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: Aquatic Macroinvertebrates

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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: Aquatic macroinvertebrates

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EXECUTIVE SUMMARY

When the OBSC noted that there was inadequate information about the physico-chemical, ecological and socio-economic effects of such possible developments in the Okavango river; it proposed 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. One of the study's specific objectives is: 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. Aquatic macroinvertebrates are among the multidisciplinary specialties EFA study comprises.

Delineation of the Okavango basin into different integrated units of analysis was done using different criteria during the preparation workshop that took place in Maun Botswana. The end results were three sites in Angola, two in Namibia and three in Botswana. The Namibian sites are EFA Site 4 at Kapako (in the floodplain area) and Site 5 at Popa rapids. Indicators for the aquatic macroinvertebrates were chosen and agreed upon by specialists from all three countries. For each site, applicable indicators were identified. For each indicator, representative families were identified to act as guidance during the sampling depending on the linkage to flow regime and social importance

Data were collected in dry low-flow and wet high-flow season. Aquatic macroinvertebrates collected were identified to the family level. It was found that the number of families such as Caenidae and Unionidae found at Kapako in the dry season was low compared to those found in the wet season, with some representative families such Dytiscidae and Planorbidae not recorded at all. At Popa rapids, although most of the representative families and more were found in the dry season, abundance doubled in the wet season e.g. Simuliidae, Hydropsychidae and Tricorythidae. This somehow shows the linkage of the aquatic macroinvertebrates to the water level and flow.

Prediction on what will happen to each indicator during different flow regime categories would be worked out at the Knowledge Capture workshop to be held in Windhoek in April 2009. Scenario development will take place in the workshop to be held in June 2009 in Cape Town, South Africa.

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ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
EFA	Environmental Flow Assessment
EF-DSS	Environmental Flow – Diagnostic Support System
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin Project
NASS	Namibian Scoring System
OBSC	Okavango Basin Steering Committee
OKACOM	Okavango River Basin Water Commission
SASS	South African Scoring System
TDA	Transboundary Diagnostic Analysis
UN-FAO	Food and Agriculture Organisation for the United Nations

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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 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 Aquatic Macroinvertebrates 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. Chapter 3 highlights the agreed aquatic invertebrates indicators and flow categories. Literature pertinent to aquatic invertebrate work in the Okavango River and other similar systems is reviewed in Chapter 4 and the indicators are listed. The field survey work undertaken for the aquatic invertebrate 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 aquatic invertebrates to flow and provide information on the flow-response relationships for use in the Okavango EF-DSS. 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

Description of the Okavango Basin

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

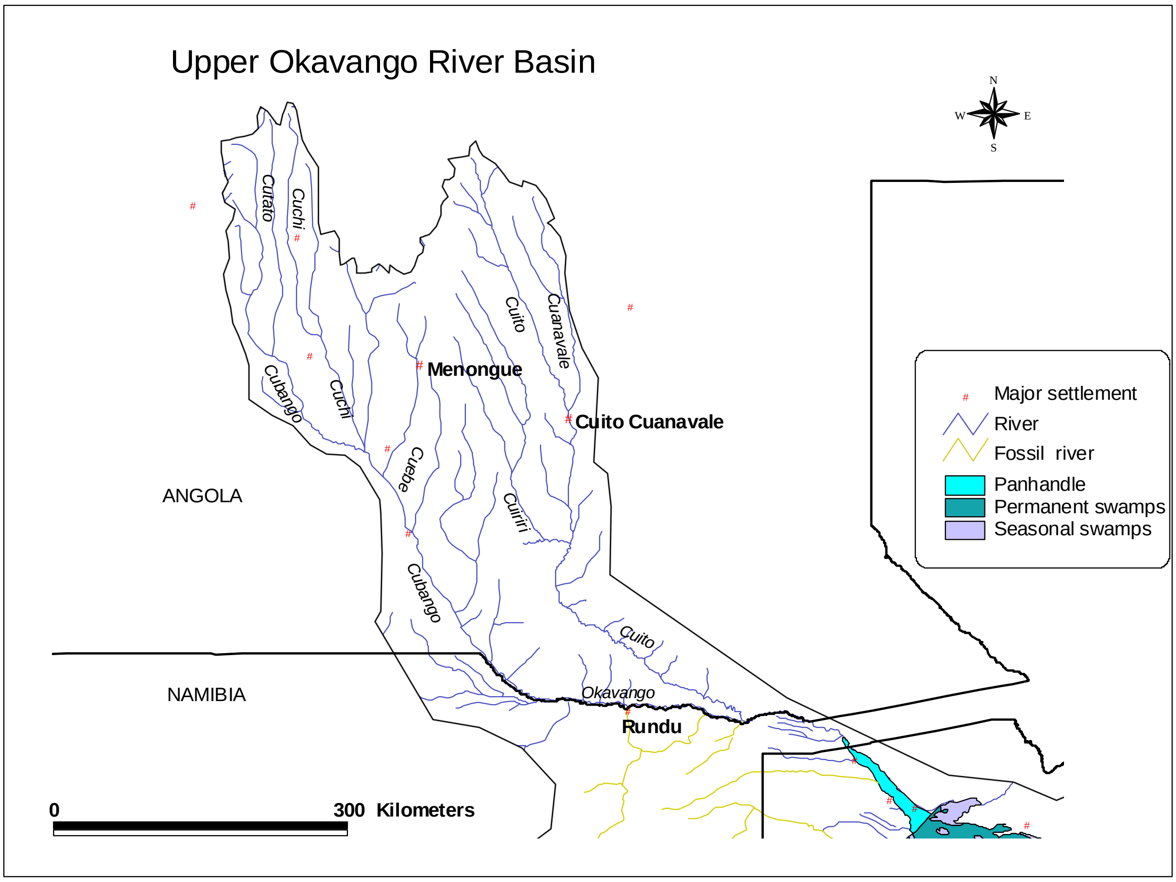

Figure 2. 1: Upper Okavango River Basin from sources to the northern end of the Delta

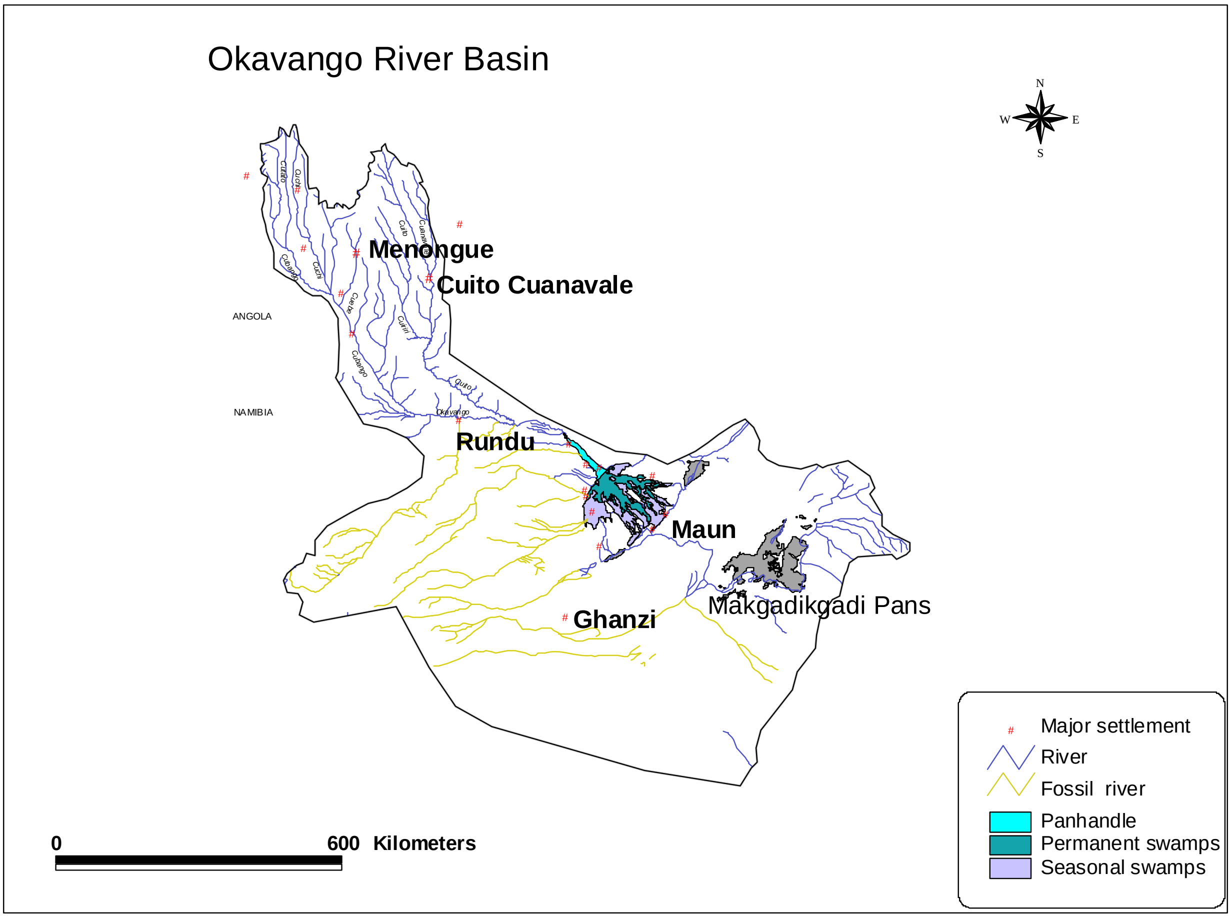

Figure 2. 2: The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans

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 2.1.

Table 2.1: 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

Overview of sites

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

2.3.1 Site 4: Okavango River at Kapako

The river is at the heart and core of the Okavango Basin, and a variety of aquatic plants animals live in and near it and make good use of the river, its water and other wetland resources. In Namibia most of the river often has broad margins of floodplains on either side beyond which there are drier, deciduous woodlands. A variety of organisms are specialised inhabitants of the floodplains.

The fish communities can be divided into two groups based on their food preference and specialization, those that feed on plant material and those that prey on other fish. Secondly they can be divided according to the habitats where the different fish occur, some preferring the mainstream, others the rocky areas and rapids, other groups in the backwaters or permanent swamps and a distinct community found in the floodplains. The floodplains are of greatest value as places in which most fish breed.

Local people have recognised that the quality of water and fish resources is decreasing in the Okavango River. Fish and fishing remain a significant feature in the lives of people at Kapako, who fish for food or to earn incomes by selling their catches as well as by providing trips for tourists. Fish stocks in the floodplains are estimated to be four times higher than in the main channel.

The riverine landscape comprises the main Okavango River channel; annually flooded floodplains with braided channels, the higher fluvial terrace with alluvial deposits are flooded less regularly (Mendelsohn and el Obeid 2004).

2.3.2 Site 5: Okavango River at Popa Falls

The southward flowing section from Mukwe to the Popa rapids is rocky without floodplains and has many sand and rock based islands set in the braided rocky channels. The shore is wooded with the exception of settled areas mainly on the western bank that have been largely cleared for settlements and crops. The islands remain well forested and several are used as burial areas for chiefs.

Popa rapids are where the river cascades down several meters before resuming its normal slow and leisurely flow. The rocks were formed from sediments deposited in rift valleys about 900 million years ago, (el Obeid, S., Mendelsohn date). During the focus group discussion by the socio-economic team, it was mentioned that due to the Popa rapids and rocky areas, it's difficult for the local fishermen to catch fish as desired. Therefore, only a few individuals owning local mukoros, hook and line, and gill fish nets have access to fish catches in the main channel.

Papyrus cyperus, papyrus dominates the deepest water margins alongside the main channels. Water can seep through the walls of papyrus to the reedbeds behind the papyrus and in places it exits into backwaters and side channels. The sandy sediments are confined to the channels. These are flanked by reed beds of Phragmites, Typha capensis or bulrushes and the sedge Miscanthus junceus in the shallower waters. The residents do not experience floods as there are no floodplains in this area. They depend on the main channel for their water and wetland resources (Mendelsohn and el Obeid 2004).

Discipline-specific description of Namibia sites

2.4.1 Site 4: Kapako

This site comprises the main channel and floodplain areas with seasonal rain fed pools and inundated backwaters on the Okavango River. The site is situated about 30km upstream of Rundu, the biggest and most populated town in the Namibian part of Okavango River. It has different habitats. The main one is aquatic with marginal vegetation found in both the main channel stream and floodplains. Although the

families found in these two similar habitats do not differ very much, different families may dominate.   Marginal vegetation in the channel is dominated by ephemeropterans such as caenids and baetids, while for floodplains the marginal vegetation is dominated by Odonata such Libellulidae and Coenagrionidae. Aquatic vegetation biodiversity is rich, dominated by Phragmites spp, oxygen weed Lagarasiphen spp, grasses (e.g. hippo grass Vossia cuspidata), River Rhus, Rhus quartiana and Myriophyllum spp in wet season; and trees on the edge of both the channel and floodplain.

2.4.2 Site 5: Popa Rapids

This site is typical of the rockier, confined section of the Okavango River in Namibia. It is characterised by shallow, rocky rapids and braided side channels. Habitats include cobbles in and out of current, aquatic and marginal vegetation as well as embedded (in fine sediment) and unembedded stones. Papyrus, Cyperus spp and Phragmites dominate the marginal vegetation found at this site. Invertebrate families such as Simuliidae, Hydropsychidae and Ecnomidae, Perlidae and Heptageniidae dominate habitats at this site. This is a protected area as part of the Namibia Wildlife Resort Popa Falls area and the community camp site on the opposite bank minimized local communities' activities. There are several large islands in the river with limited access due to deep channels around the islands. However, the banks immediately upstream and downstream of the site are being rapidly cleared of both reeds and trees.

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.

3.1.2 Indicator list for Aquatic macroinvertebrates

In order to cover the major characteristics of the river system and its users many indicators may be deemed necessary. For each of the EF site, however, the number of indicators is limited to ten (or fewer) in order to make the process manageable. The full list of aquatic invertebrate indicators was developed collaboratively by the country representatives for this discipline – Belda Mosepele and Hillary Masundire from Botswana, Shishani Nakanwe in Namibia and Maria de Fátima Livramento from Angola and is provided in table 2. Further details of each indicator, including the representative families of each biological one, are given in Appendix A, and discussed fully in Chapter 4.

Table 3.1: List of indicators for aquatic macroinvertebrates 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	Channel dwellers in submerged aquatic vegetation								
2	Channel dwellers in marginal vegetation				X	X			
3	Dwellers in fine sediments				X	X			
4	Channel dwellers in rapids pools					X			
5	Channel dwellers on stones and rocks					X			
6	Floodplain dwellers in marginal vegetation				X				
7	Floodplain dwellers in pools				X				
8	Delta dwellers in pools and backwaters)								
9	Delta dwellers on aquatic macrophyte								

3.1.3 Description and location of indicators

3.1.3.1 Aquatic macroinvertebrates Indicator 2

Name: Channel dwellers in Marginal Vegetation

Description: Invertebrates found on the marginal vegetation in the main channel at Kapako and Popa rapids, on the edge of permanent water

Representative family: Ephemeroptera (Mayflies): Family Caenidae, Tricorythidae

Other characteristic families: Odonata (dragonflies and damselflies): Family Aeshnidae and Gastropoda (snails): Family Planorbidae

Known water needs: This habitat requires certain level of inundation in all seasons to maintain the biodiversity of macroinvertebrates that prefer this habitat.

Flow-related location: Invertebrate community found in vegetated edge of the wetted surface in the channel in dry and wet season. Therefore, sustained flows at this level to sustain the marginal vegetation community.

3.1.3.2 Aquatic macroinvertebrates Indicator 3

Name: Channel dwellers in fine Sediments

Description: Invertebrates found in the fine sediments of the main channel at both Sites Kapako and Popa rapids.

Representative family: Bivalves (Families Unionidae and Sphaeridae)

Other characteristic family: Ephemeroptera: Family Polymitarcyidae and Gastropoda: Family Thiaridae

Known water needs: They need to be submerged in mud or wet sand with constant and moderate flow.

Flow-related location: Situated in the wet sand or submerged mud and gravel in the main channel. Invertebrates will not survive, either permanent or intermittent, drying out of these sandy sediments. Reduction in wet or submerged sand beds will reduce habitat size and thus productivity.

3.1.3.3 Aquatic macroinvertebrates Indicator 4

Name: Channel dwellers in Rapids or fast flowing waters

Description: Invertebrates found in shallow rocky rapids at site 5, Popa rapids

Representative family: Diptera (Family Simuliidae or blackflies)

Other characteristic family: Trichoptera: Family Hydropsychidae; Odonata: Family Libellulidae.

Known water needs: They need constant fast flowing oxygenated water with organic materials. Larvae need rapidly flowing water and need submerged rocks to attach to.

Flow-related location: Situated in the rapids on rocks, vegetation and on fairly sparse.

3.1.3.4 Aquatic macroinvertebrates Indicator 5

Name: Channel dwellers in stones and rocks (These are stones as such but may be classified as cobbles because of the size).

Description: Invertebrates found in stones and rocks at site 5, Popa rapids

Representative family: Trichoptera: Hydropsychidae and Ecnomidae

Other characteristic family: Odonata

Known water needs: this indicator has stones and or rocks and needs to be on the edge of the surface open water with moderate to strong flows. It is permanently inundated. Total area inundated may increase slightly in flood season.

Flow-related location: Not known. However, this site is situated immediately downstream of the rapids, therefore there is always flow of water.

3.1.3.5 Aquatic macroinvertebrates Indicator 6

Name: Floodplain dwellers in marginal vegetation

Description: Invertebrates found in the marginal vegetation in the floodplain at site 4, Kapako

Representative family: Odonata: Coenagrionidae and Gastropoda: Physidae

Other characteristic family: Ephemeroptera: Baetidae

Known water needs: vegetation needs to be on the edge of the surface open water. It can be inundated for about four months per year during flood season.

Flow-related location: At the edge of the wetted surface of the floodplain during wet season low and high flow.

3.1.3.6 Aquatic macroinvertebrates Indicator 7

Name: Floodplain dwellers in pools

Description: Invertebrates found in the pools in the floodplain at site 4.

Representative family: Coleoptera/Beetles: Dytiscidae

Other characteristic family: Hemiptera: Naucoridae

Known water needs: Needs to retain water in the dry-low flow season and have some open surface water.

Flow-related location: Not known. But pools fill either with water from the main channel in high flows or with rain water (or both). These pools require inundation during certain times of the year for the macroinvertebrates to complete their life cycles. Although, situated within or at the edge of the floodplain during wet and dry seasons.

3.2 Flow categories – river sites

One of the main assumptions underlying the EFA 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 4 and 5 are shown in Figure 3 to **Error! Reference source not found.**4. 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 year-on-year variability of the Cubango River, than the Cuito River.

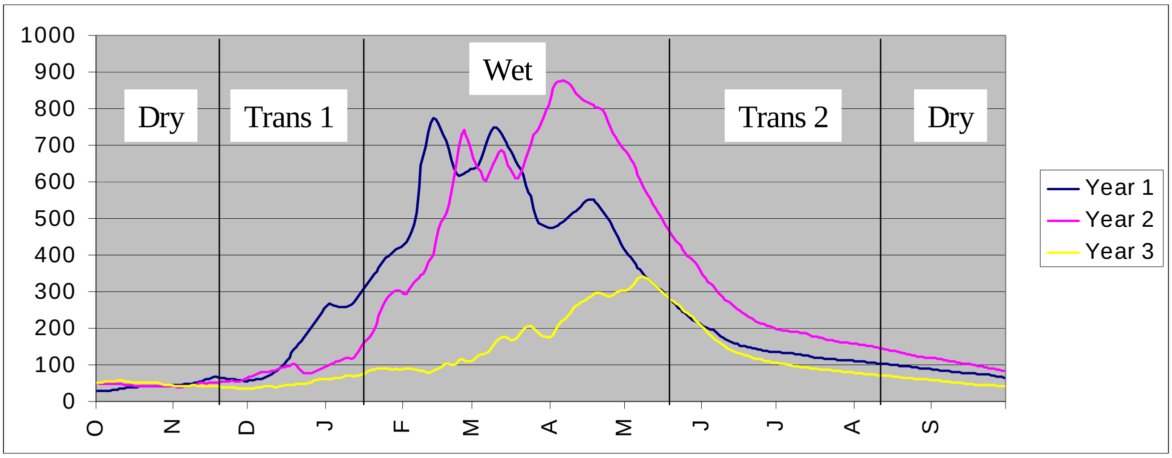

Figure 3. 1: Three representative years for Site 4: Okavango River @ Kapako (hydrological data from Rundu), illustrating the approximate division of the flow regime into four flow seasons

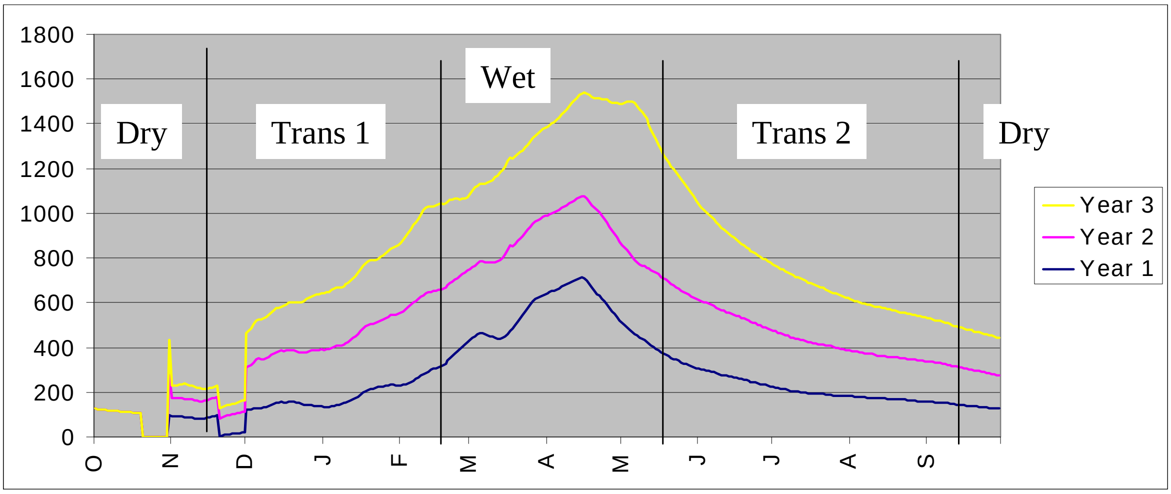

Figure 3. 2: Three representative years for Site 5: Okavango River @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

Table 3.2: Questions to be addressed at the Knowledge capture Workshop, per indicator per site. In all cases, 'natural' embraces the full range of natural variability

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

4. LITERATURE REVIEW

4.1 Introduction

Macroinvertebrates are animals without backbones that can be seen with a naked eye, although some larval forms require a microscope for identification (Dallas and Mosepele, 2007). They are essential components in the functioning of the aquatic ecosystems.

Aquatic invertebrates' assemblages and communities offer a good reflection of the prevailing flow regime and water quality (Thirion 2007). They also form an essential component of the riverine ecosystem (O'Keeffe and Dickens 2000 in Thirion 2007). Aquatic invertebrates are important for processing organic matter, purifying the water, and acting as food to larger animals within and outside the system (Skorozjewski and De Moor 1999 in Thirion 2007). They are sensitive to changes in water quality and therefore are used as good indicators of ecosystem health (Dallas and Day, 2007, Dallas and Mosepele, 2007).
Aquatic macro-invertebrates form a major component of the biota of aquatic ecosystems and are associated with one or other aquatic habitat (Palmer 1991, Dallas 1997, 2002; Dallas and Day 2007) such as stony beds, floating vegetation, marginal and instream vegetation, gravel, sand and mud. According to Dallas and Mosepele (2007), they are mostly primary feeders (feeding on plant material), secondary feeders (feeding on planktonic or benthic organisms) as well as consumers (near the base of the food chain). Some macroinvertebrates help maintain the health of the water ecosystem by eating bacteria and dead, decaying plants and animals (Wallace 1996). They include insects, annelids, molluscs, crustaceans and others ranging in size from about 0.125 mm to several centimetres.

The overall health and ecological condition of a stream can be determined by looking at the invertebrates living in that particular stream; since aquatic animals are good indicators of the health of streams (Fore 1998). All over the world studies have been undertaken to look at the animals found in rivers, streams, wetlands, lakes, and the seas, springs and pools , including South Africa (Gerber and Gabriel 2002) and Botswana (Dallas and Mosepele 2007). In Namibia, particularly in the Okavango River, such studies were conducted in the 1980s and early 90s by Curtis and Appleton (1987 in Bethune 1991), Curtis (1991) and Bethune (1991). Most attention was given to human interactions with aquatic invertebrates such as the medically important mollusc families (Curtis and Appleton 1987), that transmit water-borne diseases and those that are edible (Bethune 1991), although, all invertebrates found in aquatic systems play important roles in their functionality. Aquatic invertebrates are useful for monitoring because of their diversity, survival strategies and adaptations to changing environments (Fore 1998). However, some macroinvertebrates also are transmitters or vectors of disease such as bilharzias (Allonson and Nordin, 2003).
In South Africa, a system called SASS has been developed (Chutter 1994), deduced from a British system to use macroinvertebrates to assess the quality of water (Chutter 1994). The system uses scores allocated to each invertebrate family depending on tolerance of water quality. The same Scoring system was tested in the Okavango, Kwando, Zambezi and Kunene Rivers in Namibia (Chutter 1997, Taylor 1999). It was found that, with a few modifications, the system can be applied to assess water quality in Namibian rivers; because some invertebrates are found either in Namibian rivers or South African rivers and not in both (Chutter 1997, Taylor 1999). The Namibian version is called Namibian Scoring System version 2 (NASS2) (Palmer and Taylor 2004), and was derived from SASS4. Since this work was done, South African river specialists have developed SASS5; hence adjustments need to be done to revise NASS2, which has not been used since it was developed in 2004.

The macroinvertebrates found in the Okavango River include Ephemeroptera (Mayflies), Plecoptera (Stones flies), Simuliidae (Black flies), Chironomidae (midges), Gastropoda (snails) and Pelecypoda (bivalves), crustaceans, Hemiptera (true bugs), Trichoptera (caddisflies), Coleoptera (beetles), Odonata (dragonflies and damselflies), Culicidae (mosquitoes) and Annelida (aquatic earthworms) (Bethune, 1991, Curtis 1991, Palmer and Taylor 2004; and Gerber and Gabriel 2002). The gastropods are the best studied group in Namibian wetlands and rivers (Brown *et. al* 1992, Brown 1994 in Curtis *et. al* 1998) followed by the aquatic Coleoptera (Curtis 1991). The gastropods of the Okavango River are similar to those of the Zambezi River but this is not the case with other invertebrates (Curtis *et. al.* 1998). However, more work needs to be done on the aquatic invertebrates in Namibian rivers, particularly on the Okavango, Kunene, Kwando, Chobe and Linyanti Rivers.

Aquatic invertebrates are an essential component of the river's food web and are responsible for the secondary production occurring in rivers and wetlands; and their long life cycles, compared to other groups, give clues to temporal changes caused by environmental impacts (Davies and Day 1998).

Nationally, apart from the information in Bethune (1991) and Curtis (1991) that these taxa were recorded from Okavango River, no other detailed studies have been conducted on this group. Gastropods such *Pila occidentalis* are considered to be edible and may be food to the local communities (Curtis 1991), although, no-one interviewed by the social team admitted to eating them along the Okavango. *Bulinus* species such as *Bulinus globosus* that causes Bilharzia in humans that come in contact with them and *Bulinus tropicu*s, host to schistosomes in livestock and game (Curtis 1991), and are medically important. The studies done in Namibia on these molluscs do not point out the specific habitat in the river zone preferred by these invertebrates. There are records that they were found in Northern Rivers (Okavango and Kwando, Zambezi Rivers) and that some, e.g. *B. globosus* are found throughout the country. The ecological functioning of the dynamic Okavango River system depends on seasonal floods (Bethune 1991). Seasonal floodplains, for instance EFA site 4 at Kapako, alternate between annual dry (September to November) and wet (February to May) periods (Mostert pers. comm.).

The periodic inundation (during high flow in the wet season) and desiccation (during low flow in the dry season) of riverine and floodplain substrata can leave large areas unavailable for colonisation by aquatic macroinvertebrates for some part of the year (De Moor 1997). Physical habitat and water quality changes during low flows can adversely affect aquatic biota in the short-term (Caruso 2001).

Table 4.1: List of families and chosen representative families for aquatic invertebrate indicators.

Indicator	**List of Order**	**Representative family**	**Why this family?**
Channel dwellers in marginal vegetation	Ephemeroptera Odonata Gastropoda	Caenidae sp. Tricorythidae Aeshnidae Planorbidae	Diverse and it is food for fish. Food for birds Bilharzia vector
Channel dwellers in fine sediment	Bivalves/Pill clams	Unionidae, Sphaeriidae	Water Quality indicators
Channel dwellers in rapids or fast flowing waters	Diptera	Simuliidae- *Simulium sp.*	Reduced flow lowers its abundance, and it is a river blindness disease vector. Although disease does not occur in Namibia, some species in this family cause livestock irritation (black fly in

			sleep)
Channel dwellers in stones and rocks	Trichoptera	Hydropsychidae and Ecnomidae	Abundance affected by fluctuating flow
Floodplain dwellers in marginal vegetation	Odonata Gastropoda	Coenagrionidae Physidae, Planorbidae	Abundance. Also food for fish and birds
Floodplain dwellers in pools	Coleoptera	Dytiscidae	Food for fish and affected by fluctuations in flow

4.2 Indicator 2: Channel dwellers in Marginal Vegetation (Ephemeroptera /Odonata /Gastropoda).

4.2.1 Main characteristics of Indicator 2: Channel dwellers in Marginal Vegetation (Ephemeroptera/Odonata/Gastropoda)

This habitat is a predominant habitat at site 4 and these aquatic invertebrates, mainly ephemeropterans e.g. caenids and baetids and gastropods e.g. Thiaridae, Ampuraliidae and Planorbidae, spend most of their lives in rivers and streams (Fore 1998); and are most likely to be affected by any drastic flow change. These groups require unpolluted, well-oxygenated, cool water to survive. This makes them useful indicators of ecosystem health (Fore 1998). In many habitats they are important fish food due to their diversity. The marginal vegetation at Site 4 serves as a habitat to a large number of mayflies, damselflies and dragonflies, and snails. This habitat is under threat from humans and livestock, through overgrazing and overharvesting of reeds and grass. Since there is a decline in this habitat especially during the dry season, when it is easily accessible to livestock, any change in flow is a challenge to the invertebrates.

4.2.2 Life cycle attributes of Indicator 2: Channel dwellers in Marginal Vegetation (Ephemeroptera/Odonata/Gastropoda)

Ephemeroptera:
The sub-imagos (stage between nymphs and adults of mayflies) are poor fliers and vulnerable to predation. They are often found resting in areas, separated from contacts with others, among vegetation near water bodies from which they emerged. This group needs moderate flow, because their reproduction and developmental life cycle is very short. In dry periods, mating does not take place and females may reproduce parthenogenetically (de Moor et al. 2003).

Odonata
Odonata are hemimetabolous as they only have three developmental stages including egg, nymph and adults. Unlike other insects like Coleopterans, mosquitoes and butterflies, Odonata lack pupa stage. Adults, although not fully aquatic, spend their lifetime next to water (Suhling and Martens 2007). In dry seasons, odonates are able to survive in soft sand and mud where they wait for rain and complete their life cycles (De Moor et. al. 2003)

Gastropoda
During the dry season, some planorbids aestivate in sand or mud and perform self-fertilization after the worse environmental condition (Brown 1980 and Appleton 1996) when their habitat is re-filled with rainwater.

4.2.3 Links to flow

Habitat
Ephemeropterans such as Baetids, one of the most common families in this Order, are found climbing on the stems of submerged vegetation on the margins or instream. The larvae are aquatic and each family has preferences for a different type of habitat, which is influenced by factors such as water temperature, flow rate, chemical composition and light (http://www.ento.csiro.au/education/insects/ephemeroptera.html).

Tricorythidae tend to be found among solid submerged substrata/plants in fast flowing streams, whilst caenids and planorbids are found in muddy or vegetated areas, in aquatic vegetation or on gravel beds in flowing waters respectively (de Moor et. al. 2003).
Odonata in the family Aeshnidae are found in different habitats but prefer aquatic submerged vegetation (Suhling and Martens 2007).

Gastropods such as Planorbidae are mostly associated with aquatic plants, thus preferring to live among marginal or submerged vegetation (Appleton 1996).

Breeding of ephemeropteran
Generally, since adults are semi-aquatic, after mating, females fly back to the nearest waterbody to oviposit, (lay eggs), or enter the water and lay eggs on the substratum before the females die (De Moor et. al 2003). Eggs are laid on the water surface, where they sink, scattering along the substratum and amongst aquatic plants and debris, immediately after mating before the adults die. This requires continuous and relatively slow flow. The life span for these taxa is very short, lasting from a few hours to a few (http://www.ento.csiro.au/education/insects/ephemeroptera.html).

Odonates, after mating on land, the female adults move to nearby water bodies to dip their eggs in the water among the vegetation on the edge of the backwater or simply on the surface of the water, by lowering their abdomens into the water (De Moor et al. 2003).

Feeding
Although adult mayflies do not feed, nymphs feed on aquatic plants and other associated organisms by scraping algae and detritus from underwater stones and vegetation (http://www.ento.csiro.au/education/insects/ephemeroptera.html); nymphs are deposit feeders or grazers, with some filter-feeder and a few predators (De Moor et. al 2003).

Odonata are opportunist predators by catching a wide variety of prey (De Moor et. al. 2003). See indicator 6 more information on feeding in Odonata and Gastropoda.

4.3 Indicator 3: Channel dwellers in fine sediment (Bivalves/Pill clams: Unionidae and Sphaeridae)

4.3.1 Main characteristics of Indicator: Channel dwellers in fine sediment (Bivalves/Pill clams)

The main aquatic inhabitants of the fine sediments in the river channels are bivalves and pill-clams. These inactive macro-invertebrates are good water quality indicators as they are intolerant of polluted water or low quality water (Gerber and Gabriel 2002).

4.3.2 Life cycle attributes of Indicator Channel dwellers in fine sediment (Bivalves/Pill clams: Unionidae and Sphaeridae)

4.3.3 Links to flow

Habitat
Unionidae prefer perennial waters as compared with the Sphaeridae, which are also found in many types of waterbodies including temporary ones (Appleton 1996). They are free-living burrowers that lie partly in fine sediments with their inhalant and exhalant raised above the sediment.

Breeding
Unionidae and Sphaeridae reproduce hermaphroditically. Their eggs are fertilised internally immediately after copulation (Appleton 1996).

Feeding
Unionidae and Sphaeridae are collectors, using the large gills to filter organic particles from the moderate water flow. By opening their inhalants, bivalves are able to take food and dissolved oxygen in the passing current. Since they are capable of filtering large volumes of water in the river system (Appleton 1990), they are known as “cleansers” of water from

pollutants and excessive nutrients. However, Sphaeridae is more sensitive to polluted water; making them very good indicators of water quality.

4.4 Indicator 4: Channel dwellers in Rapids or fast flowing water (Diptera/Simulium/Blackflies)

4.4.1 Main characteristics of Indicator 4: Channel dwellers in Rapids or fast flowing waters (Diptera/Simulium/Blackflies)

The typical aquatic invertebrates living in the rapids in river channels are Simulium species. Simuliids require flowing water for them to become established and are found mostly in rapids, waterfalls and cascades (de Moor 1997), which is an uncommon feature in the Okavango River. Although common at site 5 Popa rapids- specifically chosen to indicate this family. This family includes many species of veterinary and medical importance such as Simulium damnosum, a vector for the nematode worm (Onchocerca volvulus) that causes Onchocerciasis known as River Blindness in humans (Davies and Day 1998 and Day et al 2002). In West Africa, this family is better studied than in Southern Africa as the disease is more common than in Southern Africa (Day et al 2002). Apart from being medically important, they are also ecologically important because of their ability to filter large volumes of water by processing dissolved organic matter and avail it in the food chain. It is a good water quality indicator as their larvae are unable to survive polluted waters (http://blackflies.info/en/content/information).

4.4.2 Life cycle attributes of Indicator Channel dwellers in Rapids (Diptera, Simulium/Blackflies)

Females deposit eggs on vegetation just below the water surface. Larvae emerge from eggs and attach themselves to aquatic or emergent vegetation as well as rocks (Butler and Hogsette 1998).

4.4.3 Links to flow

Habitat
Since adults are terrestrial, larvae of Simuliids are found in shallow rapids, attached to stones plants or solid surface (Gerber and Gabriel 2002), well-oxygenated in fast flowing freshwater (Davies and Day 1998 and Day et al. 2002).

Breeding
Dipterans are dioecious, meaning they have both sexes. They need blood in their systems in order to produce eggs; hence biting humans and livestock (Davies and Day 1998 and Day et al. 2002. Egg incubation takes from a few hours to a few days, depending on the temperature and other factors (Day et al. 2002).

Feeding
Simulium sp. Most black fly larvae are filter feeders, with the larvae feeding on nutrients in the water as it flows by (Butler and Hogsette 1998b) in slow-moving stream, but most species prefer rapidly flowing water (Robinson 1997). Lower flows will result in an increase in the occurrence of riffles and rapids and the populations of Simulium sp. is likely to rise with possible negative economic consequences.

- channel features, e.g., rocks in current and riffle in between.

4.5 Indicator 5: Channel dwellers on stones and rocks (Trichoptera: Hydropsychidae and Ecnomidae)

4.5.1 Main characteristics of Indicator 5: Channel dwellers on stones and rocks (Trichoptera: Hydropsychidae and Ecnomidae)

Trichoptera are characteristic of river channel reaches with loose stones or cobbles. This habitat is fairly rare in the Okavango River in Namibia and found only immediately downstream of Popa rapids.

These macroinvertebrates are found under stones in fast flowing waters, slow streams or sometimes in quiet pools (Gerber and Gabriel 2002). According to de Moor (1997), Hydropsychidae plays an important role in controlling population sizes for Simuliids in medium to large rivers. It is good water quality indicator; some genera are sensitive to pollution contaminants and suffer decline or even death if their environment has drastic changes (http://zipcodezoo.com/Key/Animalia/Hydropsychidae_Family.asp).

4.5.2 Life cycle attributes of Indicator 5: Channel dwellers on stones and rocks (Trichoptera: Hydropsychidae and Ecnomidae)

The Hydropsychid larvae spend their entire life in freshwater.

4.5.3 Links to flow

Habitat
Hydropsychids are found under stones, living in shelters made of sand grains, in fast flowing waters (Gerber and Gabriel 2002). Whilst, Ecnomids are found under stones or in submerged vegetation in slow streams (Gerber and Gabriel 2002).

Breeding
They are hermaphroditic and self-fertile. Breeding happens when the flow is constant and the temperature is optimal in the main channel.

Feeding
Hydropsychids are predators that feed on a variety of prey and ecnomids are deposit feeders (King and Schael 2001). Hydropsychidae construct dwellings called "retreats", which are fixed to the sides of rocks; composed of collected plant and mineral fragments. The nets or sieves that form at the entrance of the “retreats” catch algae, detritus, and smaller invertebrates. Due to this technique of collecting food, Hydropsychids require flowing water in order to trap prey items in these nets (*Stuijfzand 1999*).

- channel features : Sand and loose stones

4.6 Indicator 6: Floodplain dwellers in Marginal Vegetation (Odonata/Gastropoda)

4.6.1 Main characteristics of Indicator 6: Floodplain dwellers in Marginal Vegetation (Odonata/Gastropoda)

Odonata and some gastropods are typical of the marginal vegetated sections found in and alongside seasonal floodplains. Permanent floodplain pools serve as refuge for these families in dry season.

The Odonata are semi-aquatic as only growing larval stages inhabit water (De Moor et al. 2003) during low flow (October to December).

4.6.2 Life cycle attributes of Indicator Floodplain dwellers in Marginal Vegetation (Odonata/Gastropoda)

This group is typified by the Odonata: dragonflies and damselflies. Odonata are hemimetabolous as they only have three developmental stages including egg, larva and adults. Unlike other insects like Coleopterans, mosquitoes and butterflies, Odonata lack pupa stage. Adults, although not fully aquatic, spend their lifetime next to water (Suhling and Martens 2007). Some Odonata species survive in soft mud and wait for the return of flow/rains to complete their development (De Moor et al. 2003). That means if no flow is experienced or floodplain pools dry out, their development may be affected and hence their reproduction and abundance. Their egg development and growth is temperature depended (Suhling and Martens 2007).

4.6.3 Links to flow

Habitat
Odonata are found among vegetation on the edges of slow streams or backwaters as they slowly move among vegetation (Gerber and Gabriel 2002). In Southern Africa, many families prefer well-lit, weedy margins of pools, streams and rivers (De Moor et al. 2003).

Gastropods are generally associated with aquatic plants, often among marginal and submerged vegetation (Appleton 1996).

Breeding
After mating on land, the female adults move to nearby water bodies to dip their eggs in the water among the vegetation on the edge of the backwater or simply on the surface of the water, by lowering their abdomens into the water (De Moor et al. 2003).

Gastropods, pulmonates breed hermaphroditically. This is a useful strategy since their habitats are sometimes unstable, may dry out and are also subject to floods.

Feeding
Dragonfly larvae are voracious feeders. They will eat an entire specimen sample if not killed immediately (Bethune pers. observ). Some of them are strong enough to catch and eat insects as large as butterflies and other dragonflies (Suhling and Martens 2007).

They feed on various preys both smaller and larger invertebrates, that is why they are considered opportunist predators or generalists. Odonata use two distinct strategies to get its prey, ‘sit-and-ambush’ or ‘active searching’. The former is used in the rivers where predation from fish is high and the latter in temporary waters when predation from fish is low (De Moor et. al. 2003). Some Odonates grasp their prey while in flight (Suhling and Martens 2007).

According to Appleton (1996), Gastropods feed on dead and decaying organic matters and on periphyton growing on submerged surfaces which maybe include fungi, algae, protozoans and bacteria.

4.7 Indicator 7: Floodplain dwellers in pools (Coleoptera)

4.7.1 Main characteristics of Indicator 7: Floodplain dwellers in pools (Coleoptera)

These floodplain pools' dwelling aquatic macroinvertebrates can be typified by the taxon Coleoptera or water beetles. Some can fly and so move between pools.
For this taxon, both larvae and adults are aquatic (King and Schael 2001) and found in pools in the floodplains (de Moor 1997), and need water for survival; affected by alternating flooding periods and drought. Because their habitat is determined by the presence of water in the floodplains when the river overflows and feed the floodplains. Dytiscids generally prefer slow moving or stagnant water, such as ponds, lakes, pans or oshanas, dams, and pools at the edges of streams (http://www.anbg.gov.au/cpbr/WfHC/Dytiscidae/index.html).

4.7.2 Life cycle attributes of Indicator Floodplain dwellers in pools (Coleoptera)

Macroinvertebrates such as Coleoptera take refuge in floodplain pools during the dry season (July/August and November/December) as their preferred habitat, and some move back to the mainstream during wet season (February to May). But they die when they become stranded and isolated from the main flow for too long during the dry season or when the pools dry up. Although they can fly to reach new pools (Bethune pers. observ); and where there is lack of deeper pools for refuge (Caruso 2001).

4.7.3 Links to flow

Habitat
Coleoptera prefer stagnant or quiet water in pools or at the edge of streams. The strong flying ability of adults allows recolonization of aquatic habitats after drought periods (Caruso 2001).

Breeding
Coleopterans breed amongst plants found on the edges of pools in the floodplains that are inundated during the high-flow in the wet season (de Moor 1997) in (February to May).

Feeding
Coleoptera are active hunters (King and Schael 2001) and therefore prefers stagnant or slow moving water. They need stable water flow to ambush its prey.

- channel features, Good and regular floodwaters need to spill from the main channel to inundate the pools in the floodplain.

4.8 Summary

There is huge a gap in the information available on the aquatic invertebrates found in Okavango River, and their specific water flow requirements. There is good information available on the occurrence of aquatic macroinvertebrates in the Okavango River, particularly for the Namibian section e.g. Bethune (1991, Curtis 1991). There is also a wealth of literature available worldwide and even in southern Africa on the main orders and families of aquatic macroinvertebrates known to occur in the Okavango River system, which includes useful information on their lifecycles, feeding and habitat preferences. Yet, there is more to be done in order to understand the aquatic biota of Okavango with respect to their habitats, behaviour and responses to flows.

For the Okavango River, the list of families found in the system is available, but in most cases with little detailed information on when these macroinvertebrates breed or the effects of flow changes on them. This made the comparison with other river systems with better information difficult, especially with literature from Australia and America. Most of the general information used was downloaded from the Internet through Google searches. Southern African information was obtained from guide books on aquatic invertebrates for South Africa and Southern Africa (Gerber and Gabriel 2001 and 2002, Day et al 2002, De Moor et. al 2003, Suhling and Martens 2007).

Previous research on aquatic macroinvertebrates in Namibia and particularly on the Okavango River was found in reports and articles on the work of Bethune and Curtis in the 1980s to 1990s (Bethune 1991 and Curtis 1990). One group, the Odonata, has since been studied in detail in detail in Namibia and a book produced as part of BIOTA Project (Suhling and Martens 2007).

5. DATA COLLECTION AND ANALYSIS

5.1 Methods for data collection and analysis

The first field trip to Site 4 Kapako floodplain and Site 5 Popa rapids was undertaken between the 18 and 22 October 2008. Site 4 Kapako was visited on the 20th of October 2008, whereby the marginal vegetation in the mainstream of the Okavango River, and a floodplain pool were sampled. A NASS/SASS net was used to sweep the vegetation on the margins of the stream and also of the floodplain pool. This was done according to the SASS 4/NASS 2 method. The collected specimens were emptied into a white tray for identification of the invertebrates. The macroinvertebrates were identified to family level and recorded on the NASS scoring sheet. This method was repeated thrice. See figure 5 for habitats/sites sampled at Site 4 Kapako.

At Site 5 Popa rapids, the same net was used to collect invertebrates from unembedded stones-in- current; marginal vegetation and embedded stones-in-current. Here stones were thoroughly kicked, turned and washed into the net, facing upstream. Collected debris was emptied into the white tray for identification. Identified macroinvertebrates families were recorded in the NASS scoring sheet. Invertebrates from site 5 were further grouped in functional feeding groups for better understanding. See figure 6 for habitats/sites sampled at Site 5 Popa rapids.

The second field trip to the two Namibian sites was undertaken between the 05th and 13th February 2009 at the onset of the wet or high flow season. Site 5 Popa rapids, was sampled on the 5th February 2009. Three different habitats as per this discipline's indicators were sampled; namely marginal vegetation, sediment (sand), and stones-in-current. Indicators number 2, 3 and 5 were also sampled in the side channel immediately downstream in the rocky rapids at Popa.

Site 4 Kapako was sampled on the 8th and 9th February 2009. This is the floodplain area where marginal vegetation and deeper lily-filled pools in the flood plain were sampled. The marginal vegetation of the main channel was also sampled as many times as possible to get the overview of macroinvertebrates found in this habitat. Due to high flow and the depth of water, no sampling could be done in the sediments of the main channel.

As time was limited on both field survey trips, no light traps or any other specific collecting methods were used e.g. to collect snails. It is assumed that given more time, more intensive collecting could be done in subsequent studies.

During the wet season, the site was accessed by boat with 25hp engine and mukoros (wooden canoes used in the river to transport people and goods across and along the river).

The macroinvertebrates collected were identified using the field guide "South African Rivers' invertebrates" (Gerber and Gabriel 2001 and 2002) and entered in the NASS 2 scoring sheet. Specimens that could not be identified on site were preserved in 70% ethanol and were brought to the DWAF laboratory in Windhoek for identification. Snails collected were taken to the National Museum entomology division in Windhoek for further identification.

The data collected were analyzed according to the water quality standards as described in the SASS/NASS methods and then linked to the flow depending on the type of habitat the invertebrates were found in.

In parallel with this EFA work, ten other sites within the Namibia section of the river are sampled regularly, every 3rd month, using SASS/NASS method. This project was initiated in July 2008 and will run until July 2009.

5.2 Results

See Appendix B for the raw data incurred from sampling in both the dry and wet season for site 4 and 5.

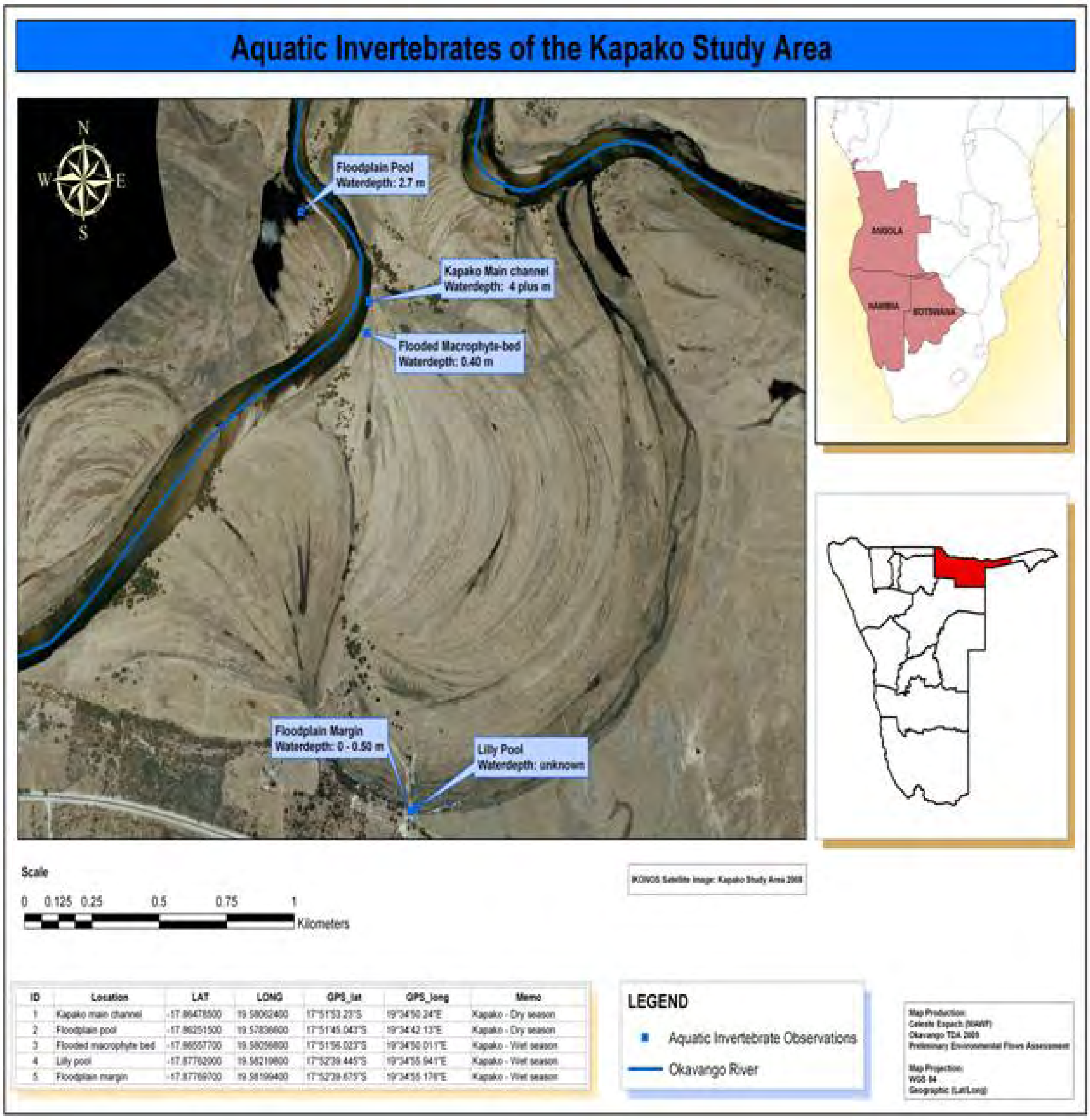

Figure 5. 1:Location of Namibia in southern Africa, the Okavango River (lower map) and the habitats sampled for aquatic invertebrates at EFA site 4, Kapako.

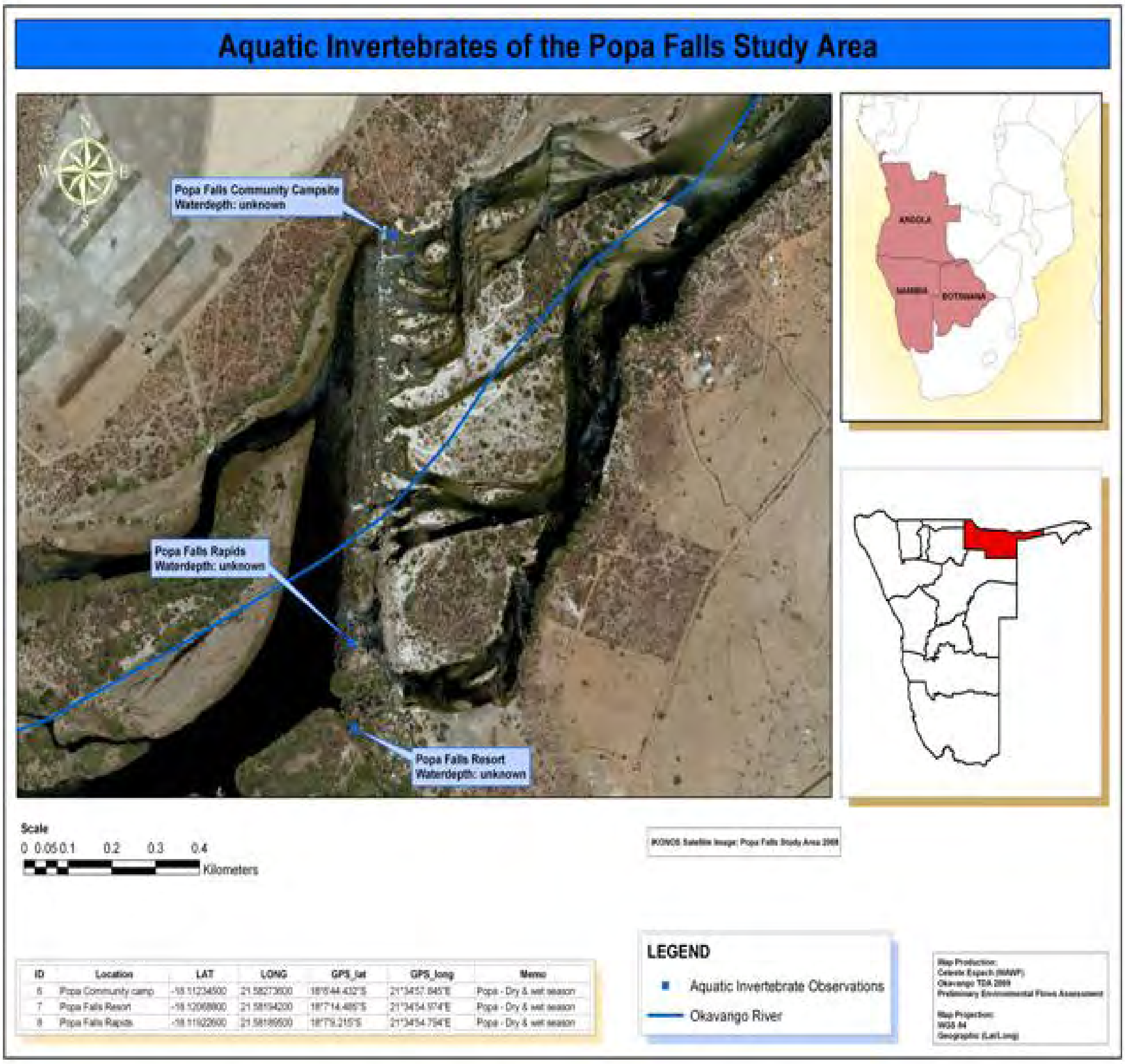

Figure 5. 2: Location of Namibia in southern Africa, the Okavango River (lower map) and the habitats sampled for aquatic invertebrates at EFA site 5, Popa rapids

Channel dwellers in Marginal Vegetation

Ephemeropterans such as Caenidae were abundant, about i.e. five to ten per scoop compared to other invertebrates especially in the wet season. Tricorythidae were rare as only two or fewer organisms were found. Aeshnidae were present but their abundance was low. For other invertebrates found at this habitat, see Appendix B. Habitats samples for Kapako and Popa are shown in figure 5 and figure 6 respectively; with known water depth specifically during wet season.

Most Ephemeroptera were found in larval stages, which is common during the early periods of wet seasons.

Social importance:
Invertebrate communities play an important role in the food web, as a food source for fish, birds, frogs and other macroinvertebrates. They also contribute significantly to the fisheries production in the river system. Unfortunately, there are no direct benefits recorded for local communities, hence the social benefit is best categorised as 'economic non-use value'.

Although *P. occidentalis* is believed to be edible no evidence was found showing this. Maybe it is a small-scale or even individual food source, although not found in the SASS/NASS samples. In the case of medically important macroinvertebrates such as molluscs, Planorbidae, which affect people through schistosomiasis (Bilharzia) by *Schistosoma spp.,* are likely to occur and can be considered harmful. There is a high incidence of bilharzia especially amongst the school children

No information on the impressions of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows; in terms of aquatic macroinvertebrates.

One can assume that remnant/vegetated pools that remain on the floodplain in the dry season could harbour bilharzias and pose a health risk.

Channel dwellers in Fine sediments

Bivalves are not too common, although Unionidae were rarely found in the dry season. They were mainly found in adult form with growth rings and eroded patches clearly visible. Sphaeridae were very rare and not recorded from this habitat during either season. High water levels at the start of the wet season made it impossible to sample the sediments in the channel.

Like Gastropoda, their importance to local communities is insignificant. No information is available of the impressions of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows in terms of aquatic invertebrates.

Channel dwellers in Rapids or fast flowing waters

Simuliidae was recorded as much more abundant in wet season than in the dry season at different habitats within the rapids, such marginal vegetation and cobbles and boulders. See Appendix B for other invertebrates found at this habitat. See figure 6.

However, human interference, such as building of weirs and flood manipulation, can lead to the development of vast populations of a single family that cause a nuisance when adults emerge in mass. They may pose health problems to humans and animals. These include simuliids and other biting midges.
No information was gathered by the social team on the impressions of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows in terms of aquatic invertebrates.

Channel dwellers in stones and rocks

As representative family for this indicator, Hydropsychidae were abundant at Site 5 Popa rapids in both seasons, although wet season numbers were higher of about ten organisms per scooping. Ecnomidae were common.

They were all found in their larval stages. See figure 6

No information on the impressions was gathered of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows; in terms of aquatic invertebrates.

Floodplain dwellers in marginal vegetation

Odonata was dominated by Coenagrionids followed by Libellulidae (although not an indicator/representative family for this study); in both seasons.

Social importance:
Apart from being a very important source of food to other invertebrates and vertebrates such as fish, reptiles, birds and frogs, this order does not have direct benefits to the local communities.

Its high abundance in both dry and wet seasons tells us little about the effect of changes in flow.

No information of the impressions of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows; in terms of aquatic invertebrates.

Floodplain dwellers in Pools

As a representative family for this indicator, Dytiscidae was not recorded from this habitat in either seasons. See Appendix B for invertebrates that were instead found. See figure 5 for this habitat/site

No information on the impressions of local communities on what happens in years when there are good rains/wet season flows, and in years when there are poor rains/wet season flows; in terms of aquatic invertebrates.

a. Summary

A summary of present understanding of the predicted responses of all (Aquatic vegetation) indicators to potential changes in the flow regime.

5.3.1 Indicator 2 (Channel dwellers in marginal vegetation)

Table 5.1: Predicted response to possible changes in the flow regime of Channel dwellers in marginal vegetation in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator (Both Kapako and Popa rapids)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Unlikely to affect	Medium
2		Water levels are higher or lower than natural	Water level lower, limited organic material transportation, accumulation of silts and low water quality. The indicator species will drastically reduce in numbers and if this persist for long, it can lead to the species perishing	Medium
3		Extends longer than natural	Low flow or no flow at all, exposing vegetation and limit the habitat, drastic reduction in number of the indicator species	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Little effect	Low
5		Flows are more or less variable than natural	Little effect if flows are more variable. Less variation is unlikely to affect	Low
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Unlikely to affect	Low
7		Natural proportion of different types of flood year changed	Possibly if larger floods are less frequent. the indicator species will be confined to the little available habitat and get more abundant as those individuals that can not survive will die	Medium
8	Transition 2	Onset is earlier or later than natural	Nil	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Little effect	Low

5.3.2 Indicator 3 (Channel dwellers in fine sediments)

Table 5.2: Predicted response to possible changes in the flow regime of Channel dwellers in fine sediments in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator (both Kapako and Popa rapids)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Nil	Low
2		Water levels are higher or lower than natural	Little effect. Unless the river dries out	Low
3		Extends longer than natural	Low flow or no flow at all, exposing sand banks and limit the habitat, it will reduce the indicator species population sizes.	Medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Nil	Low
5		Flows are more or less variable than natural	Reduced transportation of sediments, resulting in accumulation of silts	Medium
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Nil	Low
7		Natural proportion of different types of flood year changed	Little effect. If no larger floods experienced, there will be short in nutrients supply.	Medium
8	Transition 2	Onset is earlier or later than natural	Nil	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Little effect. Benthos could be smothered by sand banks collapse if hydrograph is steep	Low

5.3.3 Indicator 4 (Channel dwellers in rapids or fast flowing waters)

Table 5.3: Predicted response to possible changes in the flow regime of Channel dwellers in rapids or fast flowing waters in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator (Popa rapids only)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Nil	Low
2		Water levels are higher or lower than natural	If lower, it could affect the rapids and limit the habitat of the indicator species. The population will be less abundant	Medium
3		Extends longer than natural	Could limit the habitat, if dry for longer period, hence reducing the indicator species abundance	Medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Nil	Low
5		Flows are more or less variable than natural	Could affect if more variable	Low
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Nil	Low
7		Natural proportion of different types of flood year changed	Little effect, if larger floods are less frequent	Medium
8	Transition 2	Onset is earlier or later than natural	Nil	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Nil	Low

5.3.4 Indicator 5 (Channel dwellers in stones and rocks)

Table 5.4: Predicted response to possible changes in the flow regime of Channel dwellers in stones and rocks in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator (Popa rapids only)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Nil	Low
2		Water levels are higher or lower than natural	Lower, when rocks are exposed there is minimal habitat for the Simuliids to attach, limited food supply, indicator species will be less abundant	Medium
3		Extends longer than natural	Limit habitat area, competition for food from other invertebrates, leads to reduction in numbers of indicator species	Medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Nil	Low
5		Flows are more or less variable than natural	Nil	Low
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Little effect	Low
7		Natural proportion of different types of flood year changed	Little effect	Low
8	Transition 2	Onset is earlier or later than natural	Nil	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Nil	Low

5.3.5 Indicator 6 (Floodplain Marginal vegetation)

Table 5.5: Predicted response to possible changes in the flow regime of floodplain dwellers in marginal vegetation in the Okavango River ecosystem

Question number	Season	Possible flow change	Predicted response of indicator (Kapako only)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Unlikely to affect	Low
2		Water levels are higher or lower than natural	When lower, loss of available habitat area, hence reduction in the population of the indicator species	Medium
3		Extends longer than natural	Affected it only dries out	Low
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Little effect	Low
5		Flows are more or less variable than natural	Little effect	Low
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Nil	Low
7		Natural proportion of different types of flood year changed	Abundance affected when there are too small flood and too big floods that cause washing away of indicator species from vegetation.	Low
8	Transition 2	Onset is earlier or later than natural	Nil	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Little effect	Low

5.3.6 Indicator 7 (floodplain dwellers in pools)

Table 5.6: Predicted response to possible changes in the flow regime of floodplain dwellers in pools in the Okavango River ecosystem.

Question number	Season	Possible flow change	Predicted response of indicator (Kapako only)	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Little effect	Low
2		Water levels are higher or lower than natural	If low, it could affect the pools that the indicator species will have limited habitat, Exposure to predators and reduces the number of the species	Medium
3		Extends longer than natural	If longer, the pools may dry up and that means no habitat for this indicator species	Medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower	Little effect	Low
5		Flows are more or less variable than natural	When flows are more variable	Low
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	When later, the pools may not hold water until the floods	Medium
7		Natural proportion of different types of flood year changed	Little effect, when larger floods are less common	Low
8	Transition 2	Onset is earlier or later than natural	Unlikely to affect	Low
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower	Little effect, drying out too fast if duration is longer	Medium

5.4 Conclusion

More detailed data on the distribution of the macroinvertebrates and their life cycles in the Okavango River and other perennial rivers in Namibia and Southern Africa would have been of great help. Most of the information was for South African rivers and sometimes the habitats where certain macroinvertebrates are found differ from the Namibian ones. For example, the Caenidae found on stones and muddy areas in South Africa were found in marginal vegetation of both the channel and floodplain areas alongside the Okavango River. One can therefore speculate that their response to changes in flow would be different.

In Namibia, river ecologists have lots of regional or international examples to follow when it comes to Environmental Flow Assessment, but have no or little practical experience. Poor detailed knowledge of the aquatic biota and ecological functions specific to our rivers makes it difficult to carry out this kind of work. But there is a will to learn from experts, hence this study.

I would like to specialize in the ecological functions of rivers in Namibia and their aquatic biota. I also would like to be trained further in aquatic macroinvertebrates identification because I am keen to continue monitoring the ecology of macroinvertebrates with the other two countries, even after the EFA project.

5.5 Flow-response relationships for use in the Okavango EF-DSS

The flow-response curves were drawn at the Knowledge Capture Workshop in Windhoek from 30th April – 4th April 2009 and will be included in a CD that accompanies the project Final Report.

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APPENDIX A: FULL DESCRIPTIONS OF INDICATORS

Table 7.1: List of species and the representative species for aquatic invertebrates indicators.

Indicator	**List of Orders**	**Representative Family**	**Why this order/family**
Channel dwellers in Marginal Vegetation	Ephemeroptera Odonata Gastropoda	Caenidae sp. Tricorythidae Aeshnidae Planorbidae	Diversity, abundance and it is food for fish. Food for vertebrates such birds, frogs and fish Medically important *Bulinus globosus* is host for Schistosomes parasites that cause Bilharzia in humans. While *Bulinus tropicus* is host for livestock and game schistosomes.
Channel dwellers in fine Sediment	Bivalves/Pill clams	Unionidae, Sphaeriidae	Water Quality indicators. As filter-feeders, they are affected by polluted water
Channel dwellers in Rapids	Diptera	Simuliidae- Simulium sp.	Medically important as River blindness disease vector
Channel dwellers in cobbles and boulders	Trichoptera	Hydropsychidae and Ecnomidae	Abundance affected by fluctuating flow
Floodplain dwellers in Marginal Vegetation	Odonata Gastropoda	Coenagrionidae Physidae, Planorbidae	Abundance. Also food for fish and birds
Floodplain dwellers in pools	Coleoptera	Dytiscidae	Food for fish and affected by fluctuations in flow. With limited habitat especially during the low-flow/dry season, they become vulnerable to predation.

APPENDIX B: RAW DATA

Dry Season			
EFA Site 4: Kapako		EFA Site 5: Popa	
Representative Species	***Found Species***	***Representative Species***	***Found Species***
Channel MV	**Channel MV**	**Channel MV**	**Channel MV**
Caenidae	Baetidae	Caenidae	Baetidae
Aeshnidae	Caenidae	Aeshnidae	Libellulidae
Planorbidae	Coenagrionidae	Planorbidae	Gerridae
	Nepidae		Veliidae/Mesoveliidae
	Pleidae		
	Dytiscidae		
Channel sediment	**Channel sediment**	**Channel sediment**	**Channel sediment**
Unionidae	Unionidae	Unionidae	Oligochaeta
Sphaeridae	Oligochaeta	Sphaeridae	Perlidae
	Polymitarcyidae		Caenidae
			Heptageniidae
			Polymitarcyidae
			Libellulidae
			Ecnomidae
			Certopogonidae
			Chironomidae
			Unionidae
Channel cobbles and boulders	**Channel cobbles and boulders**	**Channel cobbles and boulders**	**Channel cobbles and boulders**
Not Applicable	Not applicable	Hydropsychidae	Perlidae
		Ecnomidae	Baetidae
			Heptageniidae
			Tricorythidae
			Ecnomidae
			Hydropsychidae
			Leptoceridae
			Hydraenidae
			Chironomidae
			Simuliidae
Channel Rapids	**Channel Rapids**	**Channel Rapids**	**Channel Rapids**
Not Applicable	Not Applicable	Simuliidae	Heptageniidae
			Simuliidae
			Hydropsychidae
			Libellulidae
			Ecnomidae
			Tricorythidae
			Perlidae
Floodplain MV	**Floodplain MV**	**Floodplain MV**	**Floodplain MV**
Coenagrionidae	Not sampled	Not Applicable	Not Applicable
Physidae			
Planorbidae			
Floodplain Pool	**Floodplain Pool**	**Floodplain Pool**	**Floodplain Pool**
Dytiscidae	Corixidae	Not Applicable	Not Applicable
	Notonectidae		
	Chironomidae		

Wet Season			
EFA Site 4: Kapako		EFA Site 5: Popa	
Representative Species	***Found Species***	***Representative Species***	***Found Species***
Channel MV	**Channel MV**	**Channel MV**	**Channel MV**
Caenidae	Baetidae	Caenidae	Baetidae
Aeshnidae	Caenidae	Aeshnidae	Tricorythidae
Planorbidae	Leptophlebiidae	Planorbidae	Libellulidae
	Oligoneuridae		Hydropsychidae
	Tricorythidae		Chironomidae
	Aeshnidae		Simuliidae
	Libellulidae		Caenidae
	Naucoridae		Ecnomidae
	Veliidae		Hydroptilidae
	Chironomidae		Leptoceridae
	Ampulariidae		
	Thiaridae		
Channel sediment	**Channel Sediment**	**Channel sediment**	**Channel sediment**
Unionidae	Water depth was about 4m, not sampled	Unionidae	Oligochaeta
Sphaeridae		Sphaeridae	Ceratopogonidae
			Chironomidae
			Ancylidae
Channel cobbles and boulders	**Channel cobbles and boulders**	**Channel cobbles and boulders**	**Channel cobbles and boulders**
Not Applicable	Not applicable	Hydropsychidae	Hydroptilidae
		Ecnomidae	Chironomidae
			Oligochaeta
			Libellulidae
			Chlorocyphidae
Channel Rapids	**Channel Rapids**	**Channel Rapids**	**Channel Rapids**
Not Applicable	Not Applicable	Simuliidae	Heptageniidae
			Simuliidae
			Hydropsychidae
			Libellulidae
			Culicidae
Floodplain MV	**Floodplain MV**	**Floodplain MV**	**Floodplain MV**
Coenagrionidae	Hydracarina	Not Applicable	Not Applicable
Physidae	Baetidae		
Planorbidae	Coenagrionidae		
	Lestidae		
	Libellulidae		
	Ampulariidae		
	Lymnaeidae		
	Thiaridae		
	Gerridae		
	Chironomidae		
	Ostracoda		
	Caenidae		
Floodplain Pool	**Floodplain Pool**	**Floodplain Pool**	**Floodplain Pool**
Dytiscidae	Corixidae	Not Applicable	Not Applicable
	Oligochaeta		
	Baetidae		

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*
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Environmental protection and sustainable management of the Okavango River Basin

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