Basin Environmental Flow Assessment Delineation Report (Report No: 04/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Hydrology Report: Data And Models(Report No: 05/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Scenario Report : Hydrology (Report No: 06/2009)*
		Jones, M.J.	*The Groundwater Hydrology of The Okavango Basin (FAO Internal Report, April 2010)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 1 of 4)(Report No. 07/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 2 of 4: Indicator results) (Report No. 07/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions: Climate Change Scenarios (Volume 3 of 4) (Report No. 07/2009)*
		King, J., Brown, C.A., Joubert, A.R. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Biophysical Predictions (Volume 4 of 4: Climate Change Indicator Results) (Report No: 07/2009)*
		King, J., Brown, C.A. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Project Final Report (Report No: 08/2009)*
		Malzbender, D.	*Environmental Protection And Sustainable Management Of The Okavango River Basin (EPSMO): Governance Review*
		Vanderpost, C. and Dhliwayo, M.	*Database and GIS design for an expanded Okavango Basin Information System (OBIS)*
		Veríssimo, Luis	*GIS Database for the Environment Protection and Sustainable Management of the Okavango River Basin Project*
		Wolski, P.	*Assessment of hydrological effects of climate change in the Okavango Basin*
Country Reports Biophysical Series	***Angola***	*Andrade e Sousa, Helder André de*	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Sedimentologia &*

			Geomorfologia
		Gomes, Amândio	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Vegetação*
		Gomes, Amândio	*Análise Técnica, Biofísica e Socio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final:Vegetação da Parte Angolana da Bacia Hidrográfica Do Rio Cubango*
		Livramento, Filomena	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina:Macroinvertebrados*
		Miguel, Gabriel Luís	*Análise Técnica, Biofísica E Sócio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Subsídio Para o Conhecimento Hidrogeológico Relatório de Hidrogeologia*
		Morais, Miguel	*Análise Diagnóstica Transfronteiriça da Bacia do Análise Rio Cubango (Okavango): Módulo da Avaliação do Caudal Ambiental: Relatório do Especialista País: Angola Disciplina: Ictiofauna*
		Morais, Miguel	*Análise Técnica, Biófisica e Sócio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final: Peixes e Pesca Fluvial da Bacia do Okavango em Angola*
		Pereira, Maria João	*Qualidade da Água, no Lado Angolano da Bacia Hidrográfica do Rio Cubango*
		Santos, Carmen Ivelize Van-Dúnem S. N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório de Especialidade: Angola: Vida Selvagem*
		Santos, Carmen Ivelize Van-Dúnem S.N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango:Módulo Avaliação do Caudal Ambiental: Relatório de Especialidade: Angola: Aves*
	Botswana	*Bonyongo, M.C.*	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Wildlife*
		Hancock, P.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report: Country: Botswana: Discipline: Birds*
		Mosepele, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Fish*
		Mosepele, B. and Dallas, Helen	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Aquatic Macro Invertebrates*
	Namibia	*Collin Christian & Associates CC*	*Okavango River Basin: Transboundary Diagnostic Analysis Project: Environmental Flow Assessment Module: Geomorphology*
		Curtis, B.A.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report Country: Namibia Discipline: Vegetation*
		Bethune, S.	*Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO): Transboundary Diagnostic Analysis: Basin Ecosystems Report*
		Nakanwe, S.N.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Aquatic Macro Invertebrates*
		Paxton, M.	*Okavango River Basin Transboundary Diagnostic Analysis: Environmental Flow Module: Specialist Report:Country:Namibia: Discipline: Birds (Avifauna)*
		Roberts, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Wildlife*
		Waal, B.V.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia:Discipline: Fish Life*
Country Reports Socioeconomic Series	***Angola***	*Gomes, Joaquim Duarte*	*Análise Técnica dos Aspectos Relacionados com o Potencial de Irrigação no Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final*
		Mendelsohn, .J.	*Land use in Kavango: Past, Present and Future*
		Pereira, Maria João	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Qualidade da Água*
		Saraiva, Rute et al.	*Diagnóstico Transfronteiriço Bacia do Okavango: Análise Socioeconómica Angola*
	Botswana	*Chimbari, M. and Magole, Lapologang*	*Okavango River Basin Trans-Boundary Diagnostic Assessment (TDA): Botswana Component: Partial Report: Key Public Health*

			Issues in the Okavango Basin, Botswana
		Magole, Lapologang	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Land Use Planning*
		Magole, Lapologang	*Transboundary Diagnostic Analysis (TDA) of the Botswana p Portion of the Okavango River Basin: Stakeholder Involvement in the ODMP and its Relevance to the TDA Process*
		Masamba, W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Output 4: Water Supply and Sanitation*
		Masamba,W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Irrigation Development*
		Mbaiwa.J.E.	*Transboundary Diagnostic Analysis of the Okavango River Basin: the Status of Tourism Development in the Okavango Delta: Botswana*
		Mbaiwa.J.E. & Mmopelwa, G.	*Assessing the Impact of Climate Change on Tourism Activities and their Economic Benefits in the Okavango Delta*
		Mmopelwa, G.	*Okavango River Basin Trans-boundary Diagnostic Assessment: Botswana Component: Output 5: Socio-Economic Profile*
		Ngwenya, B.N.	*Final Report: A Socio-Economic Profile of River Resources and HIV and AIDS in the Okavango Basin: Botswana*
		Vanderpost, C.	*Assessment of Existing Social Services and Projected Growth in the Context of the Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin*
	Namibia	*Barnes, J and Wamunyima, D*	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Socio-economics*
		Collin Christian & Associates CC	*Technical Report on Hydro-electric Power Development in the Namibian Section of the Okavango River Basin*
		Liebenberg, J.P.	*Technical Report on Irrigation Development in the Namibia Section of the Okavango River Basin*
		Ortmann, Cynthia L.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report Country: Namibia: discipline: Water Quality*
		Nashipili, Ndinomwaameni	*Okavango River Basin Technical Diagnostic Analysis: Specialist Report: Country: Namibia: Discipline: Water Supply and Sanitation*
		Paxton, C.	*Transboundary Diagnostic Analysis: Specialist Report: Discipline: Water Quality Requirements For Human Health in the Okavango River Basin: Country: Namibia*

.

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

Kavango River at Rundu, Namibia

Republic of Botswana

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Sida

OKACOM

Tel +267 680 0023 Fax +267 680 0024 Email okasec@okacom.org www.okacom.org
PO Box 35, Airport Industrial, Maun, Botswana