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: Botswana Discipline: Birds

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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: Botswana

Discipline: Birds

Author: P Hancock

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EXECUTIVE SUMMARY

Birds are generally regarded as good environmental indicators and several species found in the Okavango Delta are sufficiently well-known to be useful for the purpose of predicting ecological changes under varying water flow regimes. These are primarily waterbirds that feed and/or breed in close association with water, or terrestrial birds that depend on riparian or other water-related habitats.

This chapter lists the birds chosen as indicators for the three sites in the Okavango Delta in Botswana, and describes their characteristics in terms of flow-related habitats occupied, and their known water needs. This information is derived from a detailed literature review, and knowledge gained during fieldwork in the Okavango prior to this study.

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ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
BLB	BirdLife Botswana

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1. INTRODUCTION

1.1 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 socioeconomic effects of such possible developments. OBSC recommended at this meeting that an 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.

The EFA is a joint project of EPSMO and the Biokavango Project. One part of the EFA is a series of country-specific specialist studies, of which this is the bird report for Botswana.

1.2 Okavango River Basin EFA Objectives and Workplan

1.2.1 Project objectives

The goals of the EFA are:

- to summarise all relevant information on the Okavango River system and its users, and collect new data as appropriate within the constraints of the 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 pilot EFA, due to time constraints, as input to the TDA and to a future comprehensive EFA.

The specific objectives 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 the EFA outputs to enhance biodiversity management of the Delta.
- to develop skills for conducting EFAs in Angola, Botswana, and Namibia.

1.3 Layout of this report

This report starts with a description of the study area, the Okavango River basin, with particular emphasis on the Botswana component *viz*. the Panhandle, Okavango Delta and distal distributaries such as the Boteti River. An overview is given of each of the three representative sites in the country, as follows:

1. Okavango Panhandle at Shakawe
2. Okavango Delta at Xakanaxa
3. Boteti River at Chanoga

The characteristics of each of these sites that are relevant for birds are described in terms of available habitat and species assemblages.

This is followed by a section containing a list of suitable bird indicators that can be used to show changes in the environment under a variety of flow regimes. These bird indicators are primarily, but not exclusively waterbirds. Each indicator is described in terms of representative species, their flow-related location in the ecosystem, and their known water needs. The water flows for each site are also described in this section, based on information provided by the hydrological team.

After the identification of the bird indicators, there is a detailed literature review focusing on what is known about these indicators (relative to water flows) in the Okavango system, and where this information is scant, it is supplemented by reviewing available literature for these species from the Southern African region. The references consulted are detailed in a later section at the end of this report.

Limited fieldwork was undertaken specifically for this project, but prior ornithological research that was conducted by the author at the three Botswana sites is summarised next, and the details relative to each indicator are provided in a series of tables, forming the last part of the body of the report. A short appendix summarises the particulars of the ten bird indicators.

The responses of each indicator to varied water flows, in the form of Response Curves for each, appears elsewhere.

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 (Figure 2.1). This basin topographically includes the area that was drained by the now fossil Omatako River in Namibia. 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 (Figure 2.2). This study, however, focuses on the parts of the basin in Angola and Namibia, and the Panhandle/Delta/Boteti River complex in Botswana. The Makgadikgadi Pans and Nata River are not included.

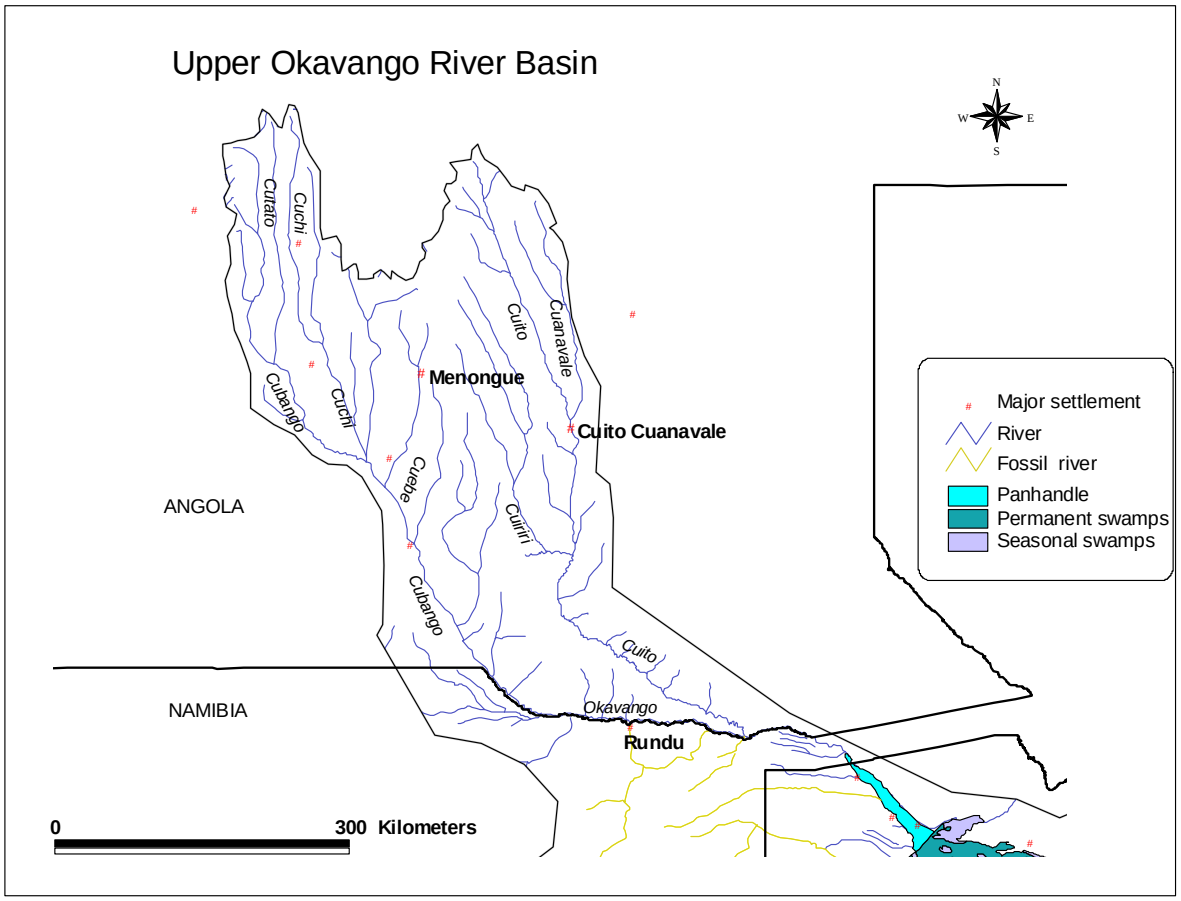

Figure 1: Upper Okavango River Basin from sources to the northern end of the Delta

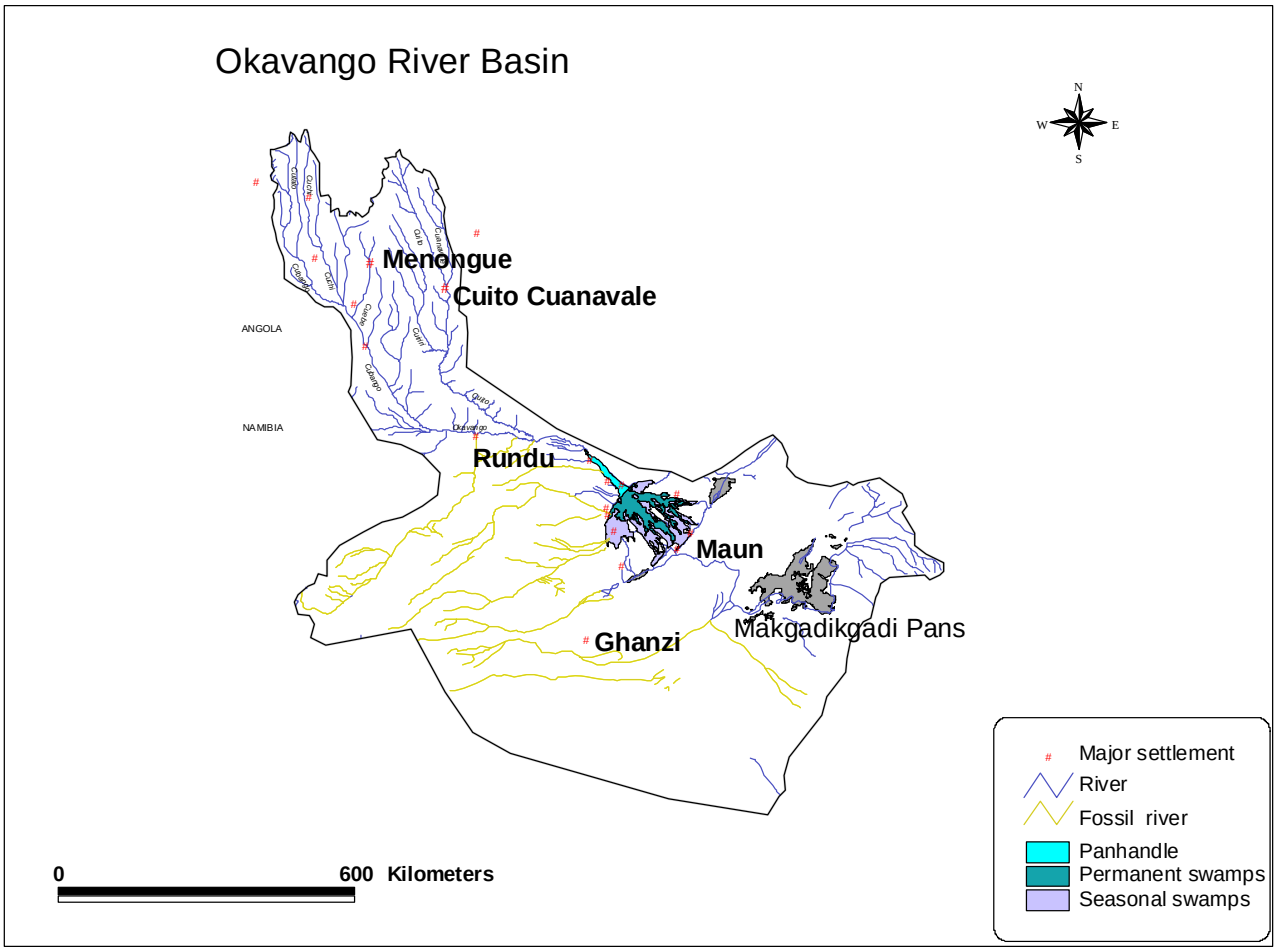

Figure 2: The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans

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. Instead, representative areas that are reasonably homogeneous in character may be delineated and used to represent much wider areas, and then one or more representative sites chosen in each as the focus for data-collection activities. 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 invertebrates;
vegetation;
harmonising the results from each discipline into one set of biophysical river zones;

dividing the basin into relatively homogeneous areas in terms of social systems; harmonising the biophysical river zones and the social areas into one set of Integrated Units of Analysis (IUAs).

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 Table 2.1.

Table 1: Location of the eight EFA sites

EFA Site No	Country	River	Location
1	Angola	Cuebe	Capico
2	Angola	Cubango	Mucundi
3	Angola	Cutio	Cuito Cuanavale
4	Namibia	Okavango	Kapako
5	Namibia	Okavango	Popa Falls
6	Botswana	Okavango	Panhandle at Shakawe
7	Botswana	Khwai	Xakanaka in Delta
8	Botswana	Boteti	Chanoga

2.3 Overview of sites

Site 6: Okavango River in the Panhandle at Shakawe

Site 7: Eastern Okavango Delta around Xakanaxa

Site 8: Boteti River at Chanoga

2.4 Discipline-specific description of Botswana sites

Site 6: Panhandle at Shakawe

The Okavango Panhandle, where the river meanders between two faultlines, is a unique area for birds. The open waters of the river itself are utilised by a few fish-eating species that can capture their prey in this habitat *viz*. African Fish-Eagles, Pied Kingfishers, African Darters and Reed Cormorants. The first two hunt from perches in the riverine trees aligning the river, while the others pursue fish underwater, taking advantage of its clarity. Pel's Fishing-Owl is relatively common in the panhandle, and is the nocturnal equivalent of the Fish-Eagle. At this site, the outer curves of the river cut steep banks that are used as nesting sites by Giant, Pied and Malachite kingfishers and Southern Carmine and White-fronted bee-eaters. The bee-eaters in particular breed in large colonies and are an important tourist attraction – the colonies near the Brigades in Shakawe and at Drotsky's Cabins are particularly important. Sand eroded from the outer curves is thrown up on the inner curves in

the form of low-lying sandbanks which are exposed during periods of low flow during September to December every year, and these are used by globally threatened African Skimmers, as well as Water Thick-knees, for breeding sites. The Panhandle is the most important breeding area for African Skimmers in Botswana.

The river fringes are lined with Papyrus and 'Hippo grass' (*Vossia cuspidate*) which are key components of the habitat of the Greater Swamp Warbler, a species which, in Botswana, is virtually confined to the Panhandle and permanent swamp. This vegetation is also used by Squacco and Green-backed Herons as perches from which to catch fish; during the annual 'barbel runs', which occur in the Panhandle primarily during the low flows of September, they are joined by large numbers of other egrets and herons.

The area between the faultlines, away from the river is a mixture of floodplain and 'backswamp' utilised by egrets, herons, jacanas, ducks and geese, and African Openbills, among other species. This area floods seasonally and as the water flows onto the floodplains, many fish eating birds are attracted here. Similarly when the waters recede and fish are trapped in drying pools, this area is important for many piscivorous birds, including the globally threatened Slaty Egret.

Site 7: Eastern Delta around Xakanaxa

At Xakanaxa, the key habitats for birds are the open waters of the lagoons and the Maunachira/Khwai River, and the permanently wet areas characterised by stands of Papyrus. In general, this site is not good for birds, as shown by the low species diversity and numbers. There are only a few piscivorous species that can hunt successfully in the open waters of Xakanaxa Lediba, and these include those (like the African Fish-Eagle, Pel's Fishing-Owl and kingfishers) that hunt from perches in the riparian trees adjacent to the water, and the diving birds (such as African Darters and Reed Cormorants) that pursue fish underwater. The Maunachira/Khwai River is very poor in nutrients and does not support many bird species – Reed Cormorants and African Darters are the most important species, (although not numerous) with low numbers of African Pygmy-Goose and African Jacana where water lilies are found in quiet backwaters. Papyrus and Water Figs lining the river are used as hunting perches by the occasional Squacco Heron.

An important feature of Xakanaxa Lediba is its islands of Water Figs used as breeding sites for African Darters, Reed Cormorants and other birds such as Marabou and Yellow-billed storks. African Spoonbills and a variety of herons and egrets breed here too, and the globally threatened Slaty Egret has also been recorded breeding here. These birds choose the security of the islands for breeding, but fly to feed elsewhere in the Delta due to the low productivity of this area in terms of fish and aquatic macro-invertebrates.

The wetland habitat at this site is currently permanent, and is juxtaposed against dry land – consequently there are no significant floodplains, and water levels do not fluctuate much seasonally or between years. This may account for its low attractiveness for waterbirds.

Site 8: Chanoga

Perhaps surprisingly, this site is one of the most important areas for waterbirds in the Okavango Delta. Although it is unprotected, large numbers of ducks, geese and other waterbirds utilise this site when it has water, since the waters are rich in nutrients that have been leached out of the upstream areas, or accumulated from grazers that are present when the area is dry. White-faced and White-backed duck, Red-billed Teal and Comb Duck are the most numerous species, but the water lily-covered areas attract significant numbers of

African Pygmy-Goose, and African and Lesser jacana. The muddy margins are utilised by African Sacred and Glossy ibis, and Blacksmith Lapwings nest along the short-grass verges.

Although this site does not support any waterbirds when it is dry, the drying-flooding-drying cycle is vitally important from a bird perspective; when Chanoga Lediba dries, large numbers of large fish (that have thrived in the nutrient-rich conditions) are trapped and attract hundreds of Great White Pelicans, Marabou Storks, African Fish-Eagles and other large piscivorous birds. This is particularly important for the pelicans which feed here and commute to the Nata River Delta to feed their flightless chicks; their breeding appears to be synchronised with the drying of the distal reaches of the Okavango system when such 'fish-traps' occur. Also found at Chanoga in large numbers when the waters recede are African Openbills, normally regarded as floodplain specialists, which here exploits the shallow water margins where Pina occidentais, and Lanistes snails are exposed as waters recede (these molluscs form its main diet). Globally threatened Wattled Cranes also feed along the margins of Chanoga Lediba; as the lagoon dries and the sedges transfer their nutrients into underground corms and bulbs, these are excavated and eaten by the cranes.

In summary, this site, although not varied in terms of habitats, is very important for waterbirds due to the large numbers that congregate here when conditions are favourable.

3. IDENTIFICATION OF INDICATORS AND FLOW CATEGORIES

3.1 Indicators

3.1.1 Introduction

Biophysical indicators are discipline-specific attributes of the river system that respond to a change in river flow by changing in 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.

3.2 Indicator list for birds

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 full list of indicators was developed collaboratively by the country representatives for the discipline – C Santos, M Paxton and P Hancock - and is provided in Table 3.1. Further details of each indicator,

including the representative species of each biological one, are given in Appendix A, and discussed fully below.

Table 2: List of indicators for birds and those chosen to represent each site

Indicator Number	Indicator name	Sites represented – no more than ten indicators per site							
		1	2	3	4	5	6	7	8
1	Piscivores of open water						X	X	X
2	Piscivores of shallow water and lagoons						X	X	X
3	Piscivores and invertebrate feeders, isolated pools						X	X	X
4	Specialist feeders on floodplains, receding waters						X	X	X
5	Specialist feeders in waterlily-covered inlets						X	X	X
6	Specialist feeders in riverine fruit trees						X	X	X
7	Breeders in reedbeds, and on floodplains						X	X	
8	Breeders in riverine overhanging trees						X	X	
9	Breeders on banks						X	X	
10	Breeders on emergent rocks, sandbanks and islands						X	X	

3.3 Description and location of indicators

Birds Indicator 1

Name: Piscivores of open water

Description: These are fish-eating birds that are able to catch fish in open, deep waters by diving or swimming after them.

Representative species: African Fish-Eagle, Reed Cormorant, Pied Kingfisher.

Other characteristic species: African Darter, Giant Kingfisher

Flow-related location: Channels in permanent swamp
Lagoons in permanent swamp
Seasonal pools in seasonally flooded zone

Known water needs: Open water surface i.e. devoid of floating vegetation such as waterlilies and Salvinia. Clarity of water may be a factor.

Birds Indicator 2

Name: Piscivores of shallow water and lagoons

Description: These are fish-eating birds that are able to catch fish near the edge, from a perch, or by static hunting in water shallower than their leg length.

Representative species: Pel's Fishing-Owl, larger herons and egrets (Great Egret, Yellow-billed Egret, Grey Heron)

Other characteristic species: Black-crowned Night-Heron

Flow-related location: Channels in permanent swamp
Lagoons in permanent swamp
Seasonal pools in seasonally flooded zone
Seasonal sedgeland in seasonally flooded zone
Seasonal grassland in seasonally flooded zone

Known water needs: Shallow water, preferably not flowing

Birds Indicator 3

Name: Piscivores and invertebrate feeders, isolated pools

Description: These are birds that capitalise on isolated pools on floodplains or in river channels to catch fish and invertebrates

Representative species: Great White Pelican, Squacco Heron, Little Egret, Red-billed Teal, Hottentot Teal

Other characteristic species: Black Heron, Hamerkop, Marabou Stork, Glossy Ibis

Flow-related location: Seasonal pools in seasonally flooded zone
Seasonal sedgeland in seasonally flooded zone
Seasonal grassland in seasonally flooded zone

Known water needs: Fluctuating amounts of water e.g. a pulse of water that would inundate a floodplain or channel, and then contract, concentrating fish and invertebrates

Birds Indicator 4

Name: Specialist feeders on floodplains

Description: These birds feed on molluscs, frogs, fish or selective vegetation occurring in floodplain situations – often along the water's edge

Representative species: African Openbill, Slaty Egret, Wattled Crane

Other characteristic species:

Flow-related location: Seasonal sedgeland in seasonally flooded zone
Seasonal grassland in seasonally flooded zone

Known water needs: Sufficient water to inundate floodplains and result in shallow areas for feeding

Birds Indicator 5

Name: Specialist feeders in water-lily covered inlets

Description: These are birds that need lily-covered inlets or floodplain pools or lagoons for feeding

Representative species: African Jacana, Lesser Jacana

Other characteristic species: African Pygmy-Goose, Allen's Gallinule

Flow-related location: Inlets off channels in permanent swamp
Lagoons in permanent swamp
Seasonal pools in seasonally flooded zone

Known water needs: Permanent water with little or no fluctuation

Birds Indicator 6

Name: Specialist feeders in riverine fruit trees

Description: These are frugivorous birds that occupy the riparian vegetation for the purpose of feeding on fruit

Representative species: African Green-Pigeon, Black-collared Barber, Burchell's Starling

Other characteristic species: Meyer's Parrot, Dark-capped Bulbul

Flow-related location: On alluvial levees of channels in permanent swamp, or at water's edge of islands/mainland in seasonal sedgeland and grassland in seasonally flooded zone

Known water needs: Surface water or high water table to ensure well-being of the fruit-bearing trees

Birds Indicator 7

Name: Breeders in reedbeds, and on floodplains

Description: These are birds from a variety of families that nest in Phragmites reeds along channels or in Cyperus beds on floodplains

Representative species: Slaty Egret, Rufous-bellied Heron, Wattled Crane, weaver spp.

Other characteristic species: Greater Swamp-Warbler, Great Egret

Flow-related location: Channels in permanent swamp, seasonal sedgeland and grassland in seasonally flooded zone

Known water needs: Permanently or seasonally flooded; if areas dry out for more than one year, they become unsuitable. Unseasonal high flood levels may inundate nests

Birds Indicator 8

Name: Breeders in riverine overhanging trees

Description: Colonial breeders or solitary nesters requiring over-hanging vegetation for nest safety or fledglings vacating the nest

Representative species: African Darter, Reed Cormorant

Other characteristic species: Green-backed Heron, White-backed Night-Heron

Flow-related location: Trees along margins of channels in permanent swamp, or along edge of small islands or mainland in seasonal sedgeland and grassland in seasonally flooded zone

Known water needs: Nesting trees must stand in water for the duration of the breeding season

Birds Indicator 9

Name: Breeders on banks

Description: Birds that require vertical banks for nest holes, or the grassy tops of banks for nest sites and fledgling development.

Representative species: Southern Carmine Bee-eater, White-fronted Bee-eater, Pied Kingfisher.

Other characteristic species: Malachite Kingfisher, Giant Kingfisher

Flow-related location: Channels in permanent swamp where the river is incised to form vertical banks, or at the edge of seasonal sedgeland and grassland in seasonally flooded zone.

Known water needs: Sufficient water to erode the bank and keep the face vertical and clear of vegetation.

Birds Indicator 10

Name: Breeders on emergent rocks, sandbanks and islands

Description: Birds which are totally dependent on emerged rocks, sandbanks and sandy islands for nesting purposes

Representative species: Rock Pratincole, African Skimmer, Water Thick-knee

Other characteristic species: None

Flow-related location: On the inside of meanders in the Okavango River and other fast-flowing channels

Known water needs: Fluctuating water levels, with low level during the period September to November. Sediment load.

3.4 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 Figures 3.1 to 3.5. 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, along with the hydrographs, 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.

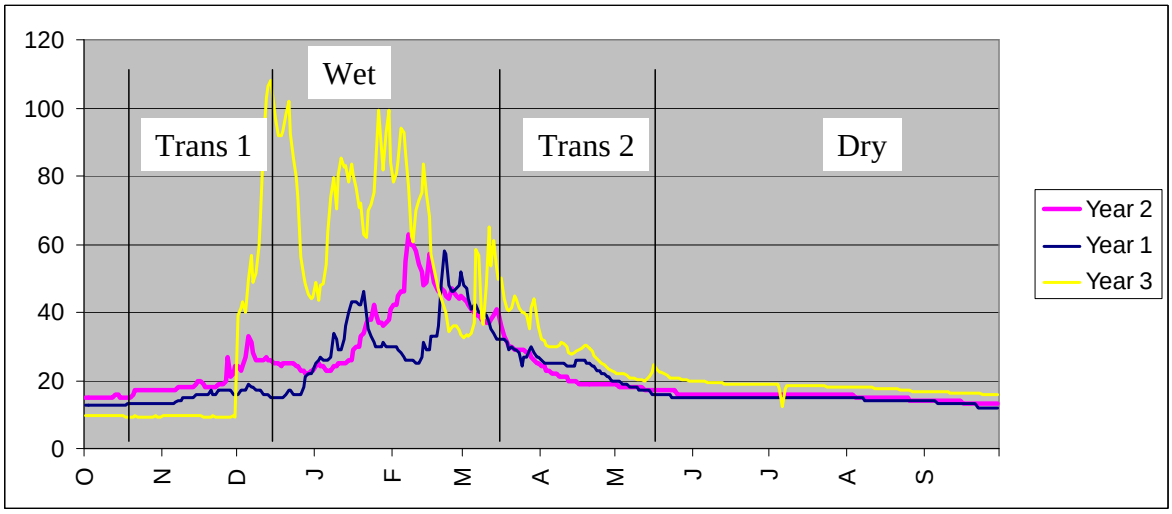

Figure 3: Three representative years for Site 1: Cuebe River @ Capico, illustrating the approximate division of the flow regime into four flow seasons

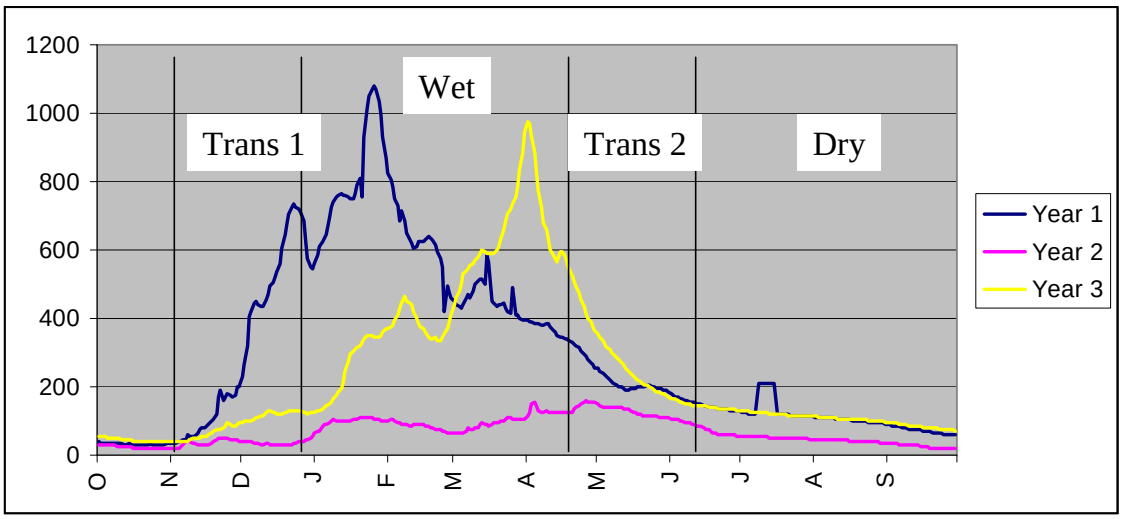

Figure 4: Three representative years for Site 2: Cubango River @ Mucindi, illustrating the approximate division of the flow regime into four flow seasons

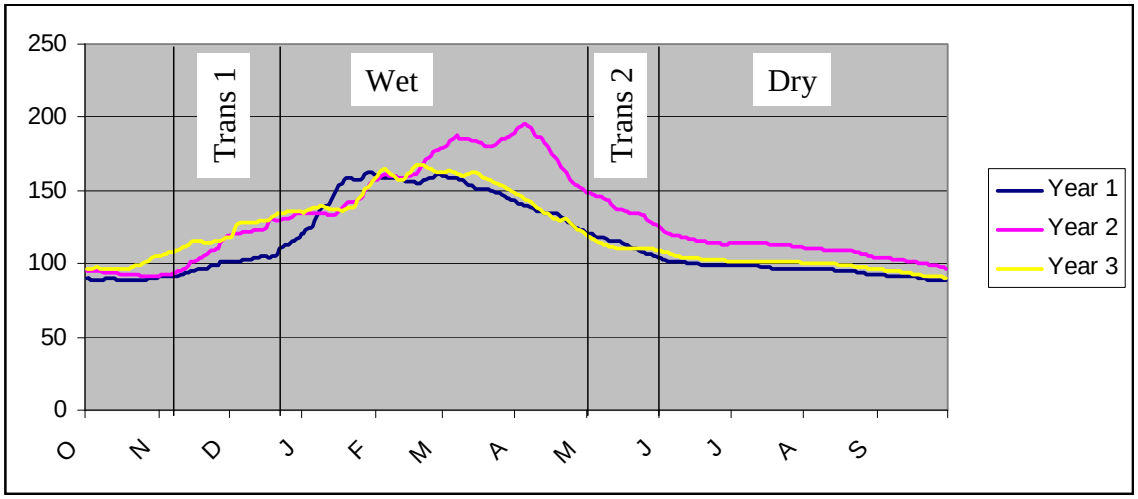

Figure 5: Three representative years for Site 3 Cuito River @ Cuito Cuanavale, illustrating the approximate division of the flow regime into four flow seasons

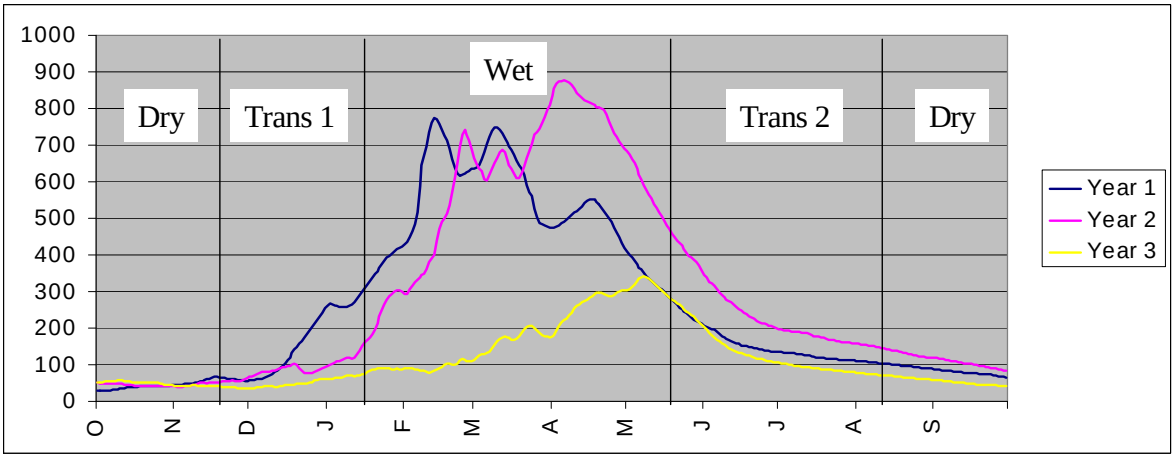

Figure 6: Three representative years for Site 4: Okavango River @ Kapoka (hydrological data from Rundu), illustrating the approximate division of the flow regime into four flow seasons

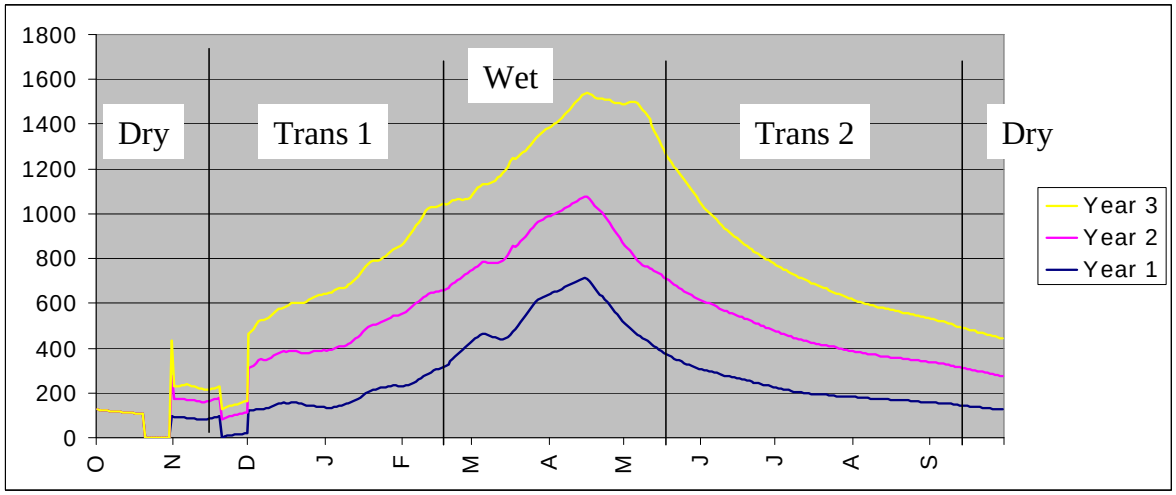

Figure 7: Three representative years for Site 5: Okavango River @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

The literature review (Chapter 4) and data collection and analysis exercises (Chapter 5) are focused on addressing what is initially expected to be nine main questions related to these flow seasons (Table 3.2).

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

3.5 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 3.3).

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

Inundation category number	Inundation category name	Description
1 CH-ps	Channels in permanent swamp	Main channels that never dry up
2 L-ps	Lagoons in permanent swamp	Areas of open water away from the main channels
3 B-ps	Backswamp in permanent swamp	Extensive stands of Papyrus and sparse Phragmites standing in water
4 SP-sf	Seasonal pools in seasonally flooded zone	Pools on floodplains that dry seasonally
5 SED-sf	Seasonal sedgeland in seasonally flooded zone	Floodplains that flood regularly and are dominated by sedges such as *Cyperus*
6 GR-sf	Seasonal grassland in seasonally flooded zone	Grassland that is infrequently inundated
7 S-sf	Savanna-dried floodplain in seasonally flooded zone	Dryland areas that are only occasionally flooded

4 LITERATURE REVIEW

Introduction

A literature review was undertaken, focusing mainly on work done on the bird indicator species in the Okavango Delta – most of the studies on birds in the Okavango Delta have been published in the biannual BirdLife Botswana scientific journal Babbler. Many bird species in Botswana are 'data deficient', and in these instances, regional works on their behaviour and ecology were consulted – in this regard, the Southern African Ornithological journal Ostrich proved invaluable. Some of the indicator species have been the subject of detailed studies in other parts of their range e.g. Bento's thesis on the Status and Prospects of Wattled Cranes Grus carunculatus in the Zambezi Delta, and these provided supplementary information. The literature consulted is detailed in SECTION 6 - References

Birds are an important part of the Okavango Delta ecosystem, both for their varied ecological roles and their value as a component of Botswana's growing tourism industry. Generally, the status and distribution of birds of the Okavango Delta are quite well-documented e.g. Bird Atlas of Botswana (Penry, 1994); Inventory of Birds of the Okavango Delta Ramsar site (Hancock et al., 2007). Birds are also good environmental indicators as they are highly mobile and can move when local conditions change e.g. the Wattled Crane is "an important indicator species for assessing deleterious changes in wetland hydrological conditions, and evaluating the impact of such changes on wetland biodiversity and subsistence production systems" (Beilfuss et al., 2003). This makes the inclusion of birds in the environmental flow assessment study essential.

A review of the literature also provided another perspective on the birds of the Okavango Delta: according to Tyler and Bishop (1998), the Okavango Delta is recognised as an

Important Bird Area (IBA) – a site that meets international criteria set by the BirdLife International Partnership. These criteria are listed below.

An Important Bird Area:
regularly holds significant numbers of a globally threatened species (or more than one globally threatened species in the case of the Okavango)
holds a significant component of a group of species whose distributions are largely or wholly confined to one biome
holds on a regular basis, >1% of a biogeographic population of a congregatory waterbird species.

These criteria help focus attention on key bird species that could be adversely affected by changes in the flow regime of the Okavango River viz. globally threatened birds and those species which are largely restricted to the Okavango River Basin. The Wattled Crane is one such species – it is globally threatened, and according to Gibson et al. (2002), the Okavango Delta holds the largest single population remaining of this species. It feeds and breeds on seasonally inundated floodplains (Motsumi et al., 2003) areas likely to be most affected by changes in water flows. Due to these factors, changes in environmental flows are more likely to have significant consequences for Wattled Cranes than for other common and widespread species, and it therefore makes sense to include the Wattled Crane among those species chosen for modelling. Similarly with the Slaty Egret; it is globally threatened and nearly endemic to the Okavango River Basin (with an estimated 85% of the global population found here) and is a floodplain specialist (Hancock et al., 2005).

Other important bird species in the Okavango are those congregatory waterbirds that occur in large numbers such that >1% of the population is found regularly in the Okavango Delta. A decade of waterbird counts in the Okavango are documented in Tyler (2001) – this review also shows clearly the importance of the nutrient-rich distal reaches of the Okavango's distributaries, namely the Thamalakane and Boteti Rivers. It is essential to include a site on the Boteti in the predictive model since reduced flows will dramatically reduce water levels here and impact large numbers of birds.

Indicator 1 - Piscivores of open water

Main characteristics of Indicator 1

These are the only birds that can access fish in deep, open water, whether it be the main Okavango River, a major channel, or deep lagoons. Representative species are listed in the table below:

Indicator 1 – Piscivores of open water

General species	African Fish-Eagle, cormorants and darter, 'fish-eating' kingfishers
Representative species	African Fish-Eagle Haliaeetus vocifer Reed Cormorant Phalacrocorax africanus Pied Kingfisher Ceryle rudis

Some indicator species like the African Fish-Eagle hunt from a perch at the water's edge, using sight to locate a fish near the surface, and then dive down and catch it in their talons. Others, as exemplified by the Reed Cormorant, swim in the water and actively pursue and catch fish underwater, in their bills, presumably by sight. The Pied Kingfisher can also access fish in open water as it can hover above the water surface and then dive in, catching in its bill

any fish seen. These three indicator species use different strategies to access fish in the open waters; they are among the most common ‘waterbirds’ at site 6 and have been quite well studied e.g. the Pied Kingfisher (Douthwaite, 1982).

These birds are important in the system because they are the only ones that can exploit this particular niche where the oligotrophic waters are clear and fish densities are low. The African Fish-Eagle is one of the icons of the Okavango, and is an important part of the tourism product. The larger species congregate at ‘barbel runs’ which usually take place during July/August/September.

Life cycle attributes of Indicator1

The African Fish-Eagle is territorial and adults are resident on their breeding territories throughout the year – these territories need to meet their year-round requirements in terms of feeding and breeding. They eat exclusively fish, and their need for fish increases during the winter months, from April to September, when they are breeding – fish availability during the latter part of this period when the chicks are large is critical. Nests are constructed in riparian trees and are re-used in successive years. The fledged young scavenge a lot and are seen at Barbel runs and fish die-offs e.g. at Guma Lagoon.

The Reed Cormorant spends most of its day in water pursuing fish that it has spotted, and catching them underwater in its bill. It roosts communally at night on trees standing in water. It also nests colonially on trees or reeds standing in water (see 3.9.2).

The Pied Kingfisher eats mostly small Cichlid fish (30 to 110mm in length) of the genera Tilapia and Haplochromis – these are located by sight from a perch or by hovering, and caught with the bill by diving into the water. Their breeding is described in section 3.10.2.

Links to flow

The African Fish-Eagle must have open water in which to catch fish – Salvinia and lily-covered water surfaces are a disadvantage for this species. Drying lagoons or floodplain pools with trapped fish are sought after especially by younger, non-territorial individuals. Acacia nigrescens is the main nesting tree in the Okavango, followed by Diospyros mespiliformis. They do not nest at the distal ends of the Delta’s distributaries when the channels are dry e.g. during low flow cycles, but soon recolonise these areas when flooded.

The Reed Cormorant prefers clear water without aquatic vegetation (submerged or floating or emergent) for optimal fishing. The breeding of this species is also linked to water flows (see below).

Since the Pied Kingfisher can hover, it is able to fish in deeper water, as long as it is clear – it also hunts in the shallows where fish are visible e.g. on floodplains. It feeds on small fish and the fry of larger fish, which is why it frequents floodplains.

Indicator 2 – Piscivores of shallow water and lagoons

Main characteristics of indicator

This indicator is typified by Pel's Fishing-Owl, a nocturnal owl which specializes in catching surface swimming fish (in its talons) in quiet backwaters overhung with large trees which are used as fishing perches. Because the species occupies a narrow niche, any changes in the system are likely to affect it. For example, when flood levels are high and water pushes into hitherto dry areas, the Pel's Fishing-Owl is brought into contact with Verreaux's Eagle-Owl, often to the detriment of the former (see Wright and Hancock, 2008).

The characteristic and representative species of this indicator are listed in the table below.

Indicator 2 – Piscivores of shallow water and lagoons	
General species	Pel's Fishing-Owl, large herons and egrets
Representative species	Pel's Fishing-Owl Scotopelia peli Great Egret Egretta alba Yellow-billed Egret Egretta intermedia

Life cycle attributes

Pel's Fishing-Owl is a specialist fish-eating nocturnal owl which catches surface swimming fish from low perches over water or from sand banks. The following prey species have been recorded: Clarias spp., Synodontus sp., Hepsetus odoe (in order of frequency in diet), and also Seranochromis sp., Tilapia sp., Schilbe mystus and Petrocephalus catostoma. Prey species are located by sight. Fishing perches are typically one to two metres above the water surface. Nests are situated in treeholes or in the forks of large riparian trees – almost exclusively Diospyros mespiliformis - and egg laying takes place at the high flood season with a peak in March. The chick remains dependent on the parents for several months, probably until low water levels and greater fish concentrations make for a better chance of surviving independently (Liversedge, 1980).

The Great Egret and Yellow-billed Egret feeds on fish which they catch by wading in shallow water and static-hunting, spearing fish with the bill. Clear water may be an important feature of this habitat. These birds do exploit the availability of fish at the 'Barbel runs' that usually take place from July to September in the Panhandle. Breeding may be linked to this phenomenon and water flows (see 3.9.2).

Links to flow

During the day, Pel's Fishing-Owl roosts in large riverine trees, usually in the darkest spot in the territory – if there is inadequate cover and they are visible, they are mobbed by other birds (in such circumstances they may be attacked and injured by African Fish-Eagles).

Favoured fishing perches are between one and two metres above the water surface.

Pel's Fishing-Owl lays its eggs during the high flood season, with a peak in March in the Okavango Panhandle (Site 6) – further downstream where flood levels peak later, eggs are laid later (June). The chick remains dependent on the parents for several months, probably

until low water levels and greater fish concentrations make for a better chance of surviving independently (Liversedge, 1980).

Great and Yellow-billed egrets move in response to flooding, to areas of shallow water where they can wade and catch fish – floodplains are their prime areas, but margins of channels and other waterbodies, where there is a shallow zone, are also utilised. Breeding of both species is linked to water flows (see 3.9.3).

Indicator 3 – Piscivores and invertebrate feeders in isolated pools

Main characteristics of indicator

These indicator species are directly flow-dependent because their lifestyles are dependent on inundation of floodplains and recession of water later. These species mainly wade in the shallow waters of the floodplains to get their food (small fish and invertebrates), or swim in shallow isolated pools of open water on the floodplains when feeding. They are indicators of floodplain health in terms of production of fish and invertebrates.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 3 – Piscivores of shallow water and lagoons

General species	Small herons and egrets, pelicans, storks, snipe, lapwings, sandpipers, gallinules, moorhens, rails and crakes
Representative species	Great White Pelican Pelecanus onocrotalus Squacco Heron Ardeola ralloides Little Egret Egretta garzetta Red-billed Teal Anas erythrorhyncha Hottentot Teal Anas hottentotus

Life cycle attributes

The Great White Pelican is highly opportunistic and occurs in large numbers at the best fishing sites in the Okavango system (and beyond). It does not utilise the upper, nutrient-poor reaches of the Delta, but prefers the distal ends of distributaries which are more productive. For example, when Lake Ngami flooded in June 2004 for the first time in over a decade, it was soon inhabited by Great White Pelicans, the numbers of which peaked at 5,200 individuals in December 2004 (Hancock et al., 2005). Since each adult pelican needs approximately 1 kilogram of fish daily, for a few months over 5 tonnes of fish were being consumed every day, mostly Schilbe intermedius, Marcusenius macrolepidotus and Clarias gariepinus. Apart from Lake Ngami, the Great White Pelican also exploits drying lagoons along the Boteti, Thamalakane and lower Boro, for example at Site 8 – usually these are drying by April/May before the new incoming floods, and this is the time that the Great White Pelican breeds. It does not breed anywhere in the Okavango, although the ‘normal’ flooding of the Okavango system is crucial for these birds since they breed in the Nata River delta in northern Sua Pan (350 kilometres to the east) and commute to the drying pools at the distal end of the Okavango on a daily basis to catch fish to feed their young. This is an energetically expensive undertaking and depends on the existence of ‘fish traps’ in the form of drying pools on floodplains or in river channels. The newly fledged pelicans from the Nata Sanctuary must also make a 350 kilometre ‘maiden flight’ to the Okavango where the existence of a surfeit of fish is essential to their independence and immediate survival (see McCulloch, 2008).

The Squacco Heron feeds on small fish and aquatic invertebrates in a variety of situations in the Okavango Delta, but is only known to breed at a few localities viz. Gadikwe Lediba, Boro floodplain, Gomoti headwaters in Xou Lediba, Lake Ngami (when suitable conditions prevail) (Tyler and Hancock, 2006). The only regularly used heronry is at Gadikwe Lediba near Site 7; breeding is mostly opportunistic and it is not known what factors trigger its onset, but it seems to be a combination of good, late rains and early incoming floodwaters.

Little Egrets are opportunistic and exploit suitable feeding conditions on flooding or receding floodplains; they are also one of the species active at Barbel runs, and occur in globally significant numbers at Lake Ngami when it has water. They breed at a few traditional heronries e.g. Gadikwe Lediba (Tyler and Hancock, 2006), usually around September, and it is not known what factor(s) trigger breeding.

The ducks and geese, typified by the two teal species, prefer the nutrient rich waters of the distal end of the Delta where they can reach high numbers. They are highly mobile and move around extensively in search of these optimal conditions. Tyler (2001) found more Red-billed Teal on the Thamalakane and Boteti Rivers than elsewhere in the Okavango Delta. Douthwaite (1979) observed over 13,000 at Lake Ngami during the summer of 1979, vastly more than recorded in the remainder of the Okavango Delta at any other time.
These species both prefer the nutrient-rich waters of the distal Okavango distributaries.

Links to flow

The feeding, and particularly the breeding of the Great White Pelican is linked to the availability of ‘fish traps’ in the distal reaches of the Okavango distributaries – ‘normally’ these are present during April/May when the pelicans have large chicks to feed at the only Botswana breeding site in the Nata Sanctuary. If this synchronised system is disrupted, the species might no longer be able to breed in Botswana.

The Squacco Heron and Little Egret seem dependent on inundation and drying of floodplains for feeding, but the importance of changes in the flow regime to these species is not clear, except for the following - floodplains that are regularly flooded annually become less productive for these birds than those that are dry for a period and then flood – this is because when dry, the floodplains are usually heavily grazed by herbivores which deposit significant quantities of nutrients back into the system in the form of dung and urine.

The ducks move to the most productive parts of the Okavango system, which are generally nutrient-rich areas that are frequently but not permanently inundated. During the 1990s when the Boro outflow was very low, the Thamalakane and Boteti Rivers were dry most of the time. During this period, Lake Ngami was also dry. These areas did not support any White-backed ducks; once water flow increased and there were changes in the distribution of water in the Delta, the southern reaches of the Delta and Lake Ngami held globally significant populations of these two species. Changes in flows will therefore affect tens of thousands of individual birds.

Indicator 4 – Specialist feeders on floodplains, receding waters

Main characteristics of indicator

These indicator species are floodplain specialists that are dependent on the recession of floodwaters for feeding and breeding. Diminution of floodplain extent, or changes in the timing of wetting or drying of floodplains can disrupt breeding. The Okavango supports globally significant populations of both Wattled Cranes and Slaty Egrets. The largest single population of Wattled Cranes in the world is found in the Okavango Delta (1,300, about 18% of the global population) (Motsumi and Hancock, 2004). The global population of Slaty Egrets is estimated at 4,000 individuals (Wetlands International, 2002), of which about 85% occur in the Okavango Delta.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 4 – Specialist feeders on floodplains, receding waters	
General species	African Openbill, Wattled Crane, herons and egrets
Representative species	African Openbill Anastomus lamelligerus Wattled Crane Bugeranus carunculatus Slaty Egret Egretta vinaceigula

Life cycle attributes

The African Openbill is a specialist feeder on molluscs (Pina occidentalis, Lanistes sp.) on shallow floodplains and channel margins – these it finds by touch, by probing in water no deeper than its legs are long. It is believed to move widely throughout the Delta in search of optimal feeding conditions, which exist in the Panhandle in April as the adjacent floodplains are inundated, and moving progressively south-eastwards following the floods. Peak numbers along the Thamalakane River are found in early summer (November to January) as water reaches its lowest level, exposing the molluscs. The molluscs are highly productive and support thousands of openbills (there are no population estimates for this species in the Okavango, although >1% of the global population is found here); any changes in waterflow that affect these molluscs will impact on the openbills.

There is only one known breeding site in the Okavango Delta (apart from a small opportunistic breeding colony at Lake Ngami), at Lediba la dinonyane, where almost 1,000 pairs nest regularly during September – this is the largest known site in the Okavango basin. It is situated in a lagoon, on Ficus verruculosa islands, where water levels do not vary greatly. During September, the Okavango floodwaters throughout the Delta would be waning, making rich feeding grounds available to this species – birds commute considerable distances between these feeding areas and the breeding site.

The Wattled Crane feeds on rhizomes, roots and bulbs of sedges, primarily Eleocharis spp. and Bento (2002) has shown clearly how they follow receding floodplain margins where Eleocharis is becoming water stressed and transferring food reserves to its underground bulbs – the cranes are still able to probe into the not-yet-hard mud in this zone to get the bulbs. In its feeding, this species is therefore entirely dependent on receding floodwaters. Breeding pairs are territorial and do not move much, so that their food requirements need to be met in a relatively small area; prime territories are along the Jao/Boro floodplains.

Breeding is also confined to floodplains.

The Slaty Egret is another floodplain specialist (Hancock et al., 2005) since it feeds exclusively in shallow floodplains with short, sparse emergent vegetation. It hunts by sight and needs a fairly open water surface and good clarity of water to see the small fish (up to 10cm in length) and invertebrates that it eats. As with the Wattled Crane, higher flood levels with more extensive flooding would create more suitable habitat for this species.

The breeding of this species is also relevant and is described below.

Links to flow

The African Openbill is totally dependent on receding waters on floodplains and channels to enable it to access its specialised diet of a few, but prolific, mollusc species – the molluscs in turn are probably also dependent on waterflows. Since there is a distinct flood pulse of water, the openbills are able to follow this, and find suitable areas that vary spatially and temporally; suitable feeding areas are always available somewhere in the Okavango at any time. The breeding of this species coincides with the period when the Okavango floodwaters are generally receding.

The feeding of Wattled Cranes is closely linked to receding floodwaters, which led Bento (2002) to implicate hydrological changes in the Zambezi Delta in the decline of the crane population there. Waterflows that affect the amount of the cranes' preferred food species (e.g. Eleocharis spp.) may also impact negatively on the birds.

The Slaty Egret feeds exclusively on shallow floodplains, and higher flow levels would make more of this habitat available. Conversely, lower levels mean less suitable habitat.

Indicator 5 – Specialist feeders in water lily-covered inlets

Main characteristics of indicator

These indicator species are highly specialised, having even evolved long toes to enable them to walk on the floating aquatic vegetation that is their preferred habitat.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 5 – Specialist feeders in water lily-covered inlets

General species	Jacanas and gallinules, pygmy-geese
Representative species	African Jacana – Actophilornis africanus Lesser Jacana – Microparra capensis Allen's Gallinule – Porphyrio alleni

Life cycle attributes

All three indicator species are closely associated with water lilies, particularly Allen's Gallinule which in addition to eating aquatic invertebrates, feeds on developing water lily seed heads. The two jacanas use water lilies as feeding platforms but eat exclusively invertebrates – they occupy slightly different niches because the Lesser Jacana actually prefers a cover of Potamogeton thunbergi.

Allen's Gallinule is liberated from the water lily covered inlets during the breeding season when it nests in floodplains and flooded grasslands, but the jacanas build floating nests of vegetation among the water lilies.

Links to flow

These indicators are likely to be affected indirectly by changes in water flow, unlike some others which will be physically displaced by, for example, high water flows. Drying out of lagoons or inlets, which will affect the productivity of Nymphaea, will diminish the habitat available for these species. Similarly, the time taken by waterlilies to regenerate will influence the time taken by these birds to recolonise new habitat.

Indicator 6 – Specialist feeders in riverine fruit trees

Main characteristics of indicator

These indicator species are indirectly affected by changes in water flow – any changes to their preferred fruiting trees in the riparian habitat will affect their numbers. They are likely to be good indicators of changes to this important habitat.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 6 – Specialist feeders in water lily-covered inlets	
General species	Parrots, starlings, bulbuls/greenbuls
Representative species	African Green-Pigeon Treron calvus Black-collared Barbet Lybius torquatus Burchell's Starling Lamprotornis australis

Life cycle attributes

The African Green-Pigeon and Black-collared Barbet in the Okavango are confined to riparian forest along the waterways, where they feed on the fruits of the Strangler Fig, African Ebony (Diospyros mespiliformis) and Bird Plum (Berchemia discolour), among others. They usually nest in the same habitat, not far from water; the Black-collared Barbet in particular is quite sedentary.

Burchell's Starling has a wider habitat tolerance than the preceding species, but like them, feeds on fruiting riparian trees. Interestingly, they roost in Phragmites reedbeds in large numbers and this may be an important component of their habitat that could be affected by changes in water flow.

Links to flow

This group of indicator species are likely to be affected indirectly by changes in water flow – dying off of the riparian vegetation after prolonged dry periods such as occurred along distal channels during the low flows of the 1990s, reduced prime habitat for these species through a reduction in their food supply.

Indicator 7 – Breeders in reedbeds, floodplains

Main characteristics of indicator

These indicator species are confined to breeding in reedbeds along watercourses or in the floodplains themselves.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 7 – Breeders in reedbeds, and on floodplains

General species	Weavers, Bishops, Widowbirds, Whydahs, Prinias, Cisticolas, Warblers, Gallinules, Crakes, Herons, Egrets
Representative species	Weavers Ploceus spp. Slaty Egret Egretta vinaceigula Rufous-bellied Heron Ardeola rufiventris Wattled Crane Bugeranus carunculatus

Life cycle attributes

Weavers breed during the summer months when climatic conditions result in an abundance of food to feed chicks. The breeding sites in reeds are however influenced by floods – the reeds must be standing in water to be suitable.

Randall and Herremans (1994) described the breeding of the Slaty Egret in the Okavango Delta, and found that they breed in Phragmites reedbeds in April/May just before the incoming floodwaters peak. During the 2004/5 baseline survey (Hancock et al., 2005), Slaty Egrets were also found breeding at this time, but in Phoenix reclinata islands. Reedbeds previously used by this species had been burnt and had not recovered due to a low flood cycle; low flood regimes allow greater access to people and the proliferation of anthropogenic fires (and reed-cutting), to the detriment of Slaty Egrets. (Prolonged low flows could also adversely affect Phoenix reclinata which thrives in permanently wet areas, on termite mounds).

The ecology of the Rufous-bellied Heron is quite similar to that of the Slaty Egret, and they breed together in the same reedbeds and Phoenix palm islands. They bred at peak flood levels in the reedbed documented by Randall and Herremans (1994). According to Tarboton et al. (1987), in South Africa egg-laying is to some extent opportunistic, according to flood levels.

The Wattled Crane breeds on floodplains; the nest is a mound of vegetation standing in about 75cm of water. Breeding takes place during winter, with egg-laying starting during July so that most pairs are incubating during August. There does not appear to be any differential in laying and hatching dates between the upper and lower reaches of the Delta despite the time difference between flooding these areas (see Hancock, 2003); this refutes the suggestion that the birds nest on receding floodwaters. Young cranes hatch at a time (September) when the Okavango floodwaters are at their lowest throughout the Delta – whether this coincides with maximum food availability is not clear since a high proportion of the diet of young cranes is insects.

During high flood years, when the flooded areas are more extensive, there may be more suitable habitat available for breeding (only a small percentage of the population bred –

between 6 and 16% in 2001, 2002 and 2003 - when flood levels were low). See also Douthwaite (1974) who found 40% of the pairs breeding during a 'normal' year and only 3% in a year of negligible flooding conditions, on the Kafue Flats.

Links to flow

Reedbeds used by weavers for breeding are influenced by the onset of the flood season, its magnitude and the duration.

Lower water levels mean less suitable breeding habitat for the Slaty Egret – there is easier access for people into the Delta, with a resulting increase in fires which destroy the species breeding habitat, Phragmites reedbeds. A combination of fire and decreased water level is fatal to Phragmites. Breeding is timed to the peak flood in late April/May and alteration of the timing may affect this activity; the same applies to the Rufous-bellied Heron.

Wattled Crane breeding takes place on shallowly inundated floodplains and should these dry our prematurely (before September), the nests would be exposed to greater predation. Higher floods may make more areas of suitable breeding habitat available. Unseasonal high water levels i.e. while the birds are incubating during July/August, may result in inundation of nests. Altered distribution of floodwaters, with the Jao/Boro system receiving less water, could adversely affect cranes because this is currently their core range, and the eastern half is protected within Moremi Game Reserve.

Indicator 8 – Breeders in riverine overhanging trees

Main characteristics of indicator

These indicator species are colonial breeders requiring overhanging vegetation for nest safety or for fledglings vacating the nest to escape danger.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 8 – Breeders in riverine overhanging trees

General species	Weavers, Herons, Cormorants, Darters
Representative species	African Darter Anhinga rufa Reed Cormorant Phalacrocorax africanus

Life cycle attributes

The African Darter nests colonially on trees (or reeds) standing in water, usually in association with Reed Cormorants – this takes place during June and July, so this is the time that the availability of fish is most important (the species is exclusively piscivorous). Several sites regularly used at JereJere Lediba, Xakanaxa Lediba, upper Phillipo Channel, east of Xigera – these all comprise trees such as Syzygium sp. standing in permanent water. When the darter nestlings are disturbed, they vacate the nest and dive into the water for safety, later clambering back up.

The Reed Cormorant uses several traditional breeding sites in the Okavango at JereJere Lediba, near Xigera, at Xakanaxa Lediba and on the Upper Phillipo Channel; however, the species will also breed opportunistically e.g. at Lake Ngami when conditions are suitable. Nesting colonies usually active during July in the Delta i.e. at peak flood, but may nest after peak flood at Lake Ngami i.e. October/November.

Links to flow

Both these species use a few traditional breeding sites in the Okavango; however, the species will also breed opportunistically e.g. at Lake Ngami when conditions are suitable. Nesting colonies are usually active during July in the Delta i.e. at peak flood, but may nest after peak flood at Lake Ngami i.e. October/November. When their nestlings are disturbed, they vacate the nest and dive into the water for safety – nesting trees are thus always in permanent water. There may be a link between the timing of breeding with the onset of the Barbel run in the Panhandle.

Indicator 9 – Breeders on banks

Main characteristics of indicator

These indicator species are colonial breeders requiring vertical banks for nest holes – these sites are at a premium in the flat Okavango – or the grassy banks for nest sites and fledgling development.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 9 – Breeders on banks

General species	Kingfishers, Bee-eaters, Lapwings
Representative species	Southern Carmine Bee-eater Merops nubicoides White-fronted Bee-eater Merops bullockoides Pied Kingfisher Ceryle rudis

Life cycle attributes

The Southern Carmine Bee-eater is an intra-African migrant that arrives in the Okavango region in relatively large numbers in August/September to breed colonially in the steep banks of the Okavango River along the Panhandle in Shakawe, downstream of Drotsky's Cabins and at Red Cliffs; they also bred elsewhere lower down the Delta at Four Rivers, Shinde and Xakanaxa – these sites are atypical and are on flat ground. By December, the adults and young disperse throughout Southern Africa before migrating northwards again during March. During low flow cycles, this species establishes more colonies in dry floodplains (see Muller and Hancock, 2007) but when these areas are again flooded, they are of course abandoned by the bee-eaters. The birds forage for insects over grasslands and woodlands away from the Okavango waterways, and this activity is independent of water flows.

The White-fronted Bee-eaters are resident in the Okavango Panhandle, and are sedentary, seldom moving more than 3 to 7 kilometres from their breeding sites in Shakawe and elsewhere along the Okavango Panhandle. They breed in early summer together with the Carmine Bee-eaters, apparently to avoid rising floodwaters following summer rains (J Drotsky, pers. comm.).

The Pied Kingfisher breeds throughout the year, but with a peak in September, in holes excavated in the banks of the Okavango River (this is when the water level is lowest and most banks are exposed). Optimal nesting habitat is found at Site 6, but further downstream where the terrain is flatter, they nest at the base of termite mounds near the water's edge.

Links to flow

Carmine Bee-eater colonies along the Zambezi River were flooded by construction of the Kariba and Cahora Bassa Dams (Barnes and Herremans, 1997).

Early, high flooding i.e. during September, will destroy the nests of all three of these indicator species. Flooding during late summer (March/April) may be needed to keep the Okavango River banks steep and free of grass and other vegetation that could conceal predators.

Indicator 10 – Breeders on emergent rocks, sandbanks, islands

Main characteristics of indicator

These indicators, especially the African Skimmer, have a very narrow breeding niche, nests being confined to low sandbanks and/or sandy islands with some vegetation nearby for chick concealment during disturbances. The Zambezi, Chobe and Okavango Rivers are the main breeding areas for the African Skimmer in Southern Africa – this Near Threatened species is extinct as a breeding bird in South Africa.

The characteristic and representative species of this indicator are listed in the table below.

Indicator 10 – Breeders on sandbars, islands	
General species	African Skimmer, Sandpiper, Thick-knees
Representative species	African Skimmer Rynchops flavirostris Water Thick-knee Burhinus vermiculatus

Life cycle attributes

The African Skimmer is a partial intra-African migrant, arriving in the Okavango Panhandle in June when the floodwaters are receding, but before sandbanks are exposed (Vial, 1995). It is a highly specialised bird which feeds by flying low over open water trailing the lower mandible in the water to detect small fish (its exclusive diet, mostly those <60mm). Species taken in the Okavango include Tilapia spp., Barbus spp., Marcusenius macrolepidotus, Herpestes odoe, Aplocheilichthys spp. and Petrocephalus catastoma (Paxton, unpubl. data). Tracts of open water, free of all vegetation, are essential for this specialised method of feeding to be successful.

Once sandbanks become exposed, during August/September (lowest flow period), this species breeds i.e. low flow needed for breeding – during 'prolonged' low flow cycles (less than a decade), other sites become available at Xigera Lagoon and on the middle Boro River, and this has been important for the skimmer because the Panhandle sites are subject to a lot of human disturbance. The sandbanks must have bare open sandy areas with some vegetation nearby; when danger threatens the chicks vacate the nest scrape and hide in the vegetation until danger has passed. Most chicks have fledged by November – any unseasonal increases in water level before this time would totally disrupt breeding. After

breeding, adult and young skimmers disperse southwards to the distal ends of the Okavango at Chanoga (Site 8) and Lake Ngami – these areas are more nutrient rich and may be important for immature survival.

The Water Thick-knee has a more catholic diet than the skimmer, feeding on frogs and tadpoles, crabs, aquatic beetles, insects and crustaceans which it finds along the water's edge at night. It also breeds on sandbars like the skimmer, with a peak during October at the time of lowest water levels.

Links to flow

The African Skimmer requires open unvegetated stretches of water with small, surface-swimming fish, for its unique feeding method to be successful.

It needs exposed, bare sandbanks for breeding during the period August to November. If water levels are high and sandbars are not exposed, it cannot commence breeding. If water levels are low earlier, this will enable them to start breeding earlier - however, if water levels increase during the period after breeding has commenced, breeding will be totally disrupted. Regular inundation of the sandbanks, outside the skimmer breeding season, and the fresh deposition of sand is necessary to prevent the breeding sites from becoming completely vegetated, and therefore unsuitable for skimmers (and thick-knees) to breed (Aspinall, 2005).

Summary

The indicator species described above vary in the extent to which they will be affected by changes in water flow. Generally, the better studied species e.g. Wattled Crane, African Skimmer, Slaty Egret, seem to be more affected than others, but this is probably a factor of the available knowledge.

Those species which depend on the Okavango water flows for both feeding and breeding are more likely to be robust indicators since they will definitely be affected by the changes; species that breed elsewhere may escape some of the negative impacts of changed water flow. Conversely, bird species that will only be affected indirectly by having their food supply altered will not be such good indicators since the effect of changed water flows will be more complicated.

5 DATA COLLECTION AND ANALYSIS

Methods for data collection and analysis

This report is based on fieldwork on birds conducted during the period 2000 to the present, and not on any specific work for this project. Previous fieldwork is summarized below:
Extensive aerial surveys of the whole Delta censusing Wattled Cranes, during 2001, 2002 and 2003. This was supported by groundwork monitoring breeding success of nesting pairs
Fieldwork gathering data for a baseline study of the Slaty Egret during 2004 and 2005.
AquaRap 2003 – birds were surveyed at two of the sites relevant to this project (viz. Shakawe and Xakanaxa) as well as at other sites, which provided the basis for selecting the indicator species at these sites.
African Waterbird Census data – these waterbird counts are conducted biannually (mid-winter and mid-summer) throughout the Okavango Delta and provide detailed information on the numbers and distribution of waterbirds which can be related to water flow levels. The three sites for this project have been regularly surveyed in the past – for some sites the dataset spans almost two complete decades.

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

The following tables summarise general responses of the indicator species to dry season variables, flood season variables and the transition between flood and dry seasons. It must be emphasised that these are general reponses as they are not area specific.

Indicator 1 (Piscivores of open water)

Table 5: Predicted response to possible changes in the flow regime of Piscivores of open water as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The low flows of the dry season will generally affect these birds positively since fish will be more concentrated and water currents will be less, so an early onset of the dry season will slightly improve their situation.	Medium
2		Water levels are higher or lower than natural	Lower dry season flows will be marginally better for these birds as it will be slightly easier to catch fish under these conditions, but the higher levels will be disadvantageous	Medium
3		Extends longer than natural	Since the dry season is best for these birds in terms of ease of fishing, the longer the dry season the better it will be for them.	Medium
4	Flood season	Onset is earlier or later than natural	The start of the flood season is the start of more difficult fishing conditions for these birds due to greater amounts of water and increased velocity of flow which will affect their ability to catch fish. Early onset will be less favourable; a late onset would be beneficial.	Medium
5		Extent of inundated area	These birds are not using the floodplain areas, so the changes in the area flooded will not be relevant for them, except insofar as the floodplains are the breeding grounds for fish (the prey base for this group)	Medium
6		Flood season duration	The flood season is the time that these piscivores are under stress as it is less easy for them to catch fish in the open waters - if the flood season were longer, this would affect them adversely, but only marginally so, since they are quite adaptable.	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	The duration of the transition period will have no effect on these indicator species	Low

Indicator 2 (Piscivores of shallow water and lagoons)

Table 6: Predicted response to possible changes in the flow regime of Piscivores of shallow water and lagoons as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The dry season is better for these birds which prefer the shallow waters at this time - an earlier onset is slightly better for them	Medium
2		Water levels are higher or lower than natural	Lower dry season flows favour these birds significantly as fish are more concentrated (this is the time of the barbel run and the herons and egrets are the birds that capitalise on it) - there is also plenty of shallow water to fish in. Higher dry season water levels will be slightly unfavourable.	Medium
3		Extends longer than natural	Since these birds favour the shallow water prevailing during the dry season, a longer dry season is better for them.	Medium
4	Flood season	Onset is earlier or later than natural	The onset of the flood season brings hard times for these birds, so an early flood season would impact on them negatively	Medium
5		Extent of area inundated	These birds are not using the floodplains for feeding so the extent to which they are inundated is not relevant (except for the fact that their prey – fish – are breeding on the floodplains)	Medium
6		Flood season duration	These birds are not using the floodplains so the length of time for which they are inundated is not relevant	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	These birds are not affected by the duration of the transition period	Low

Indicator 3 (Piscivores and invertebrate feeders in isolated pools)

Table 7: Predicted response to possible changes in the flow regime of Piscivores and invertebrate feeders in isolated pools as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The timing of the onset of the dry season will not affect this group of birds	Low
2		Water levels are higher or lower than natural	The water level during the dry season will not affect these birds	Low
3		Extends longer than natural	These birds have the extent of their suitable habitat reduced during the dry season, as there is no water on the floodplains, so a longer dry season is a period of stress	Medium
4	Flood season	Onset is earlier or later than natural	An early start to the flood season would result in increased food availability as the floodplains become inundated, thus relieving the stress of the dry season	Low
5		Extent of area inundated	The greater the area inundated, the more suitable habitat (Isolated pools) will result when the floods dry out	Medium
6		Flood season duration	The longer the flood season the better for these birds because optimal feeding conditions will persist longer	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	A quick transition will result in more fish being trapped on the floodplains, and in the rapid concentration of invertebrates, and this will be good for these birds	Medium

Indicator 4 (Specialist feeders on floodplains)

Table 8: Predicted response to possible changes in the flow regime of Piscivores and invertebrate feeders on floodplains as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The timing of the onset of the dry season is important for these birds since they need an adequate period of drying floodplains (when food availability is at a peak) to build up condition before breeding - the earlier onset, the better.	Medium
2		Water levels are higher or lower than natural	The water level during the dry season will not affect these birds	Medium
3		Extends longer than natural	A long dry season, with dry floodplains, would be disadvantageous for these birds since they depend on inundated floodplains	Medium
4	Flood season	Onset is earlier or later than natural	If the flood season started late this would not be good for these birds because it would result in ideal feeding conditions being available for a shorter period	Medium
5		Extent of inundated area	The greater the area flooded, the better for these birds because they would have more prime feeding habitat available	High
6		Flood season duration	Since these birds depend on the floodplain having some water, the longer the flood season lasts the better	High
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	A gradual transition from flooded to dry would be good for these birds because it would result in a slow sustained production of their food	High

Indicator 5 (Specialist feeders In waterlily covered inlets)

Table 9: Predicted response to possible changes in the flow regime of Specialist feeders in waterlily covered inlets as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The timing of the onset of the dry season is irrelevant for these birds	Medium
2		Water levels are higher or lower than natural	If dry season flows drop very low, waterlilies in extensive areas would die out slightly reducing habitat for these species	Medium
3		Extends longer than natural	The duration of the dry season is irrelevant for waterlilies and these birds	Medium
4	Flood season	Onset is earlier or later than natural	The timing of the onset of the flood season would not make any difference to these birds	Medium
5		Extent of inundated area	The greater the area inundated, the more widespread waterlilies would be and therefore there would be more available habitat for these birds	High
6		Flood season duration	A long flood season would favour the persistence of waterlilies and benefit these birds slightly	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	The duration of the transition period would be irrelevant for these birds	High

Indicator 6 (Specialist feeders in riverine fruit trees)

Table 10: Predicted response to possible changes in the flow regime of Specialist feeders in riverine fruit trees as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	NB This indicator depends on riparian fruit trees which are not significantly influenced by annual changes in any of the variables listed – only longer term (>10 years), low flows on the seasonally flooded areas (Site 7) and in the distal parts of the delta (Site 8)	Medium
2		Water levels are higher or lower than natural	Not relevant for this indicator	Medium
3		Extends longer than natural	Not relevant for this indicator	Medium
4	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Not relevant for this indicator	Medium
5		Extent of inundated area	If flooding of the floodplains is more extensive, more island tree copses will be reached by the floodwater resulting in increased fruit availability for these birds.	Low
6		Flood season duration	There seems to be an optimal 3 month flood duration period needed by fruit trees for fruiting - more or less than this is detrimental	Low
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Not relevant for this indicator	Medium

Indicator 7 (Breeders in reedbeds and floodplains)

Table 11: Predicted response to possible changes in the flow regime of Breeders in reedbeds and floodplains as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	The timing of the onset of the dry season will not affect these birds in any way	Medium
2		Water levels are higher or lower than natural	Water levels during the dry season will not affect these birds in any way	Medium
3		Extends longer than natural	Duration of the dry season will not affect these birds	Medium
4	Flood season	Onset is earlier or later than natural	Breeding of birds in this Indicator Group is governed by the floods and the onset of the floods often triggers breeding - an early onset of floods will result in early breeding and therefore higher productivity	Low
5		Extent of inundated area	A larger inundated area will result in potentially more available breeding sites, notwithstanding that the traditional breeding sites for these birds are at specific locations	Medium
6		Flood season duration	A longer flood season would enable these birds to complete their whole breeding cycle before the waters dried up	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	A rapid transition could result in breeding sites being left high and dry, with unfledged chicks exposed to predation	Medium

Indicator 8 (Breeders in riverine overhanging trees)

Table 12: Predicted response to possible changes in the flow regime of Breeders in riverine overhanging trees as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Timing of the onset of the dry season would not affect these birds	Medium
2		Water levels are higher or lower than natural	Water levels during the dry season would not affect these birds	Medium
3		Extends longer than natural	Duration of the dry season is irrelevant for these birds	Medium
4	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Early flood season onset coincides with the breeding season of some of these birds, and triggers breeding in others - early floods will generally provide more time for breeding	Medium
5		Extent of inundated area	A greater inundated area will produce more potential breeding sites where trees overhang water	Medium
6		Flood season duration	These birds need a long flood period in which to complete their whole breeding cycle	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	A quick transition could leave nesting birds exposed to predation, and this would obviously be disadvantageous	High

Indicator 9 (Breeders on banks)

Table 13: Predicted response to possible changes in the flow regime of Breeders on banks as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Timing of dry season onset not relevant to this indicator	Medium
2		Water levels are higher or lower than natural	These birds breed at the end of the dry season, and the lower the flows at this time, the more banks will be exposed and the better will be their breeding success	Medium
3		Extends longer than natural	A prolonged dry season will enable these birds to complete their breeding cycle before the floods arrive	Medium
4	Flood season	Onset is earlier or later than natural	If the floods arrive before the birds finish breeding this will disrupt breeding to a variable extent	Medium
5		Extent of inundated area	The extent of inundation is not relevant to these birds	Medium
6		Flood season duration	The duration of the flood season is not relevant to this indicator	Medium
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	The duration of the transition period is not relevant to this indicator group	High

Indicator 10 (Breeders on emergent rocks, sandbanks and islands)

Table 14: Predicted response to possible changes in the flow regime of Breeders on emergent rocks, sandbanks and islands as an indicator in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	If the dry season starts earlier, these birds will actually breed earlier - African Skimmers arrive in the Panhandle (site 6) before the sandbanks are exposed, and wait for them to appear	High
2		Water levels are higher or lower than natural	Low dry season flows result in more sandbanks being exposed for these birds to breed on; however when flows are very low, sandbanks become encroached with vegetation and unsuitable	High
3		Extends longer than natural	The dry season must extend beyond a certain minimum period (90 days) so that these birds can complete their breeding cycle – if it is longer than this, it will be favourable for the birds	High
4	Flood season	Onset is earlier or later than natural	If the flood season starts before the end of November, this would be disastrous for these birds as they would not have finished breeding by then	High
5		Extent of inundated area	If the floodplains are not inundated, then the food supply for these birds will be negatively affected	High
6		Flood season duration	Floods must be of reasonable duration to ensure that fish (the food source for some of the birds in this indicator) breed and maintain a sufficient level	High
7	Transition 2	Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Not relevant for this indicator	Hgh

7. CONCLUSION

Some of the indicators appear useful, particularly those species for which detailed studies have been undertaken in the Okavango Delta specifically. These species have been chosen as indicators based on facts related to the effect of changing hydrological conditions on their populations. If similar data existed for species such as the African Openbill in the Okavango system, the usefulness of this species as an indicator would be enhanced. If species have been well studied elsewhere e.g. Reed Cormorant, African Darter, this does not assist much to predict their response to changes in flow regimes.

Notwithstanding the above, it is felt that the following 10 species are going to be the most useful bird indicators:
Reed Cormorant
African Darter
Pied Kingfisher
Great White Pelican
African Openbill
Slaty Egret
Wattled Crane
Southern Carmine Bee-eater
African Skimmer
Red-billed Teal

Historical data on the numbers and distribution of the indicator birds, such as exists, was useful in substantiating some of the predictions relating to those species.

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APPENDIX A: FULL DESCRIPTIONS OF INDICATORS

	Country and Site Relevance			Representative Species			
Indicators	Angola	Namibia	Botswana	Angola	Namibia	Botswana	Comments
Piscivores of open water	Yes	Yes	Yes	Reed Cormorant, African Darter, kingfishers	Fish Eagle, Osprey, King fishers, cormorants, Darters	Fish-Eagle, Reed Cormorant, African Darter, Pied Kingfisher	Predominantly feed on fish available in main river system or adjoining pools.
Piscivores of shallow water & lagoons etc.	Yes	Yes	Yes	Larger herons/egrets	Pels Fishing Owl, Larger Herons, Larger Egrets, Terns	Pel's Fishing-Owl, larger herons/egrets	Need overhanging trees and sandbanks for breeding and feeding.
Piscivores and invertebrate feeders, isolated pools	Yes	Yes	Yes	Little Egret, Black Heron, Glossy Ibis, Saddle-billed Stork, Lapwings	Smaller herons, Smaller Egrets, Storks, Snipe, Plovers, Lapwings, Sandpipers, Gallinules, Moorhens, Rails, Crakes	Great White Pelican, Squacco Heron, Little Egret, ducks and geese	Feed on fish-fry at receding water level times after spawning in flood-plains, or fish trapped in drying pools.
Specialist feeders on floodplains	Yes	Yes	Yes	Cranes, African Openbill	African Openbill, cranes	African Openbill, Slaty Egret, Wattled Crane	Feed on molluscs, frogs, fish or selective vegetation and organisms occurring in shallow floodplain situations
Specialist feeders in water-lily covered inlets	Yes	Yes	Yes	African Jacana, Lesser Jacana	African Jacana Lesser Jacana	African Jacana, Lesser Jacana, Allen's Gallinule	Floodplain pools (rising and receding water levels) and lily-pad covered inlets. Essential for feeding habitat

Specialist feeders in riverine fruit trees	Yes	Yes	Yes	Turacos, bulbuls	Parrots, Turacos, Bulbuls	African Green Pigeon, Black-collared Barbet, Burchell's Starling	When riverine fruit trees are in fruit they are an important food source for a large variety of birds
Breeders in reedbeds, and on floodplains	Yes	Yes	Yes	Fan-tailed Widowbird, weavers, bishops, herons/egrets	Weavers, Bishops, Widowbirds, Whydahs, Prinias, cisticolas, Warblers, Gallinules Crakes, Herons, Egrets	Weavers, Slaty Egret, Rufous-bellied Heron, Wattled Crane	Nesting habitat in reedbeds lining river banks and islands.
Breeders in riverine overhanging trees	Yes	Yes	Yes	Herons, Cormorants, Darters	Herons, Cormorants, Darters	African Darter, Reed Cormorant	Colonial breeders or solitary nesters requiring over-hanging vegetation for nest safety or fledglings vacating the nest
Breeders on banks	Yes	Yes	Yes	White-fronted and other Bee-eaters	Kingfishers, Bee-eaters, Collared Pratincoles, Lapwings	Carmine Bee-eater, White-fronted Bee-eater, Pied Kingfisher	Require vertical banks for nest holes or the grassy banks for nest sites and fledgling development
Breeders on emergent rocks, sandbars and islands	Yes	Yes	No	Rock Pratincoles, African Skimmer	Rock Pratincoles, African Skimmer, Sandpipers, Thick-knees	African Skimmer, Water Thick-knee	Totally dependent on emerged rocks, sandbars and islands in the main river for nesting purposes

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 Trans-boundary 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

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