Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

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

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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: NAMIBIA

Discipline: FISH LIFE

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EXECUTIVE SUMMARY

The fish life of the Kavango River is better known in the Botswana and Namibian reaches and the about 80 known species were divided for this exercise into the following seven indicators: Resident in river [including tigerfish and larger cichlids] Migrating to floodplains – small , represented by small species such as the churchill, Migrating to floodplains – large, represented by redbreast tilapia, Rock dwellers, example Okavango suckermouth, Sandbank dwellers, example the Chobe sand catlet, Marginal vegetation dweller, example Zambezi happy and Backwater dweller, represented by the Okavango tilapia.

More groups could be identified in the Namibian section, eg nesting fish species, that could again be divided into two types, substrate and floating nesters but this approach was abandoned after consulting with the Angolan and Botswana fish biologist colleagues as it would complicate the exercise without adding much value.
.
Three visits were brought with the Namibian team to the two selected sites, Kapako, upstream of the Cuito confluence with the Kavango, representing a floodplain type of habitat, and Popa Falls, below the Cuito confluence and representing a rocky type of environment. Actual fish collections were conducted during low water conditions, during the early first peak and a month later, when the river had actually dropped a bit before the record flood peak reached later. Gear used included a set of 11 different mesh gillnets, a small mesh seine net, large scoop net in collaboration with a AC fish shocker that made it possible to investigate the fish life of rocky habitats with flowing water. Apart from the fish collections, reference could also be made to an extensive series of fish collections with a set of gill nets over the period 1995 to 2007. The predicted response of each indicator was drawn up from the existing information in literature, and personal experience with these indicator groups as well as their presence in the samples collected during this study. These predictions could then be used as guidelines for the subsequent response curves drawn for each indicator group and the ultimate joint scenario exercise.

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ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
EFA	Environmental Flow Assessment
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
OBSC	Okavango Basin Steering Committee
OKACOM	of the Okavango River Basin Water Commission
TDA	transboundary diagnostic assessment
HOORC	Harry Oppenheimer Okavango Research Centre

ACKNOWLEDGEMENTS

All the team members got their hands wet and fishy when close to the fishing team but the following colleagues of the Kavango EFA team are due my sincere thanks as they helped setting nets, collecting fish under sometimes trying and hot conditions : Mark Paxton, Kevin Roberts, as well as David Roberts, volunteer student and staff of the Kamutjonga Inland Fisheries Institute, including Dr Ekkehard Klingelhoeffer and Dominic, Peter and students Elisa and Linda. Celeste Espach gave much information on maps and GIS and is thanked for the preparation of the maps. The report is a product of frank discussions with all team members and especially Jackie King and Angolan [Miguel] and Botswana [Keta] counterparts.

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 socio-economic effects of such possible developments. OBSC recommended at this meeting that a preliminary Environmental Flow Assessment (EFA) be carried out to predict possible development-driven changes in the flow regime of the Okavango River system, the related ecosystem changes, and the consequent impacts on people using the river's resources.

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

1.2 Okavango River Basin EFA Objectives and Workplan

1.2.1 Project objectives

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

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

1.3 Layout of this report

Chapter 1 gives a brief introduction, to the background of the project and lists project objectives. Chapter 2 describes the broad study area of the Okavango River Basin and gives more detail on the two specific sites chosen for this preliminary EFA within the Namibian section of the river- Kapako and Popa rapids. In Chapter 3, highlighted the agreed fish indicators and flow categories. Literature review pertinent to freshwater fishes work in the Okavango River and other similar systems is given in Chapter 4; full indicators are listed. The field survey work undertaken for fish diversity investigation within Namibia in both the dry season (October 2008) and wet season (February 2009); together with data collection, analysis and results are outlined in Chapter 5. Chapter 6 is a first attempt to link fish indicators to flow and provide information on the flow-response relationships for use in the Okavango EF-DSS and will be completed after the Knowledge Capture Workshop in March 2009. . References are found in Chapter 7. Appendix A gives a full description of indicators and Appendix B contains my raw field data.

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. This basin topographically includes the inactive drainage are of the Omatako Omuramba. Although this ephemeral river still regularly floods along its southern portion, it has not contributed any flow to the Okavango River. Outflows from the Okavango Delta are drained through the Thamalakane and then Boteti Rivers, the latter eventually joining the Makgadikgadi Pans. The Nata River, which drains the western part of Zimbabwe, also joins the Makgadikgadi Pans from the east. On the basis of topography, the Okavango River Basin thus includes the Makgadikgadi Pans and Nata River Basin. This study, however, focuses on the active drainage parts of the basin in Angola and Namibia, and the Okavango delta in Botswana. The Omatako Omuramba, Makgadikgadi Pans and Nata River are not included.

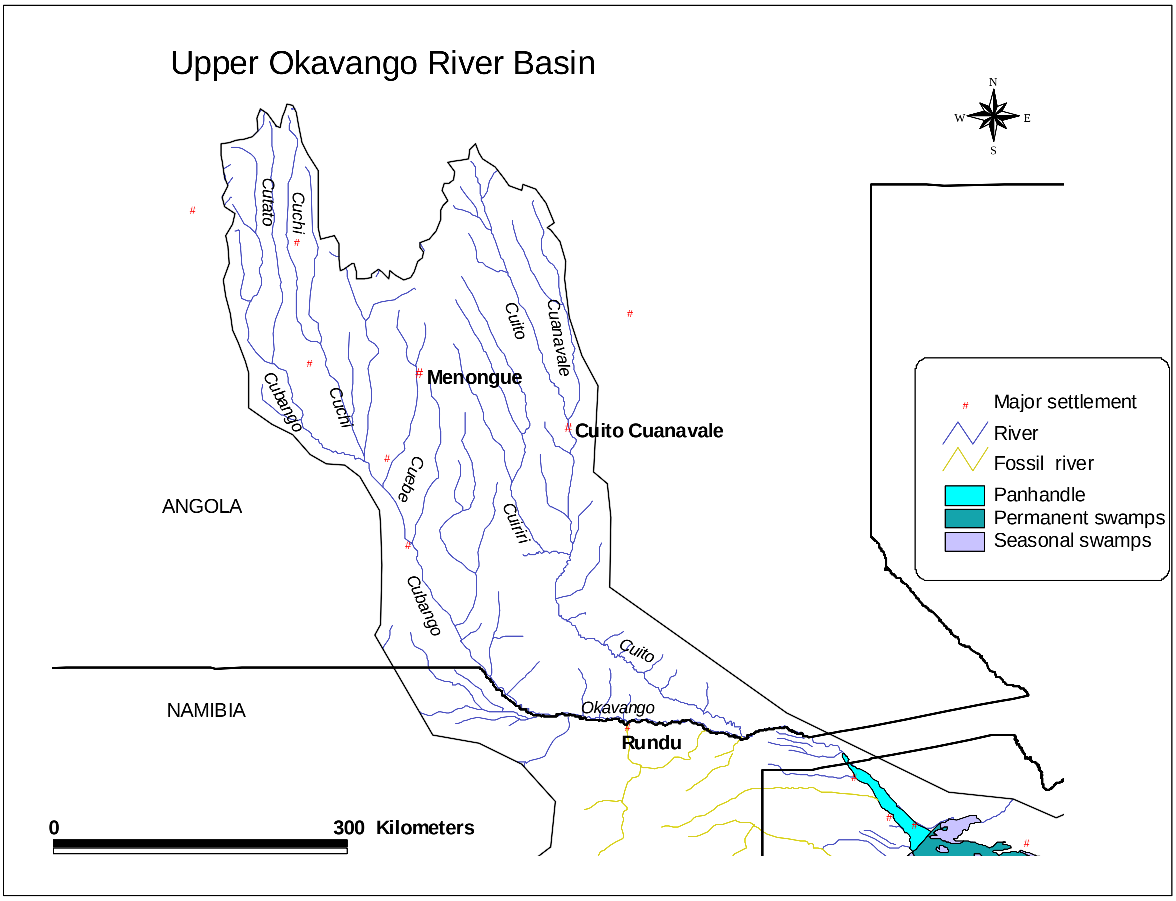

Figure 1 Upper Okavango River Basin from sources to the northern end of the Delta

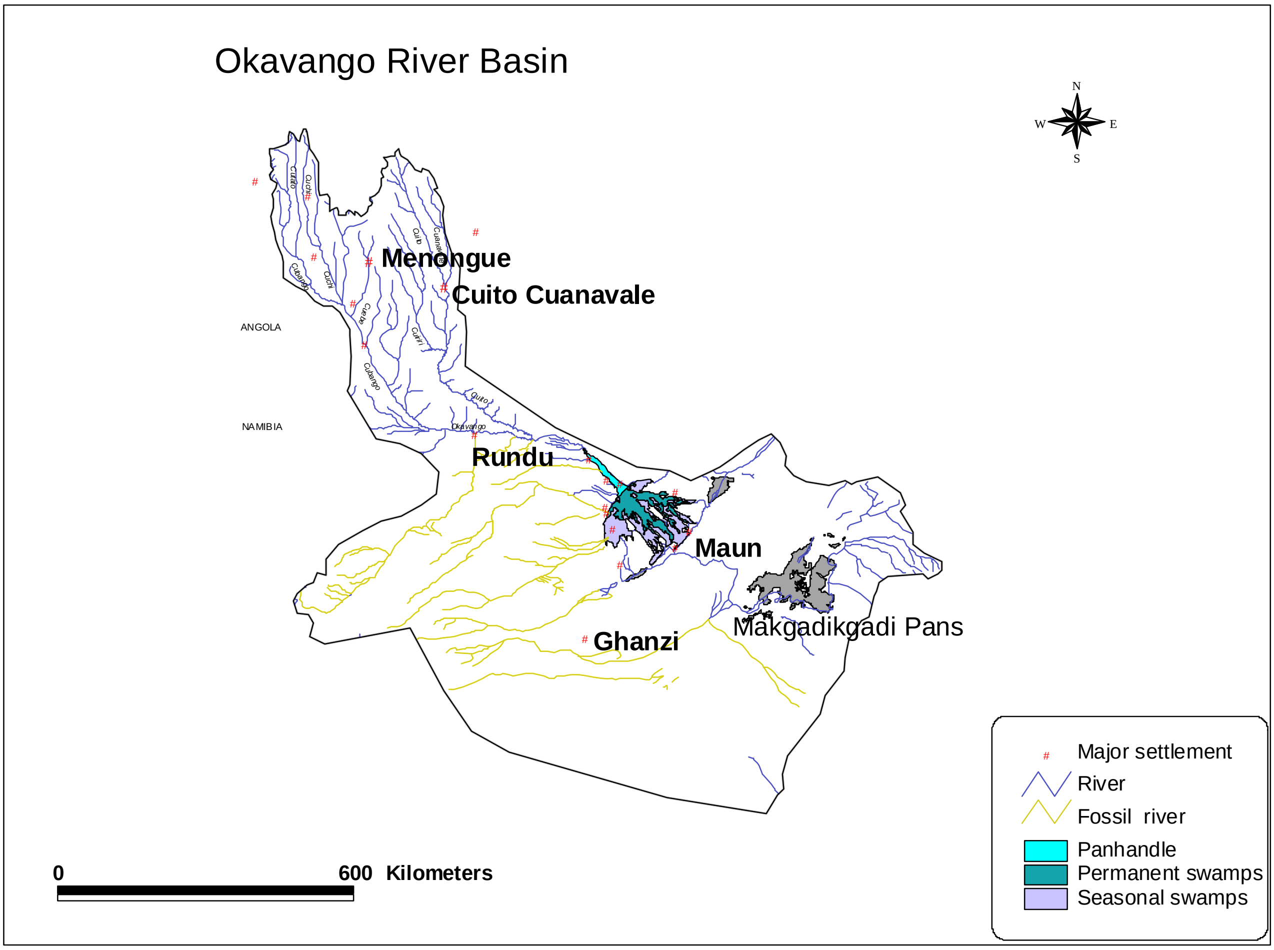

Figure 2 The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans

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

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

Using this approach, the Basin was delineated into Integrated Units of Analysis (EPSMO/Biokavango Report Number 2; Delineation Report) by:

dividing the river into relatively homogeneous longitudinal zones in terms of:

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

- vegetation;
- wildlife

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). See delineation report for details

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

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

The sites chosen by the national teams are given in Table 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	Cuito	Cuito Cuanavale
4	Namibia	Okavango	Kapako
5	Namibia	Okavango	Popa Rapids
6	Botswana	Okavango	Upper Panhandle around Shakawe
7	Botswana	Xakanaka lagoon and Khwai River	Xakanaka in Delta
8	Botswana	Boteti Rivers	Maun and Chanoga

2.3 Overview of sites

2.4 Discipline-specific description of Namibia sites

2.4.1 Site 4: Okavango River at Kapako

Fish habitat types available at Kapako include main stream with sand banks and steep clay banks, reed beds, back waters, side channels, some rocky fast flowing sites, large floodplains with pools and grass covered plains. Back waters and pools in the floodplain contain typical assemblages of submerged vegetation and the floodplains various hydrophilous grasses, some trees and other vegetation. Fish assemblages expected in these habitats would include main channel, backwater, vegetated banks and sand banks.

2.4.2 Site 5: Okavango River at Popa Falls

Fast flowing main channel with islands and mainly rocky bottom bordered by reed and papyrus beds. Small floodplains with small pools are limited. Submerged water plants were limited to small areas in bays of the main channel. Fish assemblages expected in these habitats would include those of the main channel, vegetated banks and rocky substrate.

2.5 Habitat integrity of the sites

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

3.2 Indicator list for fish species

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 – Keta Mosepele of Botswana, Miguel Morais of Angola and Ben van der Waal of Namibia - and is provided in **Error! Reference source not found.** 2. Further details of each indicator, including the representative species of each biological one, are given in Appendix A and discussed fully in Chapter 4.

Table 2: List of indicators for fish 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	**Resident in river**				X	X			
2	**Migrating to floodplains - small fish**				X	X			
3	**Migrating to floodplains – large fish**				X	X			
4	**Rock dwellers**					X			
5	**Sandbank dweller**				X				
6	**Marginal vegetation dwellers**				X	X			
7	**Backwater dwellers**				X	X			

3.3 Description and location of indicators

FISH Indicator 1

Name: **Resident in river**

Description: fish species living mainly in the deeper channel and associated backwaters during adult stages. Some important species undertake longitudinal migrations related to breeding and feeding.

Representative species: *Hydrocynus vittatus, Serranochromis* spp, *Oreochromis spp, Sargochromis spp. Labeo lunatus,*

Other characteristic species: *Brycinus lateralis,*

Flow-related location: flowing channels and deep backwaters enabling migrations up and down the river during certain seasons or water levels for breeding and feeding purposes

Known water needs[1]: require deep water where fish are safe and flow requirements to stimulate migratory response and enable movement. There may be secondary flow requirements to maintain habitat and provide flow and drift of food organisms.

FISH Indicator 2

Name: **Migrating to floodplains – small fish**

Description: Smaller [<25 cm] fish species living in the channel and associated backwaters during low water conditions but migrating into the floodplains when water covers them. On the

[1] food items of species may be even more reliant on water flow characteristics

	floodplains they breed and feed. Mass migrations back to the river occur with receding water.
Representative species:	Marcusenius macrolepidotus, Petrocephalus catostoma, Schilbe intermedius, Barbus paludinosus
Other characteristic species:	Synodontis spp
Flow-related location:	stay in main channel and permanent pools during low water flow, migrating out to floodplain during floods. Migrate back to permanent waters as soon as flood water reaches a certain critical depth.
Known water needs	require deep water where fish are safe during low water in main channel and backwaters but move to flooded floodplains during flood season for feeding and breeding. Rate of flooding and especially receding are critical to survival.

FISH Indicator 3

Name: **Migrating to floodplains – large fish**

Description:	larger [>20 cm] fish species living in the channel and associated deeper backwaters during low water conditions but migrating into the floodplains when water covers them. On the floodplains they breed and feed. Migrations back to the river as soon as water levels drop occur with receding water.
Representative species:	Clarias gariepinus, Schilbe intermedius. Tilapia rendalli,
Other characteristic species:	Clarias ngamensis
Flow-related location:	stay in main channel and permanent pools during low water flow, migrating out to floodplain during floods. Migrate back to permanent waters as soon as flood water reaches a certain critical depth.
Known water needs	require deep water where fish are safe during low water in main channel and backwaters but move to flooded floodplains during flood season for feeding and breeding. Rate of flooding and especially receding are critical to survival.

FISH Indicator 4

Name: **Rock dwellers**

Description:	fish species living amongst rocks and in crevices in strongly flowing water.

Representative species:	Labeo cylindricus, Amphilius uranoscopus, Barbus codringtonii, Synodontis macrostoma, Hippopotamyrus ansorgii, Opsaridium zambezense, Clariallabes platyprosopos, Chiloglanis fasciatus,
Other characteristic species:	Barbus eutaenia, Nannocharax macropterus,
Flow-related location:	strongly flowing water covering rocky bed and bedrock in main channels
Known water needs:	require constant flow of water with little sediments to prevent smothering of crevices.

FISH Indicator 5

Name: **Marginal vegetation dwellers**

Description:	fish species living mainly amongst vegetation on margin of river and may move into floodplains during flood conditions.
Representative species:	Pharynchochromis acuticeps, Tilapia sparrmanii, Petrocephalus catostoma, Barbus poechii, B. multilineatus, B. thamalakanensis, Aplocheilichthys johnstoni,
Other characteristic species:	Pseudocrenilabrus philander
Flow-related location:	stable flow patterns to maintain adapted vegetation on bank of river and associated backwaters and channels.
Known water needs:	require emergent and submerged vegetation for protection. There may be some flow and sedimentation/erosion requirements to maintain vegetation and habitat.

FISH Indicator 6

Name: **Sandbank dwellers**

Description:	fish species living mainly on the actively moving sandbanks or a sandy bottom.
Representative species:	Leptoglanis cf. dorae, Leptoglanis sp, Opsaridium zambezense Barbus unitaeniatus,
Other characteristic species:	Micralestes acutidens
Flow-related location:	flowing water over sandbanks with active erosion/deposition.
Known water needs:	flowing water, absence of high loads of suspended sediments. . Flow requirements to maintain habitat and provide drift of food.

FISH Indicator 7

Name: **Backwater dwellers**

Description:	fish species living mainly amongst vegetation on margin of river and associated backwaters during low water level conditions. May move into floodplains during flood conditions.
Representative species:	Tilapia ruweti, Clarias theodorae, Pollimyrus castelnaui, Barbus bifrenatus, B. barotseensis, B. fasciolatus, B. haasianus, B. lineomaculatus, B. multilineatus, B. thamalakanensis, Coptostomabarbus wittei, Aplocheilichthys A. katangae, A. hutereaui.
Other characteristic species:	Pharyngochromis acuticeps
Flow-related location:	isolated backwaters during low flow conditions and densely vegetated parts of floodplains during flood conditions.
Known water needs:	stable flood patterns [flood and dry cycle] to maintain isolated pools during dry season on the floodplains require emergent and submerged vegetation for protection.

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 **Error! Reference source not found.** to **Error! Reference source not found.** 7. These seasonal divisions will be formalised by the project hydrological team in the form of hydrological rules in the hydrological model. In the interim they provide useful insights into the flow regime of the river system suggesting a higher within-year flow variability of the Cuebe River and a higher year-on-year variability of the Cubango River.

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

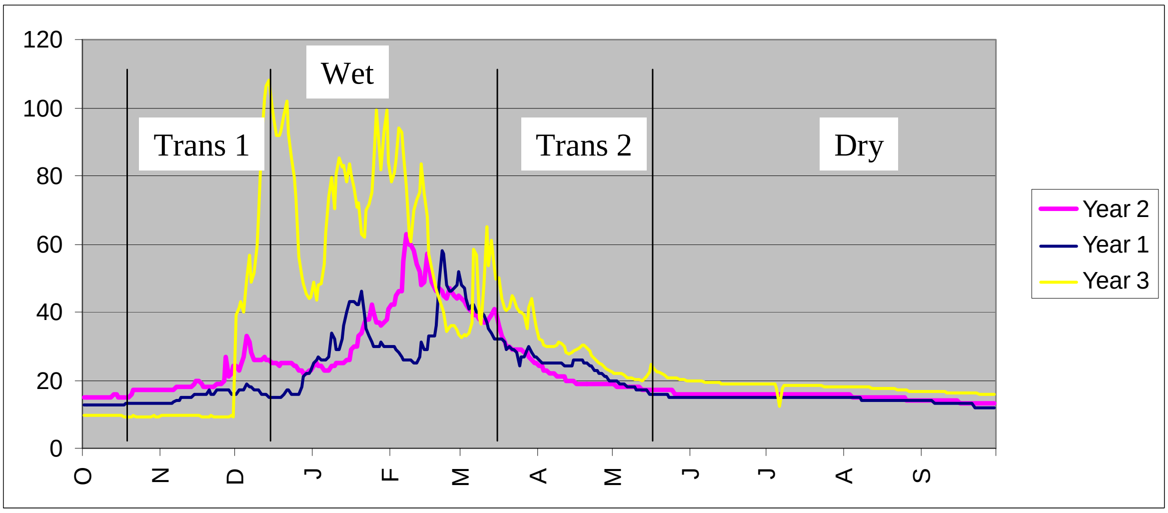

Figure 3. 1 :Three representative years for Site 1: Cuebe River @ Capico, illustrating the approximate division of the flow regime into four flow seasons

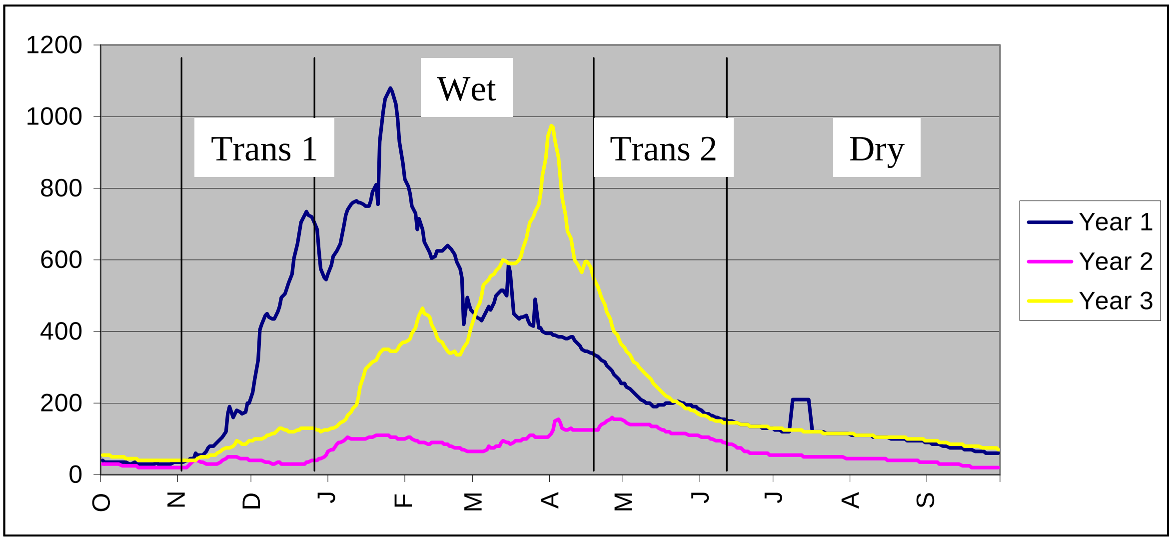

Figure 3. 2: Three representative years for Site 2: Cubango River @ Mucindi, illustrating the approximate division of the flow regime into four flow seasons

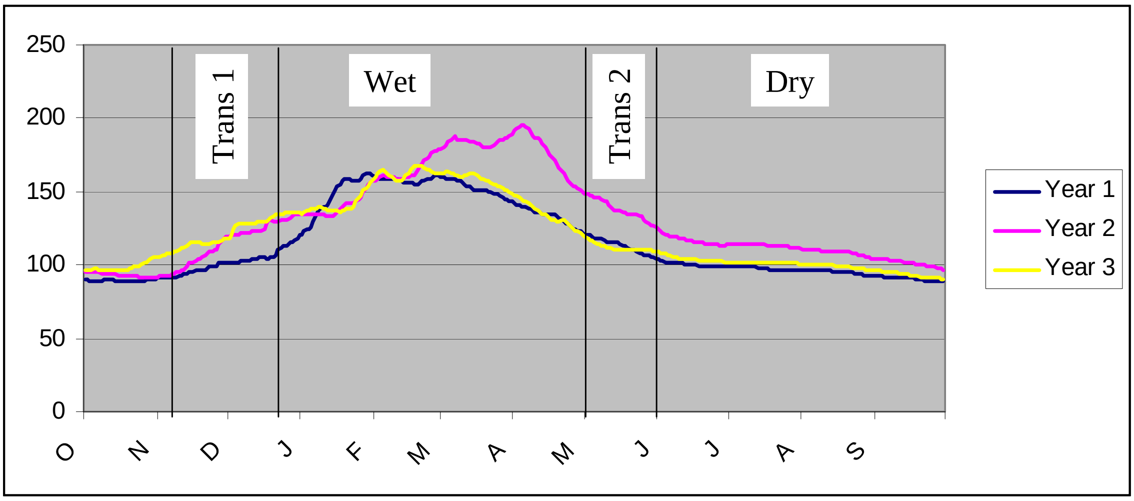

Figure 3. 3: Three representative years for Site 3 Cuito River @ Cuito Cuanavale, illustrating the approximate division of the flow regime into four flow seasons

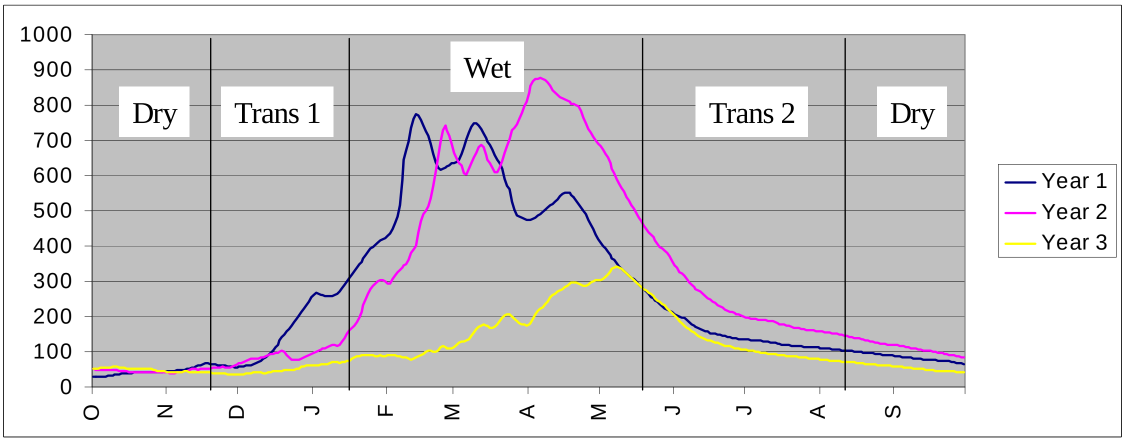

Figure 3. 4: Three representative years for Site 4: Okavango River @ Kapako (hydrological data from Rundu), illustrating the approximate division of the flow regime into four flow seasons

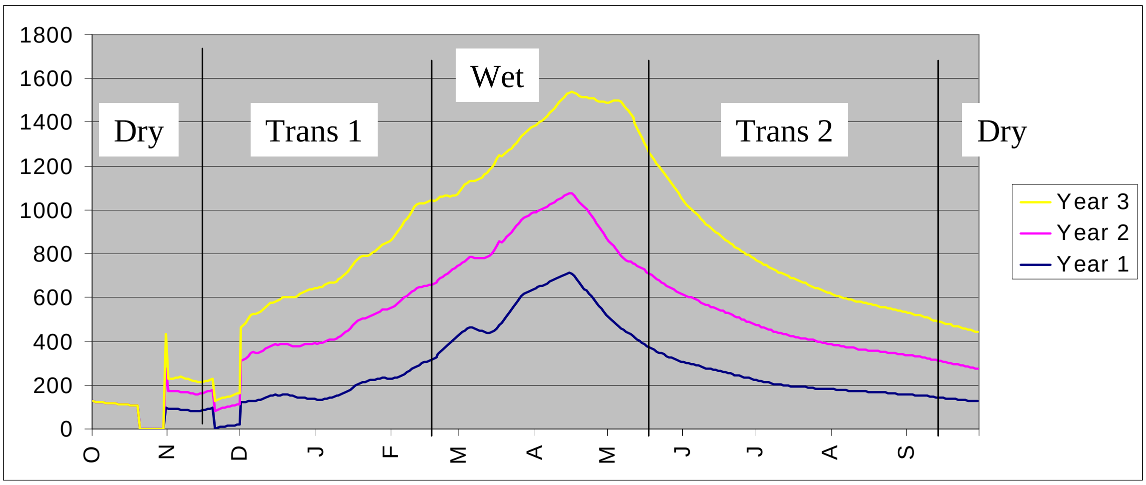

Figure 3. 5: Three representative years for Site 5: Okavango River @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

The literature review (Chapter 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 (**Error! Reference source not found.** 3).

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 and range
6	Flood season	Onset is earlier or later than natural median/average – synchronisation with rain may be changed
7		Natural proportion of different types of flood year changed
8	Transition 2	Onset is earlier or later than natural 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 shown here (**Error! Reference source not found.**).

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

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

	in seasonally flooded zones	
Boteti 1	Wet connected	
Boteti 2	Disconnected pools	
Boteti 3	Dry	

4. LITERATURE REVIEW

Quite some literature exists on the fish life of the lower portion of the Okavango River basin. Basic work on fish species present includes work by Skelton [2001] and Hay and Van Zyl who worked on the fish life of the Kavango River itself. A considerable amount of information has been gathered on changes in the fish community composition and size over 12 years by Hay and MFMR but this data has not yet been analysed or reported on. Preliminary analysis by Van der Waal and Hay [2008] indicate however that the fish populations outside the Muhango National Park [now part of Bwabwata National Park] have less larger cichlids as result of selective gillnetting by the local fishing community. This was confirmed during the experimental gillnetting during the survey [see Appendix B] The conclusion is thus reached that the fish community in the Kavango River outside the national park in Namibia is not pristine anymore but altered as result of fishing pressure. Modern tourist angling practised by lodges and the annual Crockango Bonanza angling competition, are thought to have minimal impact on the fish community as catch-and-release is practised.
Although a considerable amount has been published on the fish biology of the Kavango and Zambezi rivers, relevant information on the actual habitat requirements of fish species is vague. A considerable portion of the argumentation on indicators is therefore based on personal experience and information from colleagues that worked in the area. Apart from consulting with the EFA colleagues in Botswana and Angola, knowledgeable persons like Dr Clinton Hay were also approached for opinion on indicator groups.

4.1 Introduction

All accessible literature was consulted. There is not much specifically on the effect of floods or changes in flow on groups of fish or their behaviour. Being isolated [stationed in Katima Mulilo] without access to a library is a great disadvantage. I will try to get some literature at Kamutjonga Inland Fisheries Institute but time is also limiting. Internet access is very slow with the available landline telephone connections.

4.2 Review of fish Indicators

4.2.1 Indicator 1 Resident in river

Main characteristics of Indicator 1 - resident in river

The fishes migrating in the river stay in the main channels for most of their lives. They require normal flow patterns, including normal seasonal level changes, water quality and quantity within normal ranges. As these fish live in the river, food has to come downstream from shallower, more productive sites, including phytoplankton, detritus and associated diatoms, unicellular organisms and small fish. Upstream and [sometimes] downstream migrations of small fish species when floods recede, may be important to the survival of large resident predators [including largemouths [*Serranochromis* spp] tigerfish and catfish].
Many species undertake longitudinal migrations during specific seasons or part of the flood cycle, such as tigerfish – to breed, catfish – breeding and feeding, mormyrids and some small species – to repopulate part of the system.
This indicator is characterised by large growing species living in the main stream that are not predated on by tigerfish. Lateral migrations by juveniles of these species into the floodplain take place.

Importance of indicator: fish need river with deep holes and backwaters in which they can stay. Maintenance of the flow characteristics during the whole annual flood cycle is important. Habitats in the river must provide the food required. Other requirements for the nesting cichlids are shallower sand banks to nest on [discussed under Indicator 5].

species	**Habitat requirements**	**Chosen representative species**
Oreochromis andersonii	Deep slower flowing water, supply of detritus in current, shallower sandy sandbanks in side channels and backwater with slow flow in early spring to early summer	X
O. macrochir	Deep slower flowing water, supply of detritus in current, shallower sandy sandbanks in side channels and backwater with slow flow in early spring to early summer	x
Serranochromis robustus	Steep banks with hiding spots or aquatic vegetation along strongly flowing deep water. Also suitable nesting places in 1-2m deep still water on edge of vegetation during early spring for spawning and incubation	x
S. altus	Hiding places amongst vegetation on edge of fast flowing channels. Clean water with good visibility and nesting sites amongst aquatic and emergent vegetation in shallower areas during spring	
Sargochromis giardi	Deep water holes and backwash with detritus and mollusc life [food]] in deep channels. Breeds in shallower water on \sandbanks in slow flowing side channels and backwaters	
Hydrocynus vittatus	Open and running water of river channel and open backwaters and channels. Require deep water and clear water conditions. Migrate after food and undertake longitudinal breeding migrations	x
Labeo lunatus	Deep water in mainstream and backwaters, feed on detritus and algae. Undertake longitudinal breeding migrations	

Life cycle attributes of Indicator 1 resident in river

This guild stays in deep pools and eddies in the main stream and backwaters during low water levels and partly also during the flood season. They find their food there [detritus plays an important role as food for vegetarian cichlids] Predatory fish rely on small fish species migrating into the channel during draw down phase. Longitudinal migrations during early summer for breeding [tigerfish] and feeding [tigerfish and catfish during late summer occur. Longitudinal migrations of young of many species take place during the draw down phase. Barbs and robbers move mainly upstream but some fish [mormyrids in Zambezi] move downstream and form basis of a traditional fishery

Links to flow

- Fish require deep holes [more than 3m during low level] to feel at ease [else get spooked too often and will move away]. Such holes and pools must be maintained by the current and large floods are needed to shape the channel.
- Fish find their food mainly visually; murky water would impact seriously
- Cichlids breed on communal shallow sandbanks or backwaters, 1-2m deep during the early spring. Water temperature must be around 20o and flow rate slow. Very muddy environments will be detrimental.
- Tigerfish and others undertake spawning migrations and move also during certain seasons.
- Emergent and submerged aquatic vegetation is important for the survival of young fish. Some lateral movement by young fish into floodplains or vegetated areas occurs in summer, so some flooding would also be a necessity.

4.2.2 Indicator 2 Migrating to floodplains – small fish

Main characteristics of Indicator 2

Small fish [smaller than 25cm max length] living in the main channel but migrating into the floodplains are characterised by migrations associated with water levels, breeding activities and feeding requirements. Breeding is stimulated by rising water levels and prespawning migration and concentrations may occur [in bulldogs and barbs].

species	**Habitat requirements**	**Chosen representative species**
Marcusenius macrolepidotus	Amongst vegetation in deep channels. Moves onto floodplain to feed and breed late with the peak of the flood. Mass migrations back to the river take place with receding water levels	x
Schilbe intermedius	Lives in deep pools on side of channels. Moves into channels in floodplain and moves onto floodplain to hunt. Spawning is late with peak flood.	
Barbus paludinosus	Lives in marginal vegetation in river but moves with first floodwater onto floodplain to colonise new deeper water bodies on floodplain. Breeds on floodplain, more than one generations per year.	
Synodontis spp	Lives in deeper pools in the main river and amongst structure [stumps , roots etc] but migrates out onto the floodplain later in the season to feed and breed. Stays in pools in the floodplain and migrates back when floods recede.	

Life cycle attributes of Indicator 2

Fish of this guild live in the main river and deeper pools during the low phase of the hydrological cycle but migrate laterally into the floodplain when floods start. Reasons for this migration are feeding or breeding. It must be remembered that many juveniles of many species from other indicators all migrate out of the main channels into the floodplain for protection and feeding purposes and only return to the deeper channels when the flood recedes.

Links to flow

- Migration onto floodplain takes place at different stages of flood by different species [eg *B. paludinosus* and other *Barbus* spp are early migrators and *Marcusenius* and *Schilbe* and *Serranochromis* move later]. Timing of flood is thus very important to all these species as a late flood may depress successful spawning. A very early flood similarly affects spawning cycles negatively. This explains the absence of upstream migrations in the main channel of small fish during certain years when floods are small or out of phase.
- The rate of filling of the floodplain may be very important for the stimulation of spawning of the different species.
- Feeding success depends on continued fertility of the floodplain, again depending on sediment deposition and maintenance of the floodplain vegetation and cycling of nutrients.
- Any disruption in the erosion and sedimentation in and onto the floodplain [including removal of certain particle size by trapping in dams built higher up in the river], would have a serious cascading effect on this indicator.

4.2.3 Indicator 3 Migrating to floodplains – large fish

Main characteristics of Indicator 3

Larger growing fish living in the main channel but migrating into the floodplains are characterised by migrations associated with water levels, breeding activities and feeding requirements. Breeding is stimulated by rising water levels and prespawning migration and concentrations may occur [in tigerfish and catfish].

species	**Habitat requirements**	**Chosen representative species**
Clarias gariepinus	Deep water pools in river, but moves into shallow water for feeding purposes. Migrates into floodplain with first rise of flood to spawn on freshly inundated vegetation. Stays in deeper pools of floodplain to feed	x
Clarias ngamensis	Deep backwater pools and lakes. Feeds on molluscs and seeds, migrates onto floodplain for early breeding and feeding	
Tilapia rendalli	Moves from side of channels onto floodplain with first floodwater. Constructs nest in water shallower than 60cm amongst vegetation.	x

	Vulnerable to draw down asit is a nest brooder	

Life cycle attributes of Indicator 3

Fish of this guild live in the main river and deeper pools during the low phase of the hydrological cycle but migrate laterally into the floodplain when floods start. Reasons for this migration are feeding or breeding. It must be remembered that many juveniles of many species from other indicators also migrate out of the main channels into the floodplain for protection and feeding purposes and only return to the deeper channels when the flood recedes.

Links to flow

- Migration onto floodplain takes place at different stages of flood by different species [eg *Clarias* and *T. rendalli* are early migrators and *Oreochromis* and *Serranochromis* move later]. Timing of flood is thus very important to all these species as a late flood may depress successful spawning. A very early flood similarly affects spawning cycles negatively. This explains the absence of upstream migrations in the main channel of small fish during certain years when floods are small or out of phase.
- The rate of filling of the floodplain may be very important for the stimulation of spawning of the different species.
- Feeding success depends on continued fertility of the floodplain, again depending on sediment deposition and maintenance of the floodplain vegetation and cycling of nutrients.
- Any disruption in the erosion and sedimentation in and onto the floodplain [including removal of certain particle size by trapping in dams], would have a serious cascading effect on this indicator.

4.2.4 Indicator 4 Rock dwellers

Main characteristics of Indicator 4

Species all associated with rocky areas with strong flow where no sedimentation takes place. Many species are only known from such habitats and may be the most sensitive fish indicators. The whole life cycle is completed in this habitat. Feeding is dependent on drift from other areas with exception of algal feeders such as *Labeo cylindricus* and *Chiloglanis spp.*

species	**Habitat requirements**	**Chosen representative species R= rheophilic**
Amphilius uranoscopus	Crevices in rocks, nocturnal insectivore	X R
Labeo cylindricus	Around rocks, feeding on aufwuchs	X
Barbus codringtonii	Deeper channels amongst rocks, feeding	

	on pebble beds	
Synodontis macrostoma	Crepuscular in crevices	
Hippopotamyrus ansorgii,	Crepuscular associated with rocks	
Clariallabes platyprosopos	Found only in crevices next to fast running water	X R
Opsaridium zambezense	Over sand in cascade environments	
Aethiomastacembelus vanderwaali	Crepuscular in crevices in rocks in fast flowing water	X R
Nannocharax macropterus	Deeper water and runs next to rocks	
Chiloglanis fasciatus,	In crevices and on rocks, can move in open sucking aufwuchs from rocks	X R
Barbus eutaenia	Deeper runs associated with cascades	

Life cycle attributes of Indicator 4

All fish of this indicator prefer clear, fast flowing water with very little transported or deposited sediment. The rocks and bedrock must be kept open and no sedimentation take place or crevices filled with sediment.
All food items have to be derived from other systems in the river and exported for consumption.

Links to flow

- Real rheophilic species [marked in table with R] live in crevices in the bedrock in flowing water conditions only and are reliant on these conditions. Any change in flow rate including lowering of water level, decrease in flow rate below normal ranges, increase in sediment load, change in water quality, including water temperature, dissolved oxygen end conductivity, will affect this groups seriously.
- Associated species rely on fast flowing water over rocks providing microhabitats including course sand beds, pebbles, sparse aquatic vegetation, cascades and protected pools.
- Rock dwellers can be divided into two feeding groups: a feeding on algal growth on rocks [labeo and Chiloglanis] and insectivores [most other species] these last are fully reliant on the provision of food arriving moistly from outside this habitat.
- Breeding is associated with floods at the normal time. Some species undertake longitudinal migrations eg *Labeo* and *Barbus*.

4.2.5 Indicator 5 Marginal vegetation dwellers

Main characteristics of Indicator 5

Species living in protected environment of emergent and/or submerged vegetation on the edge of the river during low water conditions and more widely spread on the floodplain during floods. This groups also includes many young of larger cichlids [*Oreochromis, Tilapia, Sargochromis* and *Serranochromis* as well as *Clarias* spp, *Schilbe, Synodontis* and *Mormyrids]*. These fish all seek protection from predation mainly from the tigerfish but also larger *Serranochromis* species.

species	Habitat requirements	Chosen representative species
Pharynchochromis acuticeps	Associated with emergent vegetation on river edge but also in open water	X
Tilapia sparrmanii	Strongly associated with marginal vegetation, moving to floodplain during floods	X
Petrocephalus catostoma	Hiding in marginal vegetation during daytime and moving actively at night	X
Barbus poechii,	Associated with deeper water amongst vegetation.	
B. multilineatus	Amongst vegetation	
B. thamalakanensis	Amongst vegetation	
Aplocheilichthys johnstoni	Lives exclusively at the surface of water amongst submerged and emergent aquatic plants	X
Hemichromis elongatus	On river margin near aquatic plants. Nesting species constructing nest in shallow area	
Pseudocrenilabrus philander	Strongly associated with vegetation and also nesting there	X

Life cycle attributes of Indicator 5

This group lives mainly on the edge of the main channels and tributaries.
It is comprised of smaller species that are in themselves very vulnerable to predation by top predators.
Suitable marginal vegetation is important for survival. Any loss of marginal vegetation will impact negatively on this group.

Links to flow

- During low flow conditions, this group is most susceptible to predation as their habitat may not have the vegetation needed to protect them.
- Species breed along marginal vegetation and also find their food there, comprising of detritus and small aquatic organisms.
- The cichlids in this group eat insects and other invertebrates.
- Other species feed on insects and invertebrates and are dependent on the spatial distribution of these insect pests.

4.2.6 Indicator 6 Sandbank dwellers

Main characteristics of Indicator

Specialist group living on/on fast flow over sandbanks,
Live on lower, actively depositing portion of sandbanks [before drop-off]
Depend on flow rate and particle size of sandbank [course grained, sorted]

species	Habitat requirements	Chosen representative species
Leptoglanis cf dorae, L. sp	Lives only in loose graded sand on top of sandbanks in running water. Lives on small invertebrates caught while buried with eyes only exposed.	X
Barbus unitaeniatus	Prefers sandbanks and flowing water, feeds on sand bottom, selecting organisms and detrital particles.	X
Opsaridium zambezense	Active mini predator preferring clean sandy bottom on sandbanks or below rapids	X
Micralestes acutidens	Active scavenger on edge of sandbanks	

Life cycle attributes of Indicator 6

- Small fish species adapted to bury in loose sand or swim in current over sand. Some are confined to this habitat only [*Leptoglanis*] but others– have a more wide distribution [*Micralestes*].
- Fish need active flow of water over sandbanks to created unique required habitat and to provide inflow of food items from other parts of the river. The sand specialist *Leptoglanis* spp require loose graded sand, found only where sandbanks are actively moving.

Links to flow

- Sandbanks can only exist where there is a dynamic balance between flow and bed load and erosion and deposition. Any change in these will bring about a disappearance of the type of sandbanks found in the Kavango River.
- Fish species catch food on sight and need clear water.
- Fish species are all adapted to the white colour of the sand – a change in colour may make these species more visible.
- They breed on the edge of the river during summer, requiring typical early flood flow rates.

4.2.7 Indicator 7 Backwater dwellers

Main characteristics of Indicator 7

Species of this group are small species adapted to live in shallow water and dense vegetation where environmental conditions can become extreme in terms of water temperature, oxygen levels and conductivity and pH. During the low water phase, they survive in backwater pools on the floodplain and when floods arrive, they are the first to migrate with the water to colonize newly inundated areas and harvest the rich food resource. Most species are insectivores as well as plankton feeders and piscivores. Most breed on the floodplain and are stimulated by rising floods.

species	**Habitat requirements**	**Chosen representative species**
Tilapia ruweti	Densely vegetated shallow standing water at edge of floodplain	X
Clarias theodorae	Dense aquatic vegetation in pools and edge of floodplain	X
Pollimyrus castelnaui	Densely vegetated areas and pools on the floodplain	X
Barbus haasianus	Densely vegetated shallow edges of pools and edge of floodplain	X
B. bifrenatus, B fasciolatus, B. lineomaculatus, B. multilineatus	Amongst emergent vegetation on edge of streams and pools and edge of floodplain	
Aplocheilichthys katangae, A hutereaui	Amongst floating and emergent vegetation on edge of streams and pools on floodplain	X
Coptostomabarbus wittei	Densely vegetated margins of pools and edge of floodplain	

Life cycle attributes of Indicator 7

- This indicator relies on survival of fish in small inocula on the floodplain, non drying pools on the floodplain during the dry season.
- During floods they move over the floodplain and require well vegetated areas for protection and breeding.
- This group comprises small species that are adapted to live in sometimes harsh environments and play an important role in nutrient cycling, utilizing the wealth of terrestrial and later aquatic invertebrates developing on the edge of the floodplain.
- They themselves play an important role as food for many of the predatory species [there are more than 20 predators in the system]
- This group is also important to the Kavango people as they form an important part of the fish harvested with baskets by women.

Links to flow

- Indicator species depend on survival in isolated pools on the floodplain during the dry phase of the flood cycle.
- Maintenance of the vegetation cover is important during all stages of the flood.
- floods are essential for feeding and breeding. Pools must maintain their shape, depth and fertility, all a function of scouring and sedimentation during floods.
- High and strong floods are needed to maintain the existents of deep pools on the floodplain.

4.3 Summary

A considerable amount of basic research has been conducted on the fish life of the Kavango in Namibia by mainly Hay of the Ministry of Fisheries and Marine Resources [MFMR]. This research was however directed at fisheries management and not at flood and flow requirements of fish species. A substantial record of the presence and abundance of fish species at six major sites was collected over a 12 year period that is valuable to monitor any changes that have taken place or may take place in future. The identification of indicators was not easy as group 1 for instance, contain some species that warrant a separate indictor of fish remaining in the channel, like *Serranochromis robustus*, which does not show any migratory trends [according to telemetry work by Thorstad et al 2001, 2003, 2005].

5. DATA COLLECTION AND ANALYSIS

5.1 Methods for data collection and analysis

Fish data were collected at the Kapako and Popa Falls sites [and additionally at Kwetze, Mahangu, Bwabwata National Park] on the following dates:

site	KAPAKO	POPA FALLS	KWETZE
LOW WATER	20-21 October 2008	21-22 October 2008	22-23 October 2008
HIGH WATER	7-8 January 2009	97 January 2009	
HIGH WATER	8-9 February 2009	10-11 February 09	

and using the following fishing gear:

1. 2 fleets of gillnets each consisting of 11 panels of 10 m length each of the following stretched mesh size: 12, 16, 22, 28, 35, 45, 57, 73, 93, 118 and 150mm. They were set overnight in representative habitats suitable for gillnet fishing [with least flow and at least 1m depth] at each site. The fish caught overnight over a 12h period were identified and length and sexual condition established.
2. Seine net of 8m by 2 m deep with bag of 2m deep and with 10mm mesh. This was used to collect fish in pools of up to 100cm depth. All fish collected were identified and length taken for each fish.

Fish shocker in conjunction with a large D-net [scoop net]. A 900W AC 220V portable generator was directly connected to two electrodes attached to an inverted V pole keeping the electrodes 30cm apart. This was used only in the rapids of Popa to collect rock living fish species. Fish were flushed out by the current introduced with the electrodes and the strong current then washed them into the D-net held

5.2 Results

The exact localities on the two study sites where fish were collected with a variety of fishing gear are illustrated in Figures 8 to 12. downstream. This apparatus could only be used in water 50cm or less deep.

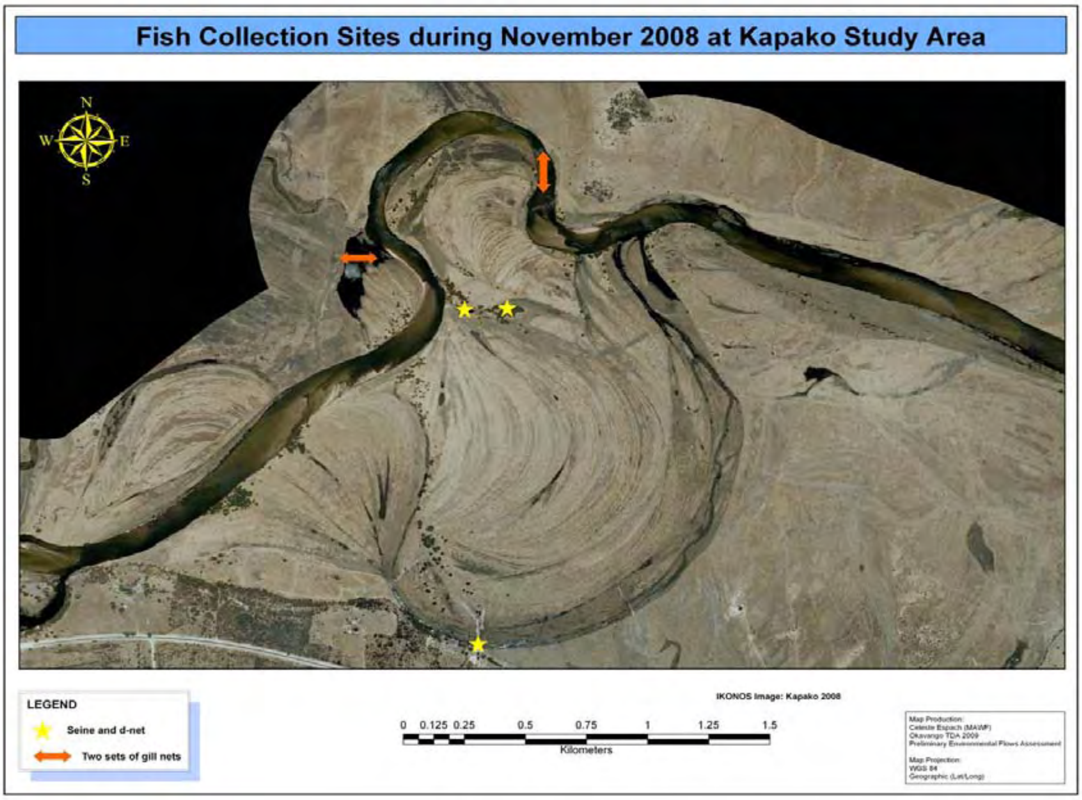

Figure 4. 1: Fish collection sites with two sets of gill nets [red arrows] and seine net [yellow stars] at the Kapako site in November 2008

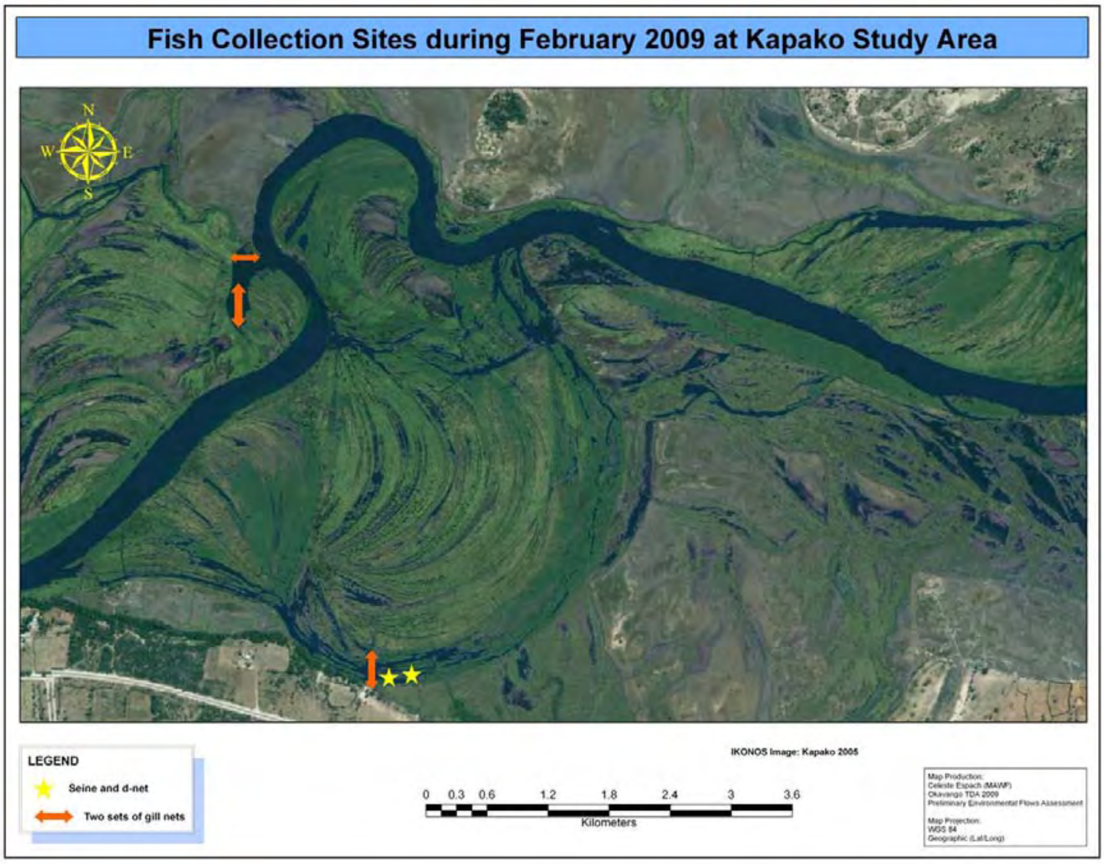

Figure 4. 2: Fish collection sites with two sets of gill nets [red arrows] and seine net [yellow stars] at the Kapako site in February 2009.

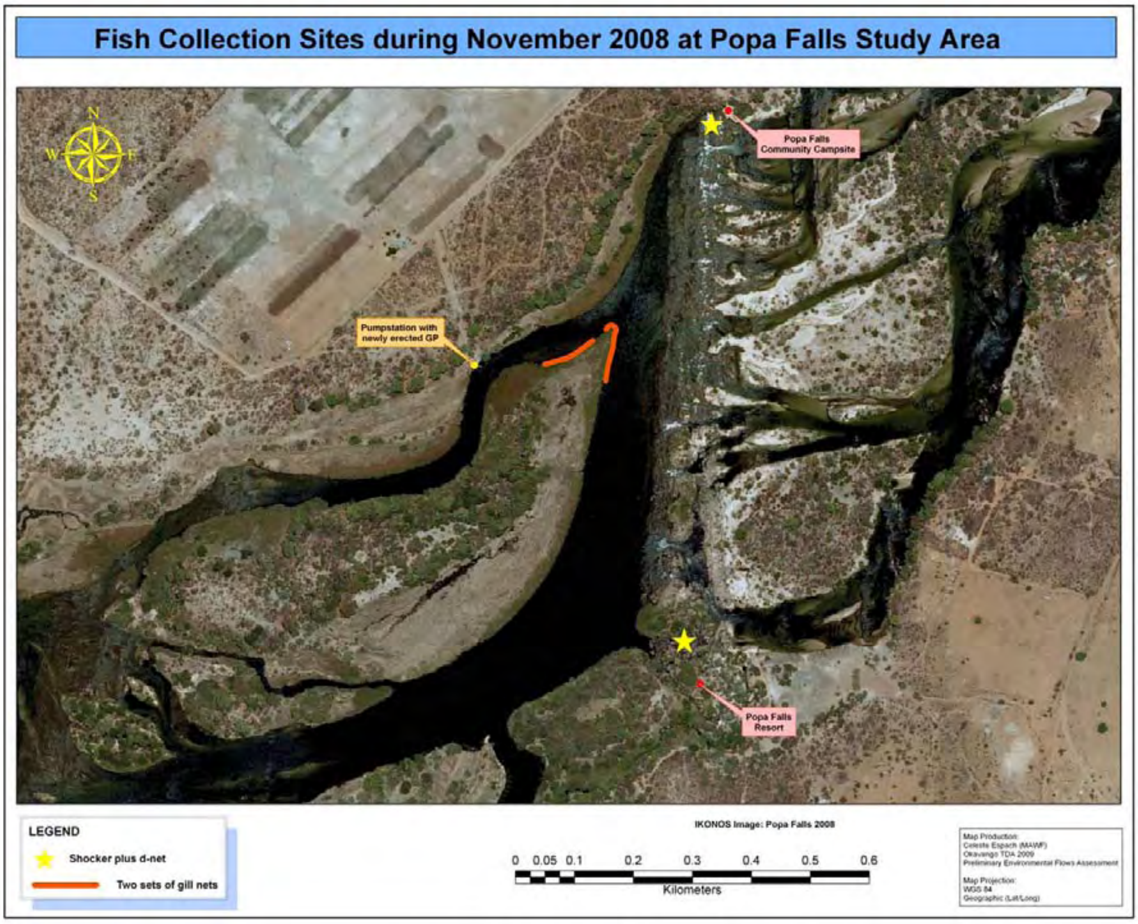

Figure 4. 3: Fish collection sites with two sets of gill nets [red arrows] and electrofisher and D-net [yellow stars] at the Popa Falls site in November 2008.

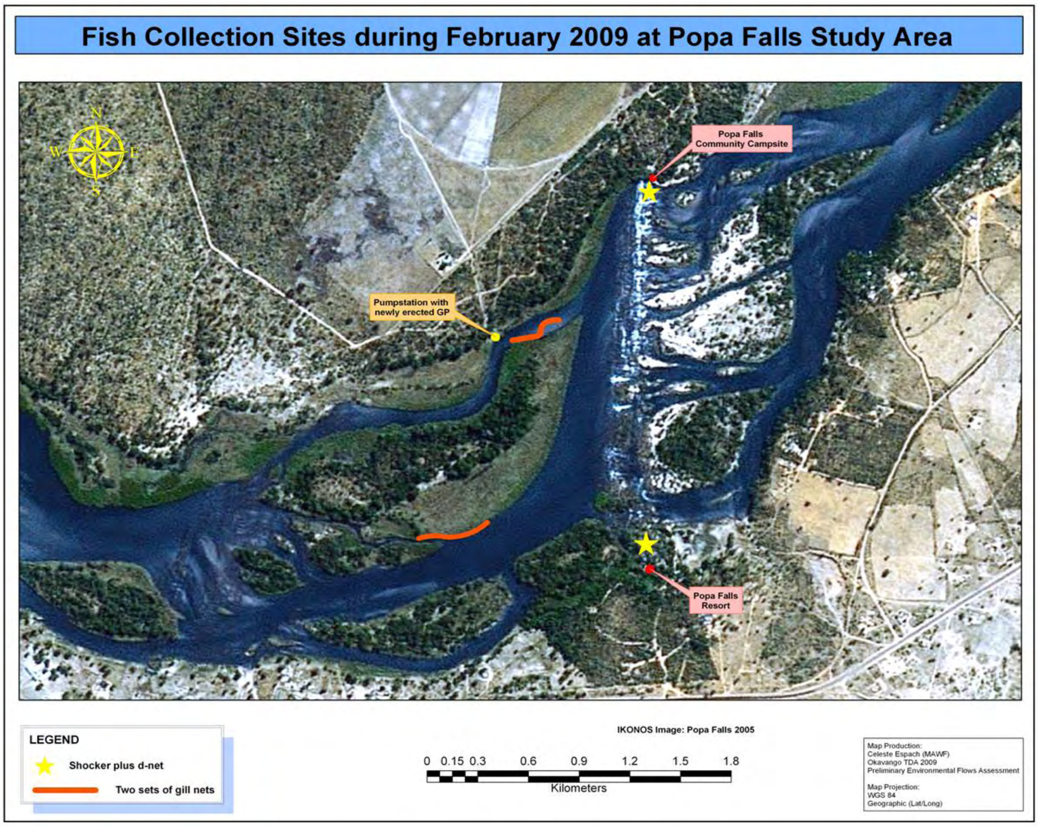

Figure 4. 4: Fish collection sites with two sets of gill nets [red arrows] and electrofisher and D-net [yellow stars] at the Popa Falls site in February 2009.

The fish collections during the low and high water levels represent the expected indicators. For details on the actual fish species, numbers and sizes collected, please refer to Appendix B. Results on the presence of indicators at the two study sites are summarized in Tables 5 and 6. Apart from data from the two surveys, previously collected data from 1982 to 2008 was also considered.

Table 5: Status of fish indicators at sites in Namibia during low water conditions at the two Namibian sites.

Indicator	**KAPAKO**	**POPA FALLS**
Resident in river	ABUNDANT	ABUNDANT
Migrating to floodplains – small fish	ABUNDANT	RARE
Migrating to floodplains – large fish	ABUNDANT	RARE
Rock dwellers	ABSENT	ABUNDANT
Sandbank dweller	RARE	VERY RARE
Marginal vegetation dwellers	ABUNDANT	RARE
Backwater dwellers	ABUNDANT	RARE

Table 6: Status of fish indicators at sites in Namibia during high water flood conditions at the two Namibian sites.

Indicator	**KAPAKO**	**POPA FALLS**
Resident in river	ABUNDANT	ABUNDANT
Migrating to floodplains – small fish	ABUNDANT	VERY RARE
Migrating to floodplains – large fish	ABUNDANT	RARE
Rock dwellers	VERY RARE	ABUNDANT
Sandbank dweller	RARE	VERY RARE
Marginal vegetation dwellers	ABUNDANT	RARE
Backwater dwellers	ABUNDANT	RARE

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

Tables of expected response of fish indicators to change in flow regime in the Namibian sector of the Kavango River are presented in the following tables [Table 7 to

5.3.1 Fish Indicator 1 - Resident in river

Table 7: Predicted response to possible changes in the flow regime of fish resident in river in the Okavango River ecosystem - Indicator 1

Question number	Season	Possible flow change	Predicted response of indicator Site 4 Kapako	Site 5 Popa rapids	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negative if earlier No effect if later unless it interferes with breeding season in case of cichlids	Negative if earlier No effect if later unless it interferes with breeding season in case of cichlids	medium
2		Water levels are higher or lower than natural	Higher = less effect Lower = vulnerable, may interfere with spawning of cichlids	Higher = less effect Lower = vulnerable, may interfere with spawning of cichlids	high
3		Extends longer than natural	Negative effect – vulnerable and spawning delayed of non-cichlids	Negative effect – vulnerable and spawning delayed of non-cichlids	high
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Steep rise may affect spawning sites of nesting species	Steep rise may affect spawning sites of nesting species	high
5		Flows are more or less variable than natural	Nil - acceptable	Nil - acceptable	Low [but system is very robust]
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier flood: may be out of synch with spawning season, Late flood : not so much [Delta fish breed later]	Earlier flood: may be out of synch with spawning season, late flood: not so much [Delta fish breed later]	medium
7		Natural proportion of different types of flood year changed	High floods are important for survival of group – direct connection between high flood and good fishery catches two years later. More lower floods – has direct depressing effect on fish production.	High floods are important for survival of group – direct connection between high flood and good fishery catches two years later]More lower floods – has direct depressing effect on fish production.	High – have data
8	Transition 2	Onset is earlier or later than natural	Early decrease – may affect breeding in late spawners Late decrease – no effect	Early decrease – may affect breeding in late spawners Late decrease – no effect	low

9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Steep hydrograph slope may affect survival of young fish negatively. Longer duration – no effect	Steep hydrograph slope may affect survival of young fish negatively. Longer duration – no effect	low

5.3.2 *Fish Indicator 2 - Migrating to floodplains – small fish*

Table 8: Predicted response to possible changes in the flow regime of fish Migrating to floodplains – small fish in the Okavango River ecosystem - Indicator 2

Question number	Season	Possible flow change	Predicted response of indicator Site 4 Kapako	 Site 5 Popa rapids	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negative for non-cichlids if later Negative for cichlids if earlier than normal	Effects not prominent	medium
2		Water levels are higher or lower than natural	Higher is OK If low, fish are affected during most sensitive stage	Affected if water levels are lower, not if higher	high
3		Extends longer than natural	Negative for all fish	Effects not prominent	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer = no effedct, shorter means no opportunity to migrate, strong currents on floodplain, loss by predation	Negative on migration if shorter	high
5		Flows are more or less variable than natural	Higher variability is detrimental	Higher variability is detrimental	high
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier flood season – may have devastating effect – no migration, no successful breeding. Late flood – may affect fish but not sure as Delta fish are adapted – same species	Earlier flood season – may have devastating effect – no migration, no breeding. Late flood – may affect fish but not sure as Delta fish are adapted –same species	low
7		Natural proportion of different types of flood year changed	Negative long term effect	Negative long term effect	medium
8	Transition 2	Onset is earlier or later than natural	Earlier = short production cycle on flood plain. Later – no effect	Earlier = short production cycle on flood plain. Later – no effect	medium
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Shorter transition– negative to fish. Extended season = beneficial for fish life.	Shorter season – negative to fish. Extended season = beneficial for fish life.	medium

5.3.3 Fish Indicator 3 - Migrating to floodplains – large fish

Table 9: Predicted response to possible changes in the flow regime of fish Migrating to floodplains – large fish in the Okavango River ecosystem - Indicator 3.

Question number	Season	Possible flow change	Predicted response of indicator		Confidence in prediction (very low, low, medium, high)
			Site 4 Kapako	Site 5 Popa rapids	
1	Dry Season	Onset is earlier or later than natural	Negative for non-cichlids if later Negative for cichlids if earlier than normal	Effects not prominent	medium
2		Water levels are higher or lower than natural	Higher is OK If low, fish are affected during most sensitive stage	Affected if water levels are lower, not if higher	high
3		Extends longer than natural	Negative for all fish	Effects not prominent	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer = no effedct, shorter means no opportunity to migrate, strong currents on floodplain, loss by predation	Negative on migration if shorter	high
5		Flows are more or less variable than natural	Higher variability is detrimental	Higher variability is detrimental	high
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier flood season – may have devastating effect – no migration, no successful breeding. Late flood – may affect fish but not sure as Delta fish are adapted –same species	Earlier flood season – may have devastating effect – no migration, no breeding. Late flood – may affect fish but not sure as Delta fish are adapted – same species	low
7		Natural proportion of different types of flood year changed	Negative long term effect	Negative long term effect	medium
8	Transition 2	Onset is earlier or later than natural	Earlier = short production cycle on flood plain. Later – no effect	Earlier = short production cycle on flood plain. Later – no effect	medium

9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Shorter transition– negative to fish. Extended season = beneficial for fish life.	Shorter season – negative to fish. Extended season = beneficial for fish life.	medium

5.3.4 *Fish Indicator 4 - Rock dwellers*

Table 10: Predicted response to possible changes in the flow regime of fish Rock dwellers in the Okavango River ecosystem – Indicator 4

Question number	Season	Possible flow change	Predicted response of indicator		Confidence in prediction (very low, low, medium, high)
			Site 4 Kapako	Site 5 Popa rapids	
1	Dry Season	Onset is earlier or later than natural	No effect	Both have negative effect	medium
2		Water levels are higher or lower than natural		Higher – no effect Lower level serious effect, shrinking of already small habitat type	medium
3		Extends longer than natural		Negative effect – breeding may be depressed	low
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		Longer – little effect Shorter – sudden changes in flow and conditions may affect feeding and breeding preparation	low
5		Flows are more or less variable than natural		Extremes both detrimental	medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed		Early flood – out of synch with natural spawning cycle Late flood – again affect breeding	low
7		Natural proportion of different types of flood year changed		Extremes, especially low flows are detrimental for these fish	medium
8	Transition 2	Onset is earlier or later than natural		Earlier drop may affect habitat food supply and breeding for late spawners Later – no effect	medium
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		Extremes may have serious effect on survival	medium

5.3.5 Fish Indicator 5 - Sandbank dwellers

Table 11: Predicted response to possible changes in the flow regime of fish Sandbank dwellers in the Okavango River ecosystem – Indicator 5

Question number	Season	Possible flow change	Predicted response of indicator Site 4 Kapako	 Site 5 Popa rapids	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negative effect if earlier. Later – little effect	Negative effect if earlier. Later – little effect	medium
2		Water levels are higher or lower than natural	Lower than normal – serious effect Higher – may affect shape and quality of sand banks directly, and thus the fish	Lower than normal – serious effect Higher – may affect shape and quality of sand banks directly, and thus the fish	high
3		Extends longer than natural	Negative impact	Negative impact	high
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Both may have effect on physical structure of sand bans. Food shortages develop with extended period	Both may have effect on physical structure of sand bans. Food shortages develop with extended period	medium
5		Flows are more or less variable than natural	Extreme flows detrimental	Extreme flows detrimental	medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Breeding season of fish species may be affected.	Breeding season of fish species may be affected.	medium
7		Natural proportion of different types of flood year changed	Extremes may affect sandbank development, feeding and breeding	Extremes may affect sandbank development, feeding and breeding	high
8	Transition 2	Onset is earlier or later than natural	Early drop may affect growth and breeding of late season spawners	Early drop may affect growth and breeding of late season spawners	medium
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Extremes may affect populations seriously	Extremes may affect populations seriously	medium

5.3.6 Fish Indicator 6 - Marginal vegetation dwellers

Table 12: Predicted response to possible changes in the flow regime of fish Marginal vegetation dwellers in the Okavango River ecosystem – Indicator 6

Question number	Season	Possible flow change	Predicted response of indicator Site 4 Kapako	 Site 5 Popa rapids	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negative effect with earlier low water Later – no effect	Negative effect with earlier low water Later – no effect	medium
2		Water levels are higher or lower than natural	Water levels lower – may be negative Higher water levels – little effect	Water levels lower – may be negative Higher water levels – little effect	medium
3		Extends longer than natural	Serious effect if longer – vegetation affected	Serious effect if longer – vegetation affected	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer transition – little effect Shorter transition – more serious, may affect vegetation that takes time to adapt to new water level	Longer transition – little effect Shorter transition – more serious, may affect vegetation that takes time to adapt to new water level	medium
5		Flows are more or less variable than natural	Extremes detrimental	Extremes detrimental	medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Earlier flood may affect breeding success negatively Late flood may affect growth and breeding	Earlier flood may affect breeding success negatively Late flood may affect growth and breeding	medium
7		Natural proportion of different types of flood year changed	Extremes negative effect	Extremes negative effect	medium
8	Transition 2	Onset is earlier or later than natural	Early drop – negative effect. Late drop - little effect	Early drop – negative effect. Late drop - little effect	medium
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Extremes negative effect	Extremes negative effect	medium

5.3.7 Fish Indicator 7 - Backwater dwellers

Table 13: Predicted response to possible changes in the flow regime of fish Backwater dwellers in the Okavango River ecosystem – Indicator 7

Question number	Season	Possible flow change	Predicted response of indicator		Confidence in prediction (very low, low, medium, high)
			Site 4 Kapako	Site 5 Popa rapids	
1	Dry Season	Onset is earlier or later than natural	Early dry season will affect vegetation , habitat availability and fish survival		medium
2		Water levels are higher or lower than natural	Higher – no effect Lower – desiccation, fish population crash		medium
3		Extends longer than natural	Desiccation, fish die		medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Longer – negative effect Shorter, little effect		low
5		Flows are more or less variable than natural	Extremes – negative effect		medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Early flood – may retard spawning of fish species Late flood season – may be out of synch for breeding [but see adaptation in Delta to late floods?		medium
7		Natural proportion of different types of flood year changed	Extreme low floods will affect fish survival		medium
8	Transition 2	Onset is earlier or later than natural	Early lower water diminishes survival of this indicator Late - no effect		low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Extremes will affect fishj		loiw

5.4 Conclusion

It was possible to divide the fish species of the Kavango into seven indicator groups that would help to describe the response of fish groups to changes in the hydrology of the river. Three fish collections were made during the study period to collect fish species at the two study sites. A third site in the Muhango conservation area was included for comparison during low water conditions. This information was blended with the previously collected data by earlier surveys by MFMR to obtain a larger picture.
There are many missing data that render this exercise inconclusive and a bit of an experimental one:

- The division of the fish species into the proposed indicators is preliminary and should be reviewed.
- Specific information on the actual habitat needs of many fish species is lacking and many fish could not easily be grouped into the proposed indicator groups or can be fitted into more than one group.
- Another factor is that the Kavango fish species are generally adaptable with few species that could be described as real habitat specialists.
- The exact environmental requirements of many species are not known at all despite the considerable amount of literature available and general literature had to be used.

Future research should look at the link between habitat requirements, water conditions and migration of fish in the system in order to better predict the effect of changed flow patterns on fish life.

FLOW-RESPONSE RELATIONSHIPS FOR USE IN THE OKAVANGO EF-DSS

Response Curves were drawn by the fish team during the Windhoek workshop in March 2009 and these curves will be included in a CD of data that accompanies the project Final Report.

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APPENDIX A: RAW DATA

Table 14 Summary of numbers of each fish species caught with all collecting gear at Kapako, Popa Falls and at Kwetche [additional collection site in Muhango [part of Bwabwata National Park] in the Kavango River during November 2008 and February 2009.

Site in Kavango River	Kapako		Popa falls		Kwetche	
Species	**NO**	**% NO**	**NO**	**% NO**	**NO**	**% NO**
Marcusenius macrolepidotus	144	20.7			112	15.2
Barbus paludinosus	124	17.9			100	13.6
Synodontis nigromaculatus			3	1.4	185	25.2
Brycinus lateralis	80	11.5	6	2.9	43	5.9
Petrocephalus catostoma	96	13.8	1	0.5	16	2.2
Synodontis sp	70	10.1	1	0.5	31	4.2
Schilbe intermedius	21	3	5	2.4	49	6.7
Barbus poechii	19	2.7	9	4.3	34	4.6
Pollimyrus castelnaui	1	0.1			50	6.8
Labeo cylindricus			38	18.4		
Opsaridium zambezense			34	16.4		
Hydrocynus vittatus	8	1.2	11	5.3	15	2
Tilapia sparrmanii	13	1.9	4	1.9	14	1.9
Barbus eutaenia	1	0.1	17	8.2	12	1.6
Clarias ngamensis	28	4			1	0.1
Pseudocrenilabrus philander	14	2	8	3.9	6	0.8
Oreochromis andersonii	26	3.7				
Aplocheilichthys johnstoni	2	0.3	1	0.5	20	2.7
Micralestes acutidens	1	0.1	19	9.2		
Barbus radiatus	7	1			10	1.4
Pharyngochromis acuticeps	6	0.9	1	0.5	8	1.1
Clarias gariepinus	12	1.7			2	0.3
Barbus codringtonii			12	5.8		
Tilapia rendalli	5	0.7	2	1	3	0.4
Ctenopoma multispine	6	0.9	3	1.4		
Chiloglanis fasciatus			9	4.3		
Serranochromis macrocephalus					8	1.1
Barbus multilineatus	6	0.9				
Serranochromis robustus			4	1.9		
Barbus fasciolatus					4	0.5
Amphilius uranoscopus			4	1.9		
Cyphomyrus discorhynchus			4	1.9		
Serranochromis altus					3	0.4
Sargochromis sp					3	0.4
Barbus bifrenatus					3	0.4
Hemigrammocharax multifasciatus			3	1.4		
Barbus unitaeniatus	1	0.1	1	0.5		
Tilapia sp.			2	1		

Labeo lunatus			2	1		
Oreochromis sp.			1	0.5		
Barbus thamalakanensis	1	0.1				
Barbus kerstenii	1	0.1				
Leptoglanis sp.			1	0.5		
Clarias stappersii	1	0.1				
Sargochromis giardi					1	0.1
Mormyrus lacerda					1	0.1
Hemichromis elongatus			1	0.5		
Aplocheilichthys katangae					1	0.1
Total	694	100	207	100	735	100

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)
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		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*
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	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*
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		Magole, Lapologang	Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Land Use Planning
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		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
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		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

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