Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module Specialist Report Country: Botswana Discipline: Aquatic Macroinvertebrates

Belda Q. Mosepele
Helen Dallas

July 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

BIOPHYSICAL SERIES

Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module

Specialist Report

Country: **Botswana**

Discipline: Aquatic Macroinvertebrates

Author: *Belda Q. Mosepele and Dr. Helen Dallas*

Date: July 05th 2009

EXECUTIVE SUMMARY

The diagnostic analysis of aquatic macroinvertebrates environmental flows for the Okavango Delta used existing data on previous research studies conducted for the Okavango Delta for the past 7 years. Freshwater aquatic macroinvertebrates are very important food for fish and other organisms. Being at the bottom of the food web, they play a role in energy transfer and ecosystem recycling. Data was collected in four focal points, which have a mosaic of habitats that represent the Okavango Delta. A scoop net was used to sample in the marginal vegetation, floating vegetation, instream vegetation, pools and lagoons from the Upper Panhandle to the lower delta in Boro, Thamalakane and Boteti rivers. There are approximately 63 families of macroinvertebrates in the Okavango Delta, some of these aquatic macroinvertebrates like blackflies can be important vectors of diseases. They are responsible for transmitting onchocerciasis (river blindness) to millions of people in tropical areas around the world. Other important aquatic macroinvertebrates found in the Okavango delta are the ancient like shrimps, and rare crustaceans (fairy shrimp) that occur mostly in pools in Moremi Game Reserve. In some previous studies, water quality parameters (Ph, DO, conductivity and temperature) was also collected. The data of previous studies, unfortunately did collect any information that relates macroinvertebrates distribution and abundance links to flow and floods, the drivers of the ecosystem, therefore several other literature from elsewhere was used to give an insight of macroinvertebrates links to flow. In addition, the EFA study used macroinvertebrates data that was identified only up to the family level.

Results from EFA study is a selection of key indicator species (families). These indicators were selected based on their feeding guild, preferred habitat, abundance/occurrence and distribution in the Delta. Another result is the knowledge captured and the development of the response curves for each indicator and relate to various development scenarios. The scenarios indicate that not many families of aquatic macroinvertebrates will have a dramatic change under any of the three development scenarios, however, from the response curves, some habitats in the lower Delta - the Boteti river might occur with any development scenario.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ABBREVIATION	MEANING
DTM	Digital Terrain Model
AquaRAP I	Aquatic Rapid Assessment one
AquaRAP II	Aquatic Rapid Assessment two
OKASS	Okavango Delta Scoring System
HOORC	Harry Oppenheimer Okavango Research Center
BIOKAVANGO	Building Local Capacity in Biodiversity Management in the Okavango Delta

ACKNOWLEDGEMENTS

I want to acknowledge Dr Dallas who inspired me to initiate work on aquatic macroinvertebrates in the Okavango Delta, the various teams that were engaged since 2003 to collect data in various sites of the Okavango Delta.

I also want to acknowledge my dear Husband - my rock, for the support, contribution and advice throughout the research done on macroinvertebrates.

I extend my acknowledgements to HOORC library for the assistance on literature search.

1. INTRODUCTION

1.1 Background

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

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

1.2 Okavango River Basin EFA Objectives and Workplan

1.2.1 Project objectives

The goals of the EFA are:

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

The specific objectives are:

- to ascertain at different points along the Okavango River system, including the Delta, the existing relationships between the flow regime and the ecological nature and functioning of the river ecosystem;
- to ascertain the existing relationships between the river ecosystem and peoples' livelihoods;

- to predict possible development-driven changes to the flow regime and thus to the river ecosystem;
- to predict the impacts of such river ecosystem changes on people's livelihoods.
- to use the EFA outputs to enhance biodiversity management of the Delta.
- to develop skills for conducting EFAs in Angola, Botswana, and Namibia.

2 STUDY AREA

2.1 Description of the Okavango Basin

The Okavango River Basin consists of the areas drained by the Cubango, Cutato, Cuchi, Cuelei, Cuebe, and Cuito rivers in Angola, the Okavango River in Namibia and Botswana, and the Okavango Delta (Figure 2.1). This basin topographically includes the area that was drained by the now fossil Omatako River in Namibia. Outflows from the Okavango Delta are drained through the Thamalakane and then Boteti Rivers, the latter eventually joining the Makgadikgadi Pans. The Nata River, which drains the western part of Zimbabwe, also joins the Makgadikgadi Pans. On the basis of topography, the Okavango River Basin thus includes the Makgadikgadi Pans and Nata River Basin (Figure 2.2). This study, however, focuses on the parts of the basin in Angola and Namibia, and the Panhandle/Delta/Boteti River complex in Botswana. The Makgadikgadi Pans and Nata River are not included.

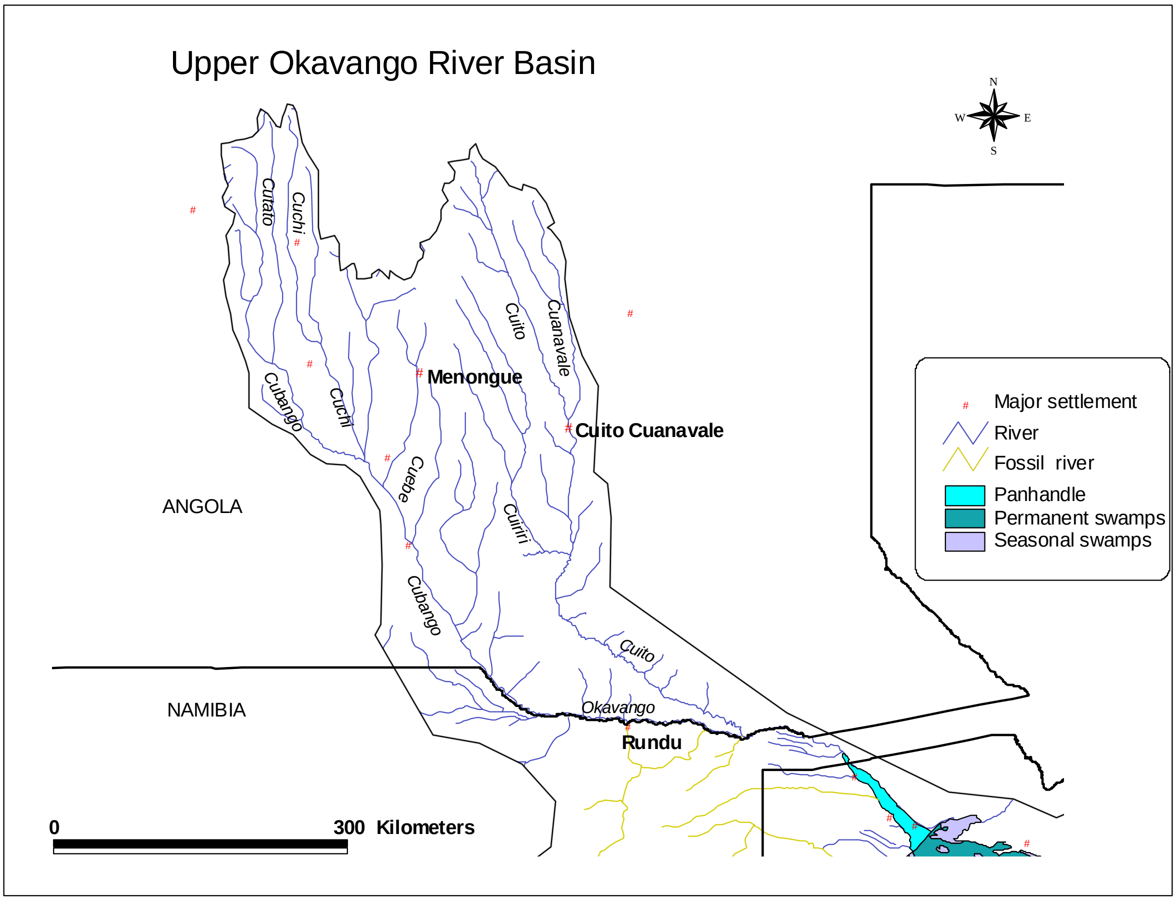

Figure 2. 1: Upper Okavango River Basin from sources to the northern end of the Delta

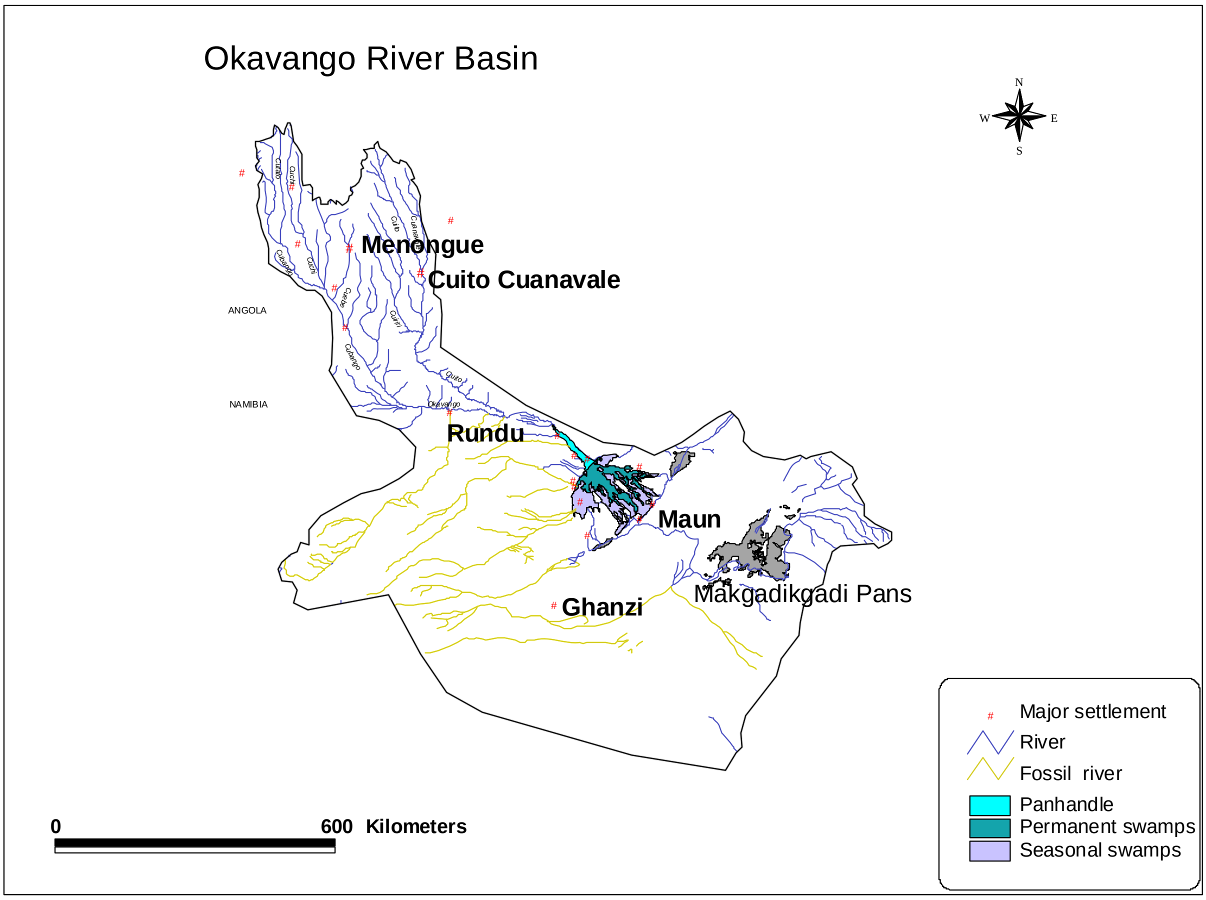

Figure 2. 2: The Okavango River Basin, showing drainage into the Okavango Delta and the Makgadikgadi Pans

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 like the Okavango Delta pilot site. Instead, representative areas that are reasonably homogeneous in character may be delineated and used to representative much wider areas, and then one or more representative sites chosen in each as the focus for data-collection activities. The results from each representative site can then be extrapolated over the respective wider areas.

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

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

The 19 recognised IUAs were then considered by each national team as candidates for the location of the allocated number of study sites:
Angola: three sites
Namibia: two sites
Botswana: three sites.

The sites chosen by the national teams are given in Table 2.1.

Table 2.1 Location of the eight EFA sites

EFA Site No	Country	River	Location
6	Botswana	Okavango	Panhandle at Shakawe
7	Botswana	Khwai	Xakanaka in Delta
8	Botswana	Boteti	Chanoga

2.3 Overview of sites

2.4 Discipline-specific description of Botswana sites

Site 6: Panhandle at Shakawe

The Upper Panhandle in the Okavango Delta receives water flowing from the Basin (Angola and Namibia) through Mohembo. This site is relevant for the aquatic macroinvertebrates because these organisms depend largely on the inundated floodplain where they refuge, and complete their life cycle. This site (around Drotskys Cabins near Shakawe) has unique backwaters area that host abundant crustacean (freshwater shrimp – family Atyidae). For the EFA study, this site and this particular indicator are very important. Its importance is also highlighted by Dallas & Mosepele (2007) that describes that a total of 98 morphospecies were recorded in this site during the study period in 2003.

Site 7: Eastern Delta around Xakanaxa

This area is within the Moremi Game Reserve, and has varied habitats that depend on the flow of the main channel and on the rain within the mopane woodland. These habitats include some marginal vegetation, fast flowing water, instream vegetation, backwaters, lagoons and seasonal pools. During the 2003 survey, 125 morphospecies were recorded and the only Leptophlebid may fly - Euthraulus sp. collected in this survey was observed in this site (Dallas & Mosepele, 2007). This area also hosts unique taxa. According to Dallas & Mosepele, 2007, an unusual record of a Setodes sp was observed, and it is presumed to be a new species. The Seasonal flooded and rain-filled pools are unique and different from other habitats with respect to their macroinvertebrates assemblage and that because they host several crustaceans, including the Anostraca and Cladodocera, although the macroinvertebrates fauna were dominated by Hemiptera and Coleoptera.

Site 8: Chanoga

Chanoga site and the Boteti river are the outflows of the Delta. Their faunal assemblages depend largely on the flow, the extent of the flood and the duration of water it receives. This site did not get much water for the past years, until recently, it has been inundated for some time. Aquatic macroinvertebrates form a major component on fish diet, and hence, communities around this site benefit from fish for their source of protein. Fish is also sold at a local market, and the money is used for other forms of livelihood.

2.5 Habitat integrity of the sites

3. IDENTIFICATION OF INDICATORS AND FLOW CATEGORIES

4. Indicators

5. 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.

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 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 aquatic macroinvertebrates discipline by – Belda Mosepele (Botswana), Maria Filomena (Angola) and Shishane Nakanwe (Namibia) - and is provided in **Error! Reference source not found.**. Further details of each indicator, including the representative species of each biological one, are given in Appendix A, and discussed fully in Chapter **Error! Reference source not found.**.

Table Error! No text of specified style in document.**.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						X		
2	Channel dwellers in marginal vegetation						X		X
3	Channel dwellers in rapids (fast flowing water)							X	
4	Channels dwellers on cobbles and boulders (rocks and stones)								X
5	Dwellers in fine sediment						X	X	
6	Floodplain dwellers in backwaters						X	X	
7	Dwellers in Pools or lagoons							X	

Description and location of indicators

Aquatic macroinvertebrates - Indicator 1

Name: Channel dwellers in submerged aquatic vegetation

Description: Channel dwellers in submerged vegetation can be described as those dwellers or aquatic macroinvertebrates that are mostly found in vegetation that is often submerged in a channel. These habitats are essential in providing food, and shelter against predators. On site 6, the Upper Panhandle area, this habitat is available and comprises mostly of vegetation commonly known as water hornworth (*Ceratophyllum demersum*) and the coarse oxygen weed (*Lagarosiphon major*). This vegetation is found in some portions of the Upper Panhandle (around Shakawe – site 6)

Representative species: Freshwater shrimps. Family: Atyidae, genus Caridina.
It is represented by the species *Caridina Africana or Caridina nilotica*.

Other characteristic species:
Caridina nilotica feeds mainly on periphyton scraped from aquatic hydrophytes and on plant detritus, but readily scavenges on the corposes of animals such as fish, insects, and shrimps.

Flow-related location:

Not known. But in Site 6, in the upper panhandle, according to Mosepele's observation, this species requires a minimum level of inundation on the habitat above described. The vegetation needs to have some level of inundation during all seasons, particularly in September/November. Their abundance decline is probably related to the low temperatures (in winter – around June/July). Their abundance declines in winter, around June-July when the water levels are reduced and in January before the floods arrive. At the high water level (in April) the abundance decline is noticeable, but around September to November this species abundance is very high.

Known water needs:

In South Africa Rivers where it occurs, this shrimp is generally a shallow water littoral inhabitant of fringing aquatic vegetation, but offshore benthic populations are known from depths of up to 40 m in Lake Sibaya, (Moor *et al.,* 2003). According to Moor *et al.,* 2003, freshwater shrimps prefer slightly saline conditions (2 to 3 parts per mil) in upper estuarine reaches, but is intolerant of temperatures maintained below 10 degrees Centigrade's and those above 30 degrees Centigrade's.

Aquatic macroinvertebrates - Indicator 2

Name: Channel dwellers in marginal vegetation

Description: Channel dwellers in marginal vegetation can be described as those dwellers or aquatic macroinvertebrates that are mostly found in vegetation that is on the margins of a channel. On site 6, the Upper Panhandle area and site 7, the Moremi Game Reserve – Xakanaka area, this habitat is available and comprises mostly of the vegetation commonly known as common reed (*Phragmites australis*), hippo grass (*Vossia cuspidata*) and in some areas a mixture of those with other plants like the fern (*Cyclosorus interrupts*).

Representative species: Family Caenidae (Ephemeroptera); Baetidae (Ephemeroptera); and Polymitarcidae (tricoptera).

Other characteristic species:

Family Caenidae has several species of nymphs, relatively small (commonly known as cainflies). They have two prominent square gills, humped backs and the nymphs are relatively small.

Flow-related location:

Not known in the Okavango Delta. In some rivers in South Africa, it has been described that this cainflies nymphs prefer slow or very slow streams habitats.

Known water needs:

Like any other macroinvertebrate, Caenids require some water to complete their cycle.

Aquatic macroinvertebrates - Indicator 3

Name: Channel dwellers in fast flowing water

Description: Channel dwellers in fast flowing water can be described as those dwellers or aquatic macroinvertebrates that prefer highly oxygenated fast flowing water. On site 7, the Moremi Game Reserve –

Xakanaka area, this habitat is available in portions of the channel either with submerged or marginal vegetation. This habitat hosts unique diversity of aquatic macroinvertebrates that require high levels of oxygen.

Representative species: Tricoptera (Family Leptoceridae) and Diptera (Family Simuliidae)

Leptoceridae (also commonly known as cased caddisflies)
The Leptoceridae is the dominant family of Trichoptera and is regarded as the most diverse of genera and species in the Afrotropical region, with 20 genera and 306 species (Day et al., 2003)
Simuliidaes are known as blackflies and there are the known to be carries of the "river blindness" sickness in many parts of the world. In Botswana, the larva occurs in a diverse of habitats, particularly in shallow, rapid streams. Observations by Mosepele, 2006 of adult blackflies were made in the distal part of the Delta, in lake Ngami, in 2006.

The female in the majority of Simuliidae species [common names: Buffalo Gnats (English); mawi (Africa); pium, borrachudos (Brazil); potu (India); jejenes (Venezuela); bocones (Costa Rica); rodadores (Cuba)] requires a blood meal for egg maturation, and it is this requirement that makes species in this family important as biting pests and in the transmission of parasites of the blood and skin in both man and warm-blooded animals. The most important parasites in man transmitted by simuliid blackflies are the nematode *Onchocerca volvulus* and *Mansonella ozzardi*. The former species is responsible for the human disease "onchocerciasis or river blindness", affecting 17 million people in the Afrotropical and Neotropical regions [http://blackflies.info/en/content/information].
In spite of the medical importance of some of the species, simuliids are also keystone species in the ecology of running water because of their rare ability to filter dissolved organic matter and make it available in the food chain. Blackflies are also important for environmental monitoring of freshwater contamination, because immature stages (larvae and pupae) are susceptible to both organic and inorganic pollution (e.g., effluent from sugar mills, slurry from farms, insecticide and fertiliser run off from farms and plantations). Blackflies also have a particular evolutionary interest as a morphologically conservative group with very extensive cryptic speciation and reticulate evolution. [http://blackflies.info/en/content/information]

Other characteristic species:

There are various taxonomic problems in Simuliidae worldwide. Firstly, several regional simuliid faunas are still poorly known and they are much in need of biodiversity surveys and revisionary studies, where new morphospecies are to be found. Second, the supraspecific classification is currently unstable and problematic; many species or species-groups are placed in the wrong genus, and whether subgenera should be ranked as species groups or genera is still in much debate. And thirdly, species limits remains poorly defined for many taxa because of the presence of species complexes ("sibling species").

Flow-related location:

Not known. But according to [Day et al., 2003], black flies can form 95% or more of the total number of individual invertebrates collected from stones in rapids and hence they can truly be considered to be specialists of that swift-flowing aquatic biotope. Because of their abundance, black flies form an important component of the aquatic food chain in swift-flowing water.

Known water needs:

These pupae of simuliids live in running water on stones and plant parts. According to Gerber and Gabriel, 2002, blackflies require water that flows fast at all seasons. The water level should be sufficient for good oxygenation. These families will not tolerate or will not survive if the flow reduces and deposition of decomposed material is high.

Aquatic macroinvertebrates - Indicator 4

Name: Channel dwellers in rock bottoms

Description: Channel dwellers in rock bottoms are those dwellers that prefer to stay in rocks or stones submerged in water in all seasons. They are unique to these habitats and are generally described as filter-feeders; Some families of tricoptera build narrow, fine-meshed finger-shaped nets on or under rocks in streams.

Representative species: Tricoptera – family Philopotamidae

The larvae feed on fine detritus that the meshwork filters out of the water, which they then clean off with their brush-like labrum. These are a caseless caddisfly, with soft white labrum which is visible when extended.

Other characteristic species:

They live in low-salt concentrations. In site 8 around the Boteti river near Chanoga, there are some areas in which the bottom is rocky and this family is expected to occur.

Flow-related location:

Not known.

Known water needs: unknown

Aquatic macroinvertebrates - Indicator 5

Name: Channel dwellers in fine sediments

Description: dwellers in fine sediments are those invertebrates that are able to burrow into sediments. Several studies indicate that chironomids, oligachaets and sphaerids are commonly associated with sediments.

Representative (species) Families: Unionidae and Sphaeriidae

Other characteristic species:

Flow-related location:

Not known.

Known water needs: Not known

Aquatic macroinvertebrates - Indicator 6

Name: Floodplain dwellers in backwaters

Description: Floodplain dwellers in backwaters occur in site 6 and 7. The floodplain when inundated with water from the main channel, creates an habitat that family Planorbidae is abundant and that family Coenagrionidae increases especially during flood recession.

Representative species: Family Planorbidae common name are known as *Orb snails,* their structure is generally flat shell, tightly coiled. It is known to host the bilharzias parasite. According to Gerber & Gabriel, 2002, Planorbis prefers gravel beds or aquatic vegetation.

Other characteristic species: Family Coenagrionidae, known as damselflies. According to Gerber & Gabriel, 2002, damselflies have slenders bodies, with three leaf-like gills and pointed tips. Certain species of this family have jointed gills. They prefer habitats with vegetation.

Flow-related location:

Not known.

Known water needs: this insects have a stage in their life cycles that requires water

Aquatic macroinvertebrates - Indicator 7

Name: floodplain dwellers in seasonal pools

Description: Seasonal pools in the mopane woodlands form an important habitat of site 7. It hosts unique taxa of fairy shrimp and other smaller crustaceans. These pools are mostly rich of green algae, the preferred food for fairy shrimps.

Representative species: Family Lynceidae, Daphnia and Gammarus sp

Fairy shrimps are found in temporary pools. They do not have have a carapace. According to Olsen *et al*., 2001; fairy shrimps swims upside down, have two pairs of eyes, one pair of stalks, and two pairs of antennae, in males the second is modified as a pair of claspers. They feed on plankton, especially algae. Representative species of fairy shrimps found in site 7 pools is *Chirocephalus sp*.

Clam shrimps (family Lynceidae) – are characterised by a head covered by a hood-shaped carapace; the female's ends in a point, while the male is blunt (Olsen *et al*., 2001). They feed on plankton, they a rare and are found just above the bottom or free swimming in small drying puddles (Olsen *et al.,* 2001). Representative species: Lynceus sp.

Water fleas (Daphnia, Chydorus sps) have a bivalved transparent shell, covering thorax and abdomen. According to Olsen et al 2001; water fleas head is covered by a hood-shaped shell with a large eye, and the abdomen ends in two claws. They are most filter-feed on plankton, which is caught by the 4-6 pairs of thoracic limbs and brought forward towards the mouth. A few species feed on carrion, freshwater polyps or are predators. They are found in all types of freshwater, except fast-flowing watercourses (Olsen et al 2001). Water fleas are important for the recycling of organic substances in ponds and lakes. They eat huge quantities of planktonic algae, break down waste and are in turn food for numerous small aquatic animals and fish, (Olsen et al., 2001).

Other characteristics: Water fleas normally reproduce by parthenogenesis. Under certain conditions – such as too many solutes in the water, too little food, a pond drying out, and when the temperature falls in autumm – the smaller males are produced, and they then fertilise the females (Olsen et al., 2001). These females produce thick-shelled dormant eggs, which can remain unhatched for several years and in many species can withstand desiccation and frost.

Flow-related location:

Not known.

Known water needs:

Pools or ponds require water for families mentioned above for reproduction. Pools can be inundated for a short period of time, e.g. three months per year during the rainy season.

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.**. 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.

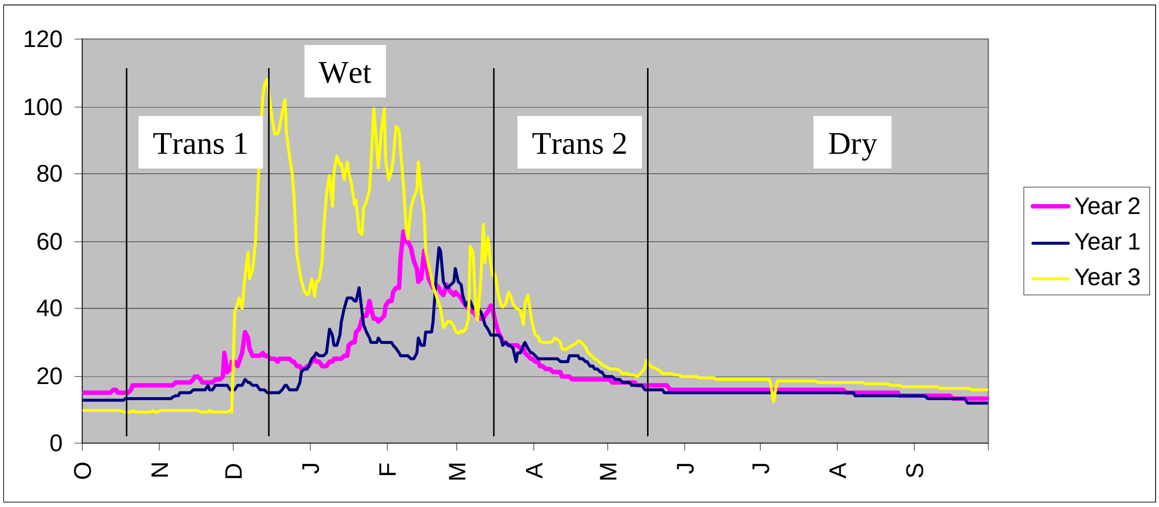

Figure 3. 1: Three representative years for Site 1: Cuebe River @ Capico, illustrating the approximate division of the flow regime into four flow seasons

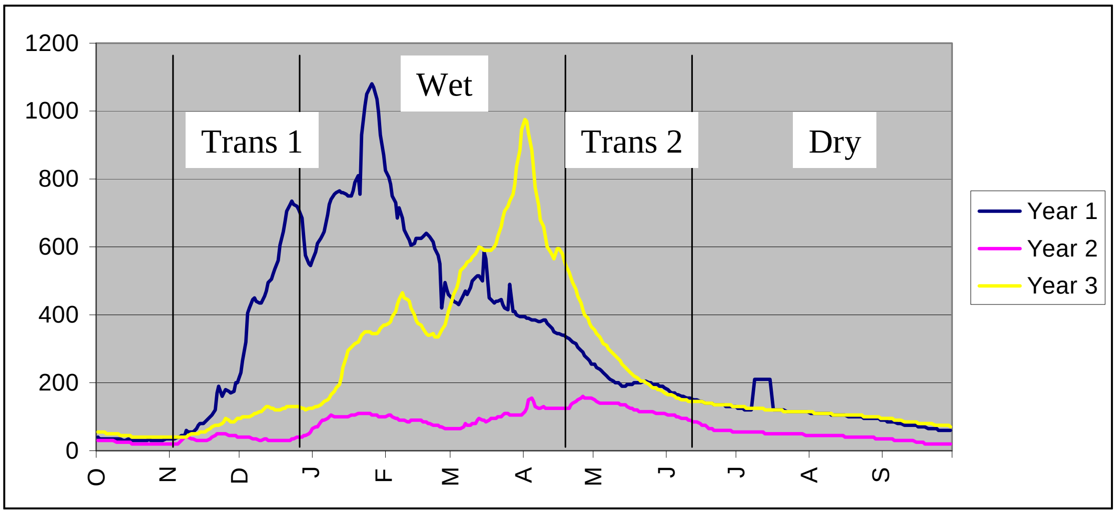

Figure 3. 2: Three representative years for Site 2: Cubango River @ Mucindi, illustrating the approximate division of the flow regime into four flow seasons

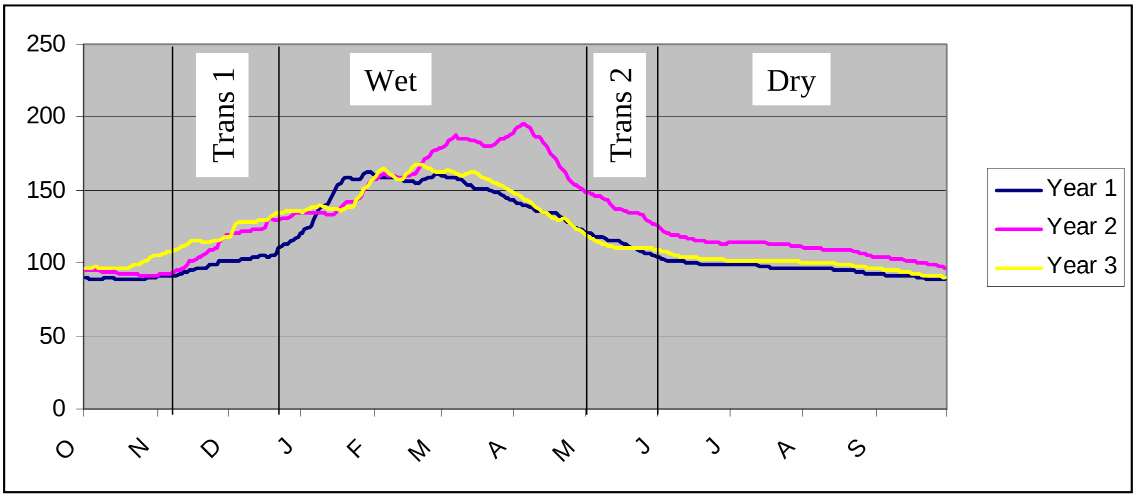

Figure 3. 3: Three representative years for Site 3 Cuito River @ Cuito Cuanavale, illustrating the approximate division of the flow regime into four flow seasons

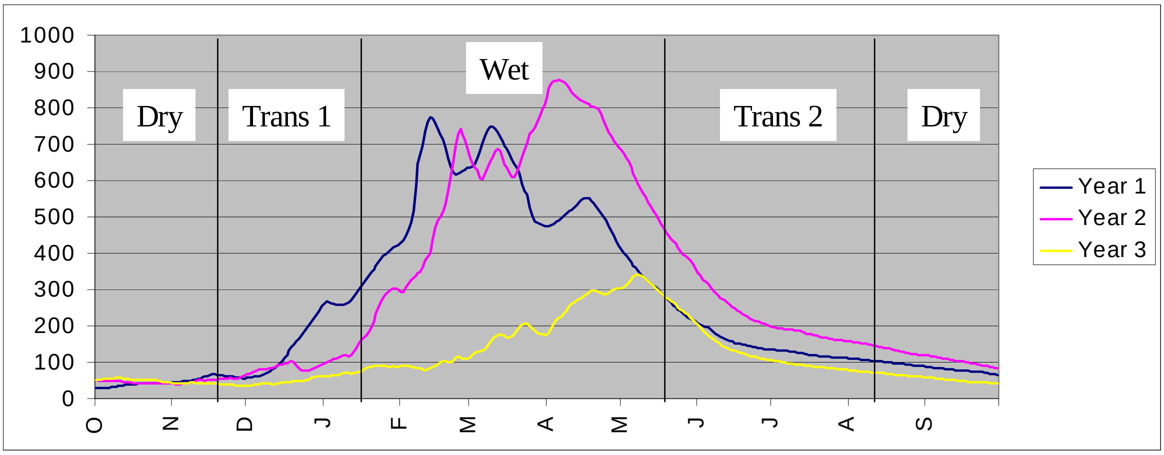

Figure 3. 4: Three representative years for Site 4: Okavango River @ Kapoka (hydrological data from Rundu), illustrating the approximate division of the flow regime into four flow seasons

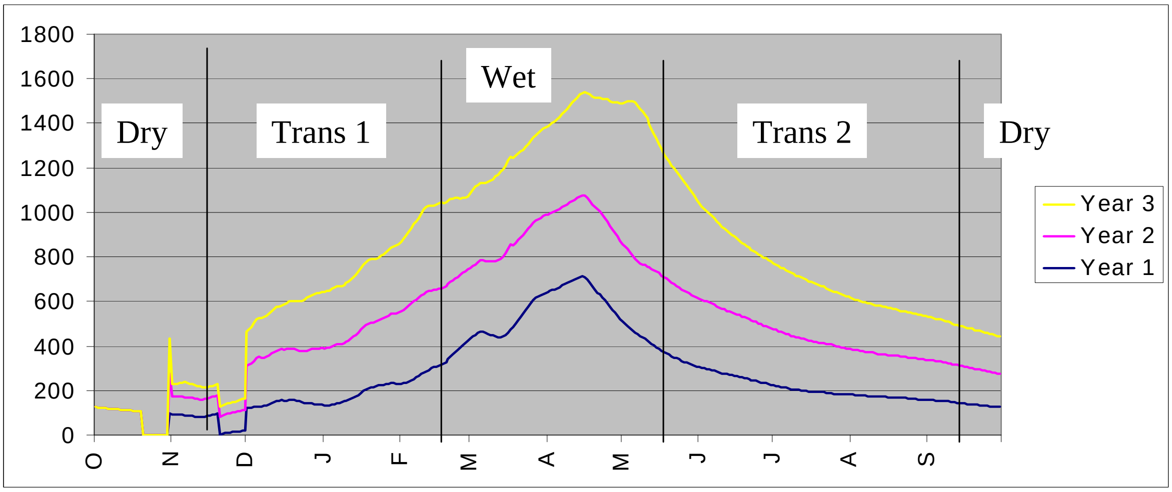

Figure 3. 5: Three representative years for Site 5: Okavango River @ Popa (hydrological data from Mukwe), illustrating the approximate division of the flow regime into four flow seasons

The literature review (Chapter **Error! Reference source not found.**) and data collection and analysis exercises (Chapter **Error! Reference source not found.**) are focused on addressing what is initially expected to be nine main questions related to these flow seasons (**Error! Reference source not found.**).

Table Error! No text of specified style in document.**.1 Questions to be addressed at the Knowledge Capture Workshop, per indicator per site. In all cases, 'natural' embraces the full range of natural variability**

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

Inundation categories – delta sites

The recognised river flow categories are not relevant in the Delta, where inundation is the major driver of ecosystem form and functioning. The main inundation categories recognised by the inundation model developed by the Harry Oppenheimer Okavango Research Centre (HOORC) are used here (**Error! Reference source not found.**).

Table Error! No text of specified style in document.**.2 Inundation categories for the Okavango Delta as recognised by the HOORC inundation model**

Inundation category number	Inundation category name	Description

(The hydrologists and relevant Delta specialists are presently defining the main inundation categories for the Delta, and these will be supplied to the Botswanan team as soon as they have been finalised.)

6 LITERATURE REVIEW

6.1.1 Literature review - Macroinvertebrates of the Okavango

No studies have been conducted in the Okavango Delta that relates macroinvertebrates with flow. The few studies conducted (six) on macroinvertebrates were to assess macroinvertebrates distribution during the high and low water periods in 2000 and 2003 respectively. Other studies on macroinvertebrates were related to the impact of the aerial spray of deltamethrin on macroinvertebrates.

For the purpose of this report, literature review included the publish journal articles, internet search and any other available regional published information that relates macroinvertebrates with flow and water needs were possible.

According to (Alonso and Nordin, 2003) aquatic rapid assessment survey during the high-water period in 2000 focused in four focal areas of the delta, selected to represent areas in the permanent swamp, the seasonal swamp and the drainage rivers, including the deltaic and pool habitats. The study further looked at selected aquatic groups including Hirudinea (leeches), Gastropoda (snails), Bivalvia (mussels), Decapoda (crabs and shrimps), Heteroptera (water bugs), Ephemeroptera (mayflies) and Odonata (dragonflies and damselflies). Heteroptera and Odonata were the most diverse group. Deltaic and temporary pool habitats had different macroinvertebrate assemblages. Several new species and new records for the delta were recorded.

The low-water level aquatic rapid assessment survey conducted in 2003 (Mosepele, In Press; Dallas and Mosepele, In Press) included the same four focal areas of the Delta as used for Aquatic Rapid Assessment during the high-water level survey. The macroinvertebrates component was also published in scientific journal (Dallas and Mosepele 2007). Seventy-five samples were taken in a range of aquatic habitats at 29 georeference points Over 180 morphospecies (approximately 63 families) were recorded during the survey.
With respect to the different aquatic habitats sampled, the highest number of taxa was recorded in marginal vegetation in the channels and lagoons, although inundated floodplains, floating vegetation and marginal vegetation in backwaters also supported many taxa. The fewest taxa were recorded in sediment. This survey, whilst representing a ‘snapshot’ of the system under low-water conditions, highlights the importance of maintaining a mosaic of aquatic habitats in the Delta. Generally, more macroinvertebrate taxa were sampled during this survey than in Aquatic Rapid Assessment (AquaRAP) I.

(Dallas and Mosepele, 2007) & (Dallas *et al.* 2007) provide a preliminary overview and analysis of spatial distribution of aquatic macroinvertebrates in the Okavango Delta. The studies aimed at assessing the aquatic biodiversity and water quality of the Okavango Delta by examining zooplankton, macroinvertebrates and fish; and to use this information to develop a monitoring programme for the Delta that would assist in its conservation and management.

Macroinvertebrates associated with inundated floodplains in the Shakawe area were most different from other deltaic habitats. The abundance in this habitat peaks in April, June and September. In April and June are generally the peak flood season in Shakawe area, with most of the floodplains inundated depending on the amount of the flood.

Notwithstanding the fact that flooding periods occur at different times of year at the different focal areas; the flood arrives in Shakawe in February/March, peaks in April/May, and recedes from June. In Guma areas, the flood arrives in April/May, peaks in June/July, and recedes from August, while in Nxaraga/Xakanaka, the lower distal parts of the Delta, the flood waters reach there around June/July, and recede from September (Dallas and Mosepele, 2007). Rainfall occurs during December/January and February. Both the univariate (number of taxa and abundance) and multivariate analysis do not suggest that macroinvertebrate communities respond to the seasonal flood regime of the Okavango Delta, although further studies were recommended to validate this finding.

6.1.2 Flows, Water level fluctuations and Macro-invertebrates

According to King and Brown (2006), increasing demands for water are degrading rivers worldwide, resulting in a loss of vital goods and services they provide. Moreover, changes in climate, low rainfall, floods, drought, growing population, has a negative impact in the aquatic ecosystems and its organisms. The Okavango delta is among the more pristine wetland-wilderness regions of the world (VanderPost, *et al*., 2005) and it is estimated that the input of water to the Okavango Delta to be 66% from stream flow originating in Angola and 33% from rainfall over the Botswana portion of the Okavango basin, resulting in flow variations that make the Okavango Delta highly dynamic alluvial fan, with wetted extents varying from 6,000 to 12,000 km.

The Okavango Delta gets its water from the Angolan highlands that pass through Namibia, before entering Botswana in Mohembo (Wilson and Dincer, 1976). Changes in flow and water level will affect aquatic biodiversity, particularly of macroinvertebrates since there are on the base of the food chain. Challenges to maintain a pristine ecosystem functioning that provides all goods and services for its users is great particularly if steps to conserve and protect the basic element of its existence – *water*, is not done. This challenge is augmented by the lack of important data on hydrology that relates to the ecology and biology of macroinvertebrates of the Okavango Delta. Scientific data on macroinvertebrates that can be linked to flow change, water levels dynamics are important to predict scenarios that can describe impact of river change and be used to guide decision makers on monitoring and on ecosystem management.

Miller (2007) was able to show that macro-invertebrates respond to water level fluctuations through indirect environmental alterations that intensify with the magnitude and duration of water level fluctuation. He observed that changes in community composition were associated with interacting thresholds of reduced discharge and altered water quality (i.e., increased conductivity and temperature) and that similar responses were observed at the population level; growth and development alterations.

Introduction

Aquatic macro-invertebrates form a major component of the biota of aquatic ecosystems and are associated with one or other aquatic habitat (Palmer *et al*., 1991, Dallas 1997, 2002; Dallas and Day, 2007) such as stony beds, floating vegetation, marginal and instream vegetation, gravel, sand and mud (Dallas, HF, 2008). 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 half 0.25 mm to several centimetres.

Macroinvertebrates are animals without backbones that can be seen with a naked eye, although some larval forms require a microscope for its identification. They are largely dependent on the aquatic system they live and are sensitive to factors such as water quality, water quantity (environmental flows), habitat and food availability (Dallas and Mosepele, 2007); making them essential components in the functioning of the aquatic ecosystems. Therefore, macroinvertebrates are often referred to as health ecosystem indicators, because they are frequently used as indicators of the general ecological condition.

Indicator 1: Channel dwellers in submerged aquatic vegetation

Main characteristics of Indicator 1

Table 4.1. List of species and the representative species for aquatic invertebrates indicators.

Indicator	List of species	Representative Families (species)	Why this species
Channel dwellers in submerged aquatic vegetation	*Caridina africana*	Family Atyidae (Freshwater Shrimp)	Is one of the most important food items for numerous fish and other predators. Generally are known to be used as indicators of good water quality.
Marginal vegetation	Ephemeroptera: Baetidae Odonata (Anisoptera): Libellulidae	Baetidae (Baetis sp) Libellulidae (Libellula sp)	These groups are common in this habitat. The Ephemeroptera and Odonata, are the only extant insects with a paleopterous flight mechanism. These two relatively small orders, sometimes classified as the infraclass Paleoptera, constitute the remnants of an extensive fauna which mostly became extint at the end of the Mesoic Era (Daly, H.V. et al, 1998). Mayflies and odonates also constitute food for fish.
Channel dwellers in fast flowing waters	Diptera: Simuliidae and Tricoptera: Hydropsychidae	Simuliidae and Hydropsychidae	• Simulidae is also known as black-flies. It has been recorded that this family comprises of three genera containing thirty-five species, (Glegg, 1952). This family is also known as pests of cattle. • Tricopterans also known as caddis flies. Some types make for itself a protective case from pieces of stick, leaves, stones, sand grains or even snail-shell.

Channels dwellers on cobbles and boulders (rocks and stones)	Tricoptera: Hydroptildae		This group make their case when they are few months old, having no gills, apparently they breathe through their body surface. The cases made when the creatures are older are usually made of silk only and are not tubular, but flattened.
Dwellers in fine sediment	Unio sp. & Sphaerium sp.	Family Unionidae & Sphaeridae	Freshwater cockles or orb mussels are common names for the bivalves Sphaerium and Unio. These bivalves are found primarily among plants near baksn or lakes and rivers in slow moving outflows (Olsen at al., 2001). In the Okavango Delta, some Unio sps were observed in fine sediments (Dallas and Mosepele, 2007).
Floodplain dwellers in backwaters (Seasonal floodplain backwaters)	Dysticidae and Planorbidae	Coleoptera (Dytiscus sp.; Hydrobius sp.) & Mollusca Ramshorn snails (Planorbis sp.); Pond snail (Lymnaea stagnalis)	Diving beetles are represented by several species. The common species found in the Okavango Delta is known as “great diving beetle” – *Dytiscus marginalis*. According to Olsen *et al*., 2001; diving beetle larvae pupate in a small hole in soft soil near the water’s edge. After few weeks the beetle emerges. Over winters as adult in water lays eggs in spring, usually in water. Most are found all year round, making them important for the system where they live. Both adults and larvae are predators. Moreover, according to Weaving, A., 1977; beetles make up the largest insect order with around 300000 species; and are considered a highly successful group of insects, and certain of their characteristics have contributed towards this. Beetles are also the largest order in the animal kingdom, and contains some of the smallest and largest of insects. Several families in the suborder Adephaga are aquatic, the most important being the water beetles (Dytiscidae) and the whirligig beetles (Gyrinidae), (Weaving, A., 1977). Pulmonate snails (e.g. *Lymnae* sps) have no gills; they breathe through their skin and use a kind of a lung (Olsen et al., 2001). Almost all are found on aquatic plants or hanging beneath the water’s surface. In the Okavango Delta these snails are common in backwaters. On the other hand, Pond snails (e.g. *Lymnaea stagnalis*) and ramshorn snails (e.g. *Planorbis sps*)

			rarely have completely regular shells. Usually the exterior of the shell has flat surfaces separated by ridges. This phenomenon is cased by the snail being an intermediate host for some kind of fluke, causing growth irregularities in the snail (Olsen et al., 2001). Most ramshorn snails have red blood.
Dwellers in Pools or lagoons (seasonal pools in mopane woodlands)	Anostraca and Cladocera	Gammarus sp.; Lynceus sp.; Daphnia sp.	According to Olsen et al., 2001; the common freshwater shrimp *Gammarus pulex* are probably the most important food for numerous fish and other predators. Water fleas (e.g. *Daphnia sps*.) make up a large proportion of the food of freshwater polyps (e.g. Hydras), which are paralysed by the stinging cells of the tentacles. However, a small (0.5 mm) water flea, *Anchistropus emarginatus*, which is rare, actually feeds on Hydra, which is often destroyed, (Olsen et al., 2001).

Indicator 1: Channel dwellers in submerged aquatic vegetation
Main characteristics of Indicator 1

Submerged vegetation is an essential habitat; it provides food, and shelter for many macroinvertebrates against predators. On site 6, the Upper Panhandle area, this habitat is available and comprises mostly of the vegetation commonly known as water hornworth (Ceratophyllum demersum) and the coarse oxygen weed (Lagarosiphon major).

Indicator 2: Marginal vegetation

Marginal vegetation can be found in most areas of the Okavango Delta. On site 6, the Upper Panhandle area and site 8, the Moremi Game Reserve – Xakanaka area, this habitat is available and comprises mostly of the vegetation commonly known as common reed (Phragmites australis), hippo grass (Vossia cuspidata) and in some areas a mixture of those with other plants like the fern (Cyclosorus interrupts).

Indicator 3: Fast flowing water

Fast flowing water are unique habitats in which the water flows very fast, and hence the oxygen levels are increased. These habitats host species of macroinvertebrates that require oxygenated waters for their survival.

Indicator 4: Rock bottoms

Rock bottoms or bedrocks habitats are generally found along the main stream or channel. These habitats require some inundation so that they can host certain species of macroinvertebrates. According to [http://desertmuseum.org/books/], in rifles, obviously insects must be able to hold on. Some mayflies are streamlined for lessened resistance to the force of moving water, as they cling to the rocks, plants or other substrates with sharp tarsal claws.

Indicator 5: Fine sediments

According to Townsend et al. (1997), species diversity of benthic macroinvertebrates was highest at intermediate levels of peak flow frequency and that invertebrated density decreased in frequently flooded streams in New Zealand. Further, during low flow periods, periphyton and a distinct community of sediment-tolerant benthic grazers rapidly colonized sandy areas, (de la Cretaz, 2007). Unionid mussels once were diverse and abundant in the river (Cape Fear River), but the number of species present and their densities have declined over the years, probably in response to decreasing water quality and competition from the Asiatic clam (Benke and Cushing, 2005).

Indicator 6: Backwaters

Backwaters serve as refuge for many macroinvertebrates taxa, particularly of coleopteran and some snails. According to Quinn et al., (1991), referring to the lower river Murray in South Australia, floodplains are potentially most threatened by regulation and alteration of the flooding regime.

Indicator 7: Pools

Pools in site 7 are a diverse habitat that is either filled with water from rain or water from the main channel when the flood is high. These pools require a certain amount of inundation for at least 3 months for various species of macroinvertebrates, particularly rare crustaceans (fairy shrimp) complete their life cycles. Certain species dessicate when these pools dry, however they may hatch if conditions are favourable, i.e. if pools have certain amount of water for a certain period of time. According to [http://desertmuseum.org/books/],insects living in pools or slow-moving water tend to be bulkier. Pools provide habitat to a great many aquatic beetles. Both larval and adult stages are aquatic in the family Dytiscidae (predaceous diving beetles).

Life cycle attributes

Indicator 1: Submerged vegetation (freshwater shrimp)

Freshwater shrimps have external fertilisation, with the ova being fertilized as they are extruded and then attached to the pleopods of females. According to Thorp and Covich (2001), freshwater shrimps varies from species to species and regions. Furthermore, the number of eggs produced per female is highly variable, ranging from 8 to 160, with fecundity generally a linear function of total length. The incubation period depend on the water temperature and varies from 12 to 24 days; zoeae larval lengths are approximately 4 mm at hactching and these free swimming larvae pass through six stages (varies from 3 to 8) in about three weeks.

Indicator 2: Marginal vegetation (Mayfly – Family Baetidae)

Females of few baetidae species retain the fertilized eggs within the body, where they will develop, a phenomenan called ovoviviparity, and these adult females might live one or two weeks. Most mayflies of Alberta have one generation a year (univoltine); but several, especially those in the family Baetidae, have more than one (usually two) generations a year (multivoltine), Cliford (1991), the Bigoray River of west central Alberta, larvae of the new generation first appear in late July. Larvae are found on soft, small-particle substratum.

Indicator 3: Fast flowing water (Blackflies: Family Simuliidae)

Female Blackflies lay eggs in hatches of 200-500 on vegetation or other objects in or adjacent to fast flowing well oxygenated rivers, usually at dusk (Cox, 1993). Oviposition behaviour is communal, eggs batches being deposited in close proximity to each other. According to Cox (1993), the eggs are sensitive to desiccation, and if water levels are lowered, they can be easily destroyed. The duration of the egg is dependent on temperature but at tropical temperatures hatching to the larval stages takes 4-6 days. There are four larval instars before pupae are formed. According to Cox (1993), blackfly pupae are conical, firmly attached to the substrate and have characteristic anterior respiratory threads and the duration of the pupal stages varies from 3 to 7 days.

According to [http://www.depweb.state.pa.us/blackfly/], the immature stages of blackflies are aquatic and exclusively inhabit flowing streams and river. Life cycle include four stages: egg, larva, pupa, and adult. All are aquatic except the adults, which leave the water to search for food and mates.

Indicator 4: Rock bottoms and stones (Caddisfly: Family Hydroptilidae)

According to Wiggins (2004), adult caddisflies are obscure animals, usually active only at night, although mass flights may be seen around water during evening hours. The smallest of them all belong to the cocoon-making family Hydroptilidae and are from 2 to 5 mm long. At temperate latitudes over much of North America, most caddisflies complete a single generation in the course of one year. After hatching from egg, most larvae pass through five larval moulting stages of instars and a resting pupal stage under water. Metamorphosis of the resting pupa to the adult stage is completed within about three weeks at temperate latitudes (Wiggins, 2004).

Indicator 5: Fine Sediments

(Freshwater cockles, orb mussels: Family Unionidae; Sphaeridae)

Unionidae are distinguished by a unique and complex life cycle. Most Unionids are of separate sex (although some species, such as *Elliptio complanata*, are known to be hermaphroditic). According to [http://zipcodezoo.com/Key/Animalia/Unionidae_Family.asp], the sperm is ejected from the mantle cavity through the male's excurrent aperture and taken into the female's mantle cavity through the incurrent aperture. Fertilized eggs move from the gonads to the gills (marsupia) where they further ripen and metamorph into glochidia, the first larval stage. Mature glochidia are released by the female and then attach to the gills, fins or skin of host fish. A cyst is quickly formed around the glochidia, and they stay on the fish for several weeks or months before they fall off as juvenile mussels which then bury themselves in the sediment [http://zipcodezoo.com/Key/Animalia/Unionidae_Family.asp].

Indicator 6: Backwaters (Coleoptera: Family Dytiscidae)

Diving beetle (Dyticus marginalis) larvae pupate in a small hole in soft soil near the water's edge. After a few weeks the adult beetle emerges. Overwinters as adult in water and lay eggs in spring, usually in water, (Olsen et al. 2001). According to Stafford (2006), the Dytiscidae family is one of the largest and most commonly encountered groups of aquatic beetles. Both the adults and the larvae in this family are predaceous and feed on a wide variety of smaller aquatic species. Although most adults are medium sized (15-25 mm), some attain a length just over 30 mm.

Indicator 7: Pools in mopane woodland (fairy shrimp)

Female fairy shrimp carry their eggs in a ventral brood sac. The eggs are either dropped to the pool bottom or remain in the brood sac until the mother dies and sinks. When the pool dries out, so do the eggs. They remain in the pool bed until rains or floods and other environmental stimuli hatch them. Hatching can begin within the same week that a pool starts to fill. Average time to maturity is forty-nine days. In warmer pools, it can be as few as nineteen days, http.//wikipedia.org/wiki/conservancy_fairy_shrimp]

Links to flow

Flood and drought disturbances are a fundamental part of most streams and rivers and play a central role in the regulation of populations, the structuring of communities and the functioning of aquatic ecosystems, (Lancaster et al. 2008).
Life history and behavioural adaptations, and these relate to flow regime components such as disturbance timing, frequency and predictability is discussed by Lancaster et al. 2008. Although in general, Lancaster et al. (2008), refers that unlike floods, the onset of drought is often accompanied by proximate cues such as an increase in temperature and ionic concentrations, and decrease in flow rate and water level. Lancaster et al. 2008 suggest that particularly in the Trichoptera and Plecoptera, these cues may allow facultative entry into a drought-resistant stage, or provide a signal to adjust growth and development rates accordingly.
According to Lancaster et al. (2008), for aquatic insects, behaviours may be subdivided into those facilitating within-stream during flood or drought. Instances of behavioural flood escape are best known in the Hemiptera and Coleoptera, possibly because their ability to breathe air allows them to persist out of water for relatively long time periods.

Summary

Freshwater aquatic macroinvertebrates are very important food for fish and other organisms. Being at the bottom of the food web, they play a role in energy transfer and ecosystem recycling. Some of these aquatic macroinvertebrates like blackflies can be important vectors of diseases. They are responsible for transmitting onchocerciasis (river blindness) to millions of people in tropical areas around the world [http://www.dep.web.state.pa.us/]. Other important aquatic macroinvertebrates found in the Okavango delta are the ancient like shrimps, and are rare – called fairy shrimp. They occur mostly in Site 7 – in seasonal pools within the mopane woodland in Moremi Game Reserve. For this study, seven indicators were indentified based on habitat, abundance and some knowledge of its importance and links to communities; however, not much information so far exists on these organisms, especially information on life cycles and their links to flow. Therefore, a refinement of indicators with a combination of a continued data collection and field observations that relates to flow is crucial. Some inferences made based on the best knowledge of certain aquatic macroinvertebrates families require further research to validate the assumptions made. Aquatic macroinvertebrates have mostly large groups and hence many families and species that behaves and relate to flood, flow or other environmental conditions differently. In this study knowledge was captured at the family level, therefore the report does not reflect precisely what are the dynamics of each species within that group or family. Further studies on species identification are required. Research to establish relationships between aquatic macroinvertebrates and flow, flood, drought, habitat distribution, abundance is need to understand the dynamics and role of these organisms in the Okavango Delta ecosystem.

7. DATA COLLECTION AND ANALYSIS

No new data were collected for this study.

Methods for data collection and analysis

No new data was collected specifically for this study. Knowledge was gathered to the existing data and field observations from various research/data collection conducted in the Okavango Delta.

6.3 Methodology
6.3.1 Collection of macroinvertebrates samples from major habitats at each site during low and high flow seasons, all linked to flow.

Three sampling sites have been chosen for this study, namely *Site 6* – Upper Panhandle around Shakawe); *Site 7* – Moremi Game Reserve (around Xakanaka); and *Site 8* – Lower Delta (around the Boteti / Thamalakane river), following the basin-wide site delineation. Eight different habitats have also been chosen in these sites to account for the various macroinvertebrates species that can be impacted one way or the other by changes in water flow. The habitats are: submerged vegetation, marginal vegetation, fine sediments, rapids or fast flowing water, marginal vegetation in floodplains, pools or backwaters in floodplains, pools or backwaters, and aquatic macrophytes.

Data for this study has previously been collected following the sampling methodology described by Dallas, 2005.

6.3.3 Identification of macroinvertebrates to species or morphospecies.

All macroinvertebrates data from previous studies to be used to describe change in relation to flow have been identified to family level.

6.3.4 Estimation of abundance of macroinvertebrates and analysis of community composition linked to flow/inundation/hydraulic habitat/season

Abundance estimates and analysis of family composition of macroinvertebrates for each habitat were done using the PRIMER v5 statistical package, but none were related to flow.

6.3.5 Prediction of changes of macroinvertebrates due to flow variations

With the available data and knowledge on macroinvertebrates, predictions curves will be produced to explore changes in macroinvertebrates abundance due to flow variations. These curves will therefore inform the possible scenarios in predicting impacts on macroinvertebrates due to flow variations.

Results

No new data.

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

Macroinvertebrates Indicator 1: Channel dwellers in submerged vegetation

Table Error! No text of specified style in document.**.3 Predicted response to possible changes in the flow regime of Channel dwellers in submerged vegetation in the Okavango River ecosystem**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Relatively nil	medium
2		Water levels are higher or lower than natural	Higher water levels implies more habitat available; lower than natural there will be some decline in abundance of shrimps	medium
3		Extends longer than natural	Reduced water level, reduced habitat, hence might affect spawning	High
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier, changes in behaviour to adjust to arrival of water may occur, however this can be relatively with no impact since the habitat might have received rain.	medium
7		Natural proportion of different types of flood year changed	Natural floods or higher will provide nutrients therefore is good for the habitat and the indicator; however if the flood changes during the flood season, some changes may occur but not significant.	medium
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 2: Channel dwellers in marginal vegetation

Table Error! No text of specified style in document.**.4 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	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	If the dry season is earlier than natural, then the habitat will be lost for the reproductive cycle of the mayflies. If the dry season is later than natural, the habitat will still have some moisture/water therefore their abundance might remain stable.	medium
2		Water levels are higher or lower than natural	Higher water levels than natural, implies that the marginal vegetation will be submerged for longer time, hence abundance might be stable. Lower levels than natural during dry season might have a negligible effect	medium
3		Extends longer than natural	Extended dry seasons will result in no habitat, no water and hence no macroinvertebrates	High
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	Higher water levels than natural, implies that the marginal vegetation will be submerged, hence reduced habitat available for spawning, hence less abundance of mayflies; lower than natural might not affect any change	medium
7		Natural proportion of different types of flood year changed	Negligible as long as the habitat is available.	medium
8	Transition 2	Onset is earlier or later than natural		

9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 3: Channel dwellers in fast flowing waters

Table Error! No text of specified style in document.**.5 Predicted response to possible changes in the flow regime of Channel dwellers in fast flowing waters in the Okavango River ecosystem**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	It will affect the life cycle. Balk flies require fast flowing water for the immature stages	low
2		Water levels are higher or lower than natural	Higher water levels implies more habitat available; lower than natural there will be some decline in reproduction	low
3		Extends longer than natural	Dry season extends therefore there will be reduced water level, reduced habitat, hence no dwellers in these habitat	low
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier, changes in behaviour to adjust to arrival of water may occur, however this can be relatively nil;	low
7		Natural proportion of different types of flood year changed	Natural floods or higher will provide fast flowing water and a conducive oxygenated habitat.	medium
8	Transition 2	Onset is earlier or later than natural		

9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 4: Channel dwellers in stones and rock bottoms

Table Error! No text of specified style in document.**.6** **Predicted response to possible changes in the flow regime of Channel dwellers in stones and rock bottoms in the Okavango River ecosystem**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	negligible	low
2		Water levels are higher or lower than natural	Stones or rocks will have some flow, hence mayflies and caddisflies will have habitat	low
3		Extends longer than natural	Reduced water level, reduced habitat, hence no macroinvertebrates	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier, it relatively nil impact; but if it is later, rocks might be exposed to drought and hence desiccation or reduction of macroinvertebrates. If rains are available before floods, rocks will have moisture and probably enough water to continue an uninterrupted life cycle.	medium
7		Natural proportion of different types of flood year changed	Natural floods or higher will provide habitat. As long as the rocks are flooded the habitat will be conducive, and hence little change might occur.	low
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 5: Channel dwellers in fine sediments

Table Error! No text of specified style in document.**.7 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	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Will affect habitatl	medium
2		Water levels are higher or lower than natural	Higher water levels implies more habitat available; lower than natural there will be some decline in abundance of Unionidae, but negligible	medium
3		Extends longer than natural	Reduced water level, and extended periods of drought may result in desiccation of macroinvertebrates in fine sediments.	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier or later will not affect the fine sediments dwellers.	low
7		Natural proportion of different types of flood year changed	Natural floods or changes in flood variability might have a negative effect on the habitat, but as long as there is some water in the sediments, these changes if any will be negligible	low
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 6: Channel dwellers in backwaters

Table Error! No text of specified style in document.**.8** **Predicted response to possible changes in the flow regime of Channel dwellers in backwaters in the Okavango River ecosystem**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negligible response	low
2		Water levels are higher or lower than natural	Higher water levels will lead to inundation of more areas of the floodplain, hence habitat conducive for snails.	medium
3		Extends longer than natural	If it extends longer than natural, macroinvertebrates will stay in desiccation for longer periods.	medium
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier, changes in behaviour to adjust to arrival of water may occur, however this can be relatively with no impact since the habitat might have received rain.	medium
7		Natural proportion of different types of flood year changed	Natural floods or higher might impact on reproduction cycles, but not in high proportions; however if the flood is lower, they might change behaviour to accommodate changes.	medium
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Macroinvertebrates Indicator 7: Channel dwellers in seasonal pools in mopane woodland

Table Error! No text of specified style in document.**.9 Predicted response to possible changes in the flow regime of Channel dwellers in seasonal pools in mopane woodland in the Okavango River ecosystem**

Question number	Season	Possible flow change	Predicted response of indicator	Confidence in prediction (very low, low, medium, high)
1	Dry Season	Onset is earlier or later than natural	Negligible response	medium
2		Water levels are higher or lower than natural	Higher water levels or lower than natural during dry season implies prolonged spawning and hence increase in abundance	medium
3		Extends longer than natural	Reduced abundance and desiccation for longer periods	High
4	Transition 1	Duration is longer or shorter than natural - i.e. hydrograph is steeper or shallower		
5		Flows are more or less variable than natural		
6	Flood season	Onset is earlier or later than natural – synchronisation with rain may be changed	If the onset of the flood is earlier or later than natural it will not have any impact since the pools will mostly get water from rain during rainy season.	high
7		Natural proportion of different types of flood year changed	Higher floods might prolong the timing for spawning and hence delays or adjustment in their life cycles. Abundance might reduce or not much affected.	medium
8	Transition 2	Onset is earlier or later than natural		
9		Duration is longer or shorter than natural – i.e. hydrograph is steeper or shallower		

Conclusion

This study used several data sets from previous research studies conducted in the Okavango Delta. However, none of these data was collected in relation to flow, hence more research is needed, specifically data that relates/links abundance and distribution of aquatic macroinvertebrates and flow/flood levels. Several studies conducted in Delta looked at spatial and temporal distribution of macroinvertebrates of some key habitats of the Okavango Delta. Of recent, other areas like the Boteti river have been flooding regularly but there is no a comprehensive studies on aquatic macroinvertebrates to quantify and establish their abundance and distribution in relation to flow, and hence its dynamics in the Delta. Therefore I recommend that more specific research studies should be conducted in detail to gather information on aquatic macroinvertebrates distribution and abundance of key indicators species and their linkages or relationships with the flood and flow regime in the Delta. Moreover, more training and research on identification of macroinvertebrates to species level is required and should be the focus of the basin wide decision makers to ensure good quality data is collected and that a database on aquatic macroinvertebrates *species* for the Okavango basin is generated.

FLOW-RESPONSE RELATIONSHIPS FOR USE IN THE OKAVANGO EF-DSS
Response curves to be inserted by the EF-DSS

REFERENCES

Alonso and Nordin, 2003 AQUARAP (2000). Rapid assessment of the aquatic ecosystems of the Okavango Delta, Preliminary report. Botswana, June 5-22, 2000. 80p.

Benke, A.C., and Cushing, E.C., (2005). Rivers of North America. Editors. Stream Ecology – North America.

Cliford, H.F., (1991). Selective foraging by the crayfish Orconectes virilis and its impact on macroinvertebrates. Freshwater Biology, 24: 69-80.

Thorp J.H. and Covich, A.P., (2001). Ecology and Classification of North American Freshwater Invertebrates.

Cox, F.E.G., (1993). Plasmodia of rodents. In: Parasitic Protozoa, 2nModerm Parasitology. Second Edition. Oxford, Black- wells Scientific Publications.

Dallas H.F., (2007). The influence of biotope availability on macroinvertebrate assemblages in South African rivers: implications for aquatic bioassessment Freshwater Biology 52: 370-380.

Dallas H.F. (2002). Spatial and temporal heterogeneity in lotic systems: implications for defining reference conditions for riverine invertebrates. Doctor of Philosophy, Department of Zoology, University of Cape Town. 213pp

Dallas, H.F., and Day, J.A., (2007). Natural variation in macroinvertebrate assemblages and the development of a biological banding system for interpreting bioassessment data – a preliminary evaluation using data from upland sites in the south-western cape, South Africa. Hydrobiologia 575 (1):231-244.

Dallas, H.F., and Mosepele, B., (2007). Preliminary survey and analysis of the spatial distribution of aquatic macroinvertebrates in the Okavango Delta, Botswana. African Journal of Aquatic Science, vol. 32, number 1.

Dallas, H.F., and J.A. Day (1993). The Effect of Water Quality Variables on Riverine Ecosystems: A review. Water Research Commission, Pretoria, Report TT 61/93, 240pp.

Dallas, H.F., (1997). A preliminary Evaluation of aspects of SASS (South Africa Scoring System) for the rapid bioassessment of water quality in rivers, with particular reference to the incorporation of SASS in a national biomonitoring programme. Southern African Journal of Aquatic sciences 23: 79-94.

Dallas, H.F., (2002). Spatial and temporal heterogeneity in lotic systems: implications for defining reference conditions for riverine macroinvertebrates. Proceedings of the 3rd WARFSA/WaterNet Symposium: Integrating water supply and water demand management for sustainable use of water resources. Dar Es salaam, Tanzania, October 2002.

Dallas H.F., (2007). The influence of biotope availability on macroinvertebrate assemblages in South African rivers: implications for aquatic bioassessment. Freshwater biology 52: 370-380.

Daly, H.V., Doven J.T., Purcell A.H. III (1998). Introdcution to Insect Biology and Diversity. Oxford University Press, Oxford, UK.

De la Cratez, A. (2007). Land Use effects on streamflow and water quality in the Northeastern United States. eBook, pg 97.

Day, J. A., Harrison, A. D., and de Moor, I. J., (2003). The Invertebrates of South Africa – Identification keys. (WRC Project No. 916). Water Research Commission, SA.

Gerber, A. and Gabriel, M.J.M., (2002). Aquatic Invertebrates of South African Rivers – Field Guide. Department of Water Affairs and Forestry, South Africa, First edition.

Glegg (1952). Compendium of Recommended Keys for British Columbia Freshwater Organisms: Part 2 (Simuliidae). HTLM

http://blackflies.info/en/content/information

http://desertmuseum.org/books

http://wikipedia.org/wiki/conservancy_fairy_shrimp

http://www.depweb.state.pa.us/blackfly. [Blackfly biology and life history]

http://zipcodezoo.com/key/animalia/Unionidae_Family.asp

King and Brown 2006 King, J., and C. Brown. 2006. Environmental flows: striking the balance between development and resource protection, Ecology and Society 11 (2):26. [0nline] URL: http://www.ecologyandsociety.org/vol11/iss2/art26/.

Lancaster, J., Briers, C., and Macadam, C. (2008). Aquatic Insects. Science. Life historyand adaptation to flow regime. Pg 122.

Quinn, G.P. Hillman, T.J. and Cook, R.,(1991). The response of macroinvertebrates to innundation in floodplain wetlands: possible effect of river regulation? In Boulton, A.J. and Lloyd, L.M. (Editors).Regulated Rivers: Research and Management, Vol 16, Issue 5, pg 469-477.

Miller, 2007 Miller, S W (2007) The effects of irrigation water withdrawals on macro-invertebrate community structure and life history strategies. PhD Thesis, Oregon State University, WA.

Mosepele, B. (2006). Blackflies in Lake Ngami, Personal Observation.

Mosepele K., and Mosepele, B., (2003) (Editors). Rapid Assessment of the aquatic ecosystems of the Okavango Delta. Preliminary report, Botswana, January 31 – February 21, 2003. 154 pgs.

Olsen, L-H., Sunesen, J., and Pedersen, B.V., (2001). Small Freshwater Creatures. Oxford. Natural History.

Palmer, R.W., (1991). Ecological Effects of Impoundments in the Buffalo River, Eastern Cape, with Particular Reference to the Distribution of Blackflies (Diptera, Simuliidae). Unpublished Phd thesis, Zoology Department, Rhodes University, Grahamstown. 238pp.

Stafford, (2006). Predaceous water beetles.Earth force news. [www.earthforce.org]

Townsed et al 1997. Management of flows for aquatic ecosystems in the Lindis River. (Published in 2008). Otago Regional Council, ISBN 1-877265-63-2.

Vanderpost et al, 2005 Vanderpost, C., Ringrose, S., and Seely, M. (2005). Preliminary Land-use and Land-cover Mapping in the Upper Okavango Basin and implication for the Okavango Delta. Botswana Notes and Records Vol 37, Pg 236-252.

Walace, J. B. 1996. The role of macroinvertebrates in stream ecosystem function. Annual Review Entomol. 41:115-39.

Fuller, R.L., LaFave, C., Anatasi, M., Molina, J., Salcedo, H., and Ward, S., (2007). The role of canopy cover on the recovery of periphyton and macroinvertebrate communities after a month-long flood. Hydrobiology. Vol 598, number 1.

Wiggins, G.B. (2004). Caddisflies. Pg 292

Wilson, B.H., and Dincer, T., (1976). An introduction to the Hydrology and hydrography of the Okavango Delta. In the Proceedings of the Symposium on the Okavango Delta and its Future utilisation. Botswana Society. Pp 33-47.

APPENDIX A: FULL DESCRIPTIONS OF INDICATORS

Table Error! No text of specified style in document.**.10 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 (Freshwater shrimps)						X		
2	Channel dwellers in marginal vegetation (Family Baetidae and Family Libellulidae)						X		X
3	Channel dwellers in rapids (fast flowing water) (Family Simuliidae)							X	
4	Channels dwellers on cobbles and boulders (rocks and stones) (Family Hydroptilidae)								X
5	Dwellers in fine sediment (Family Unionidae and Family Sphaeridae)						X	X	
6	Floodplain dwellers in backwaters (Family Dytiscidae and family Planorbidae)						X	X	
7	Dwellers in Pools or lagoons (fairy shrimp)							X	

The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

In 1994, the three riparian countries of the Okavango River Basin – Angola, Botswana and Namibia – agreed to plan for collaborative management of the natural resources of the Okavango, forming the Permanent Okavango River Basin Water Commission (OKACOM). In 2003, with funding from the Global Environment Facility, OKACOM launched the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project to coordinate development and to anticipate and address threats to the river and the associated communities and environment. Implemented by the United Nations Development Program and executed by the United Nations Food and Agriculture Organization, the project produced the Transboundary.

Diagnostic Analysis to establish a base of available scientific evidence to guide future decision making. The study, created from inputs from multi-disciplinary teams in each country, with specialists in hydrology, hydraulics, channel form, water quality, vegetation, aquatic invertebrates, fish, birds, river-dependent terrestrial wildlife, resource economics and socio-cultural issues, was coordinated and managed by a group of specialists from the southern African region in 2008 and 2009.

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

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

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

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

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

Kavango River at Rundu, Namibia

Republic of Botswana

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Sida

OKACOM

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