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Developing a monitoring framework for the aquatic flora and fauna of the Ishana Sub-basin in the Cuvelai Basin.

Author: Shishani Namutenya Nakanwe

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Department of Water Affairs and Forestry

Ministry of Agriculture, Water and Forestry

EXECUTIVE SUMMARY

The Cuvelai catchment falls between the Kunene catchment in the west and Cubango/Okavango catchment in the east; and it empties into Etosha pan through the Ekuma River.

The system supports a variety of animals and plants. Since the system is temporary it only holds water during the wet season, it support large numbers of short-lived animals such as macroinvertebrates. These organisms can be used to assess the health of the wetlands in a process referred to as biological monitoring. The main aim of this study was to develop a monitoring framework for the wetlands in the Cuvelai, and also to compare with the study done on the system about ten years ago. To achieve these aims, a biological sampling method, using, scoop nets to collect macroinvertebrates from different habitats from oshanas or watercourses and ondombes or deep pools was established.

The invertebrates found were used to draw conclusions about the health integrity of the wetlands; using the relative abundances of Taxa sensitive to water quality (e.g. Tabanidae) and tolerant taxa (e.g. Chironomidae). *Branchipodopsis spp, Daphnia spp, Lovenula falcifera* and notonectids recorded the highest abundance and were compared to what was found in 1997. No major changes were detected and it could be concluded that the water quality is still in a good condition.

From the vegetation collected, there were not many changes; however, sites like Ogongo east and Lashivanda recorded large populations of *Pechuel-Loeschea leubninitziae and Geigeria ornativa* which are associated with and indicative of overgrazing.

It was recommended that for the protection and sustainable management of our wetlands, the Department of Water Affairs together with other involved ministries such as MET and MFMR and also traditional authorities should work together.

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ABBREVIATIONS

ABBREVIATION	MEANING
AV	Aquatic Vegetation
BMC	Basin Management Committee
DWAF	Department of Water Affairs
EC	Electrical Conductivity
GPS	Geographical positioning System
IB	Iishana Basin
IBI	Index of Biological Integrity
IBMC	Iishana Sub-Basin Management Committee
MPCA	Minnesota pollution Control Agency
MV	Marginal Vegetation
NASS	Namibian Scoring System
NWRMR	Namibia Water Resources Management Review
OW	Open Water
SASS	South African Scoring System
TDS	Total Dissolved Solids

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I would like to thank the following people for the invaluable assistance during this study. For without their dedication, I would not have completed this project

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3. Leonard Hango, he helped me with the site visit and rented us his equipment at times and he was on standby for in case there were emergencies. Since this was a high water sampling season with damaged roads etc.
4. The regional Governor and councillors for Omusati region, Ongenga and Engela constituencies respectively for informing the public about our work in areas. We were well welcomed.

1 Introduction

The Cuvelai Basin or oshana system, as it is popularly known is a series of ephemeral, shallow channels or oshanas originating from Angola (Clarke 1999). Its catchment falls between the Kunene catchment in the west and Cubango/Okavango catchment in the east (Barnard 1998, Mendelsohn *et al.* 2003). The wetlands and shallow pans join together and end at Lake Oponono (Barnard 1998, NWRMR 2000). Lake Oponono is situated about 70km north of Etosha Pan and is the largest water body in the Cuvelai Basin. The Lake is the source of the Ekuma River that flows into the pan when in flood. Etosha receives water about twice every three years (Barnard 1998, Clarke 1998b). Its climate is semi-arid (Marsh & Seely 1992), characterized by unpredictable rainfall of approximately 400- 500mm per annum (Clarke 1998b).

This inland delta/drainage system is, by far, the largest wetland system in Namibia, covering about 30 000km^2 (Kolberg *et. al.* no date) and has been important to the people of this part of the country for approximately 600 years since the first settlement in the area (Klintenberg *et. al* 2007).

Clarke (1999) described Cuvelai a very important wetland as so many people depend on it in terms of water and wetland resources. Approximately 400,000 people benefited from Oshanas in 1996 and with the Namibian population increase since then, it is assumed that more people are now utilizing resources in this system.

Episodic Cuvelai floods occur when heavy local rainfall is received in Namibia and or in the highlands of southern Angola flooding into Namibia (Barnard 1998, NWRMR 2008). When the flood events occur, they bring a number of ecological benefits such as groundwater recharge, influx of huge biomass of fish and frogs, other aquatic fauna, good growth of vegetation in and adjacent to the floodplains, flushing out of the system, filling of Etosha pan through the Ekuma River and breeding of flamingos and other bird species (Brown 2008, op.cit and Bethune 2008). According to Barnard (1998) the system supports about 49 species of fish, the highest richness after perennial rivers.

Apart from the ecological benefits resulting from flood events, economic benefits are also reaped. Fish and frogs become a source of income to many inhabitants of the basin.

Grass also has been a source of income since it is used for thatching and grazing. Oshanas are bordered by wide flat floodplains dominated by short grasses with the main channel, several meters wide and containing water for much longer (Clarke and Rayner, 1999).

The Cuvelai system forms important wetlands on the central northern Namibia with its flora and fauna studied by a number of scientists. Its wide range of ephemeral crustaceans and other aquatic invertebrates, both micro and macro, is worth mentioning. These wetlands contain massive amounts of water during floods, hence the support for aquatic plants and animals. Freshwater species in the class of Crustacea are generally well represented in Namibia; and of these ostracods and branchiopods top the list (Roberts, Clarke and Curtis 1998)

1.1 What are wetlands?

Wetlands are defined in (Bethune 2007) as "areas where there is permanent or temporary surface water. These include perennial and ephemeral rivers and their floodplains, lakes, pans, dams, sinkhole lakes, water filled caves, swamps, seeps, marshes, estuaries and oshanas".

They are of vital importance to humans, animals and the ecosystem and this explains why it is so important to protect them. In terms of natural resources, wetlands provide water for human and animal consumption, to maintain the environment and also for agricultural and industrial activities (Bethune 2007). They also provide vegetation, which can be used for grazing, building, for food, for fire wood, and medicines (Shaw *et.al* 2004, Bethune 2007). Wetlands are a home to a wide variety of aquatic animals like fish, frogs, birds, reptiles and invertebrates; whilst the larger animals congregate at wetlands. Macroinvertebrates and vegetation are good indicators of the water quality of wetlands (Gerber and Gabriel 2002). One can look at the fauna and flora of a certain wetland and determine its health. That is why these resources need to be taken care of and be protected from destructive ways.

Generally, wetlands in Namibia are pressurized by over-exploitation of wetland resources due to human population increases and poverty, pollution from domestic,

agricultural and industrial sources, erosion caused by overgrazing and deforestation, increased water demand, etc (Shaw *et. al* 2004.). Hence, the urgent need to study them and understand them better in order to manage them sustainably.

This year's flood (2008) is worth mentioning because not only benefits were reaped but also misery; which at some point outweigh than the benefits. Misery has been experienced by inhabitants in the basin. During flood events many households and fields were being washed away and completely or partly destroyed by floodwaters. This year's flood event is one good example of misery experienced in Omusati, Oshana and Ohangwena Regions. Most towns such as Outapi, Oshakati and Oshikango were submerged. Inhabitants of flood prone areas were /immediately evacuated and they were accommodated in the Ongwediva Trade Fair, Oshakati soccer stadium and other safe sites in Ongwediva. Business had come to halt due to flooding. Many schools, hospitals and clinics were also closed due to flooding and alternatives had to be sought either to transport learners and patients to safer ground by helicopters or to build emergency bridges between the affected areas; at Engela hospital in Ohangwena Region. Crop and animal farming was not good in 2008. Most fields were submerged making it difficult to grow crops and many were even abandoned as people were evacuated. As for animals, cattle, goats and sheep died of hunger as there were no grazing areas because they were under water. From my observation, little vegetation was found in the pans compared to other years; and this raised another drought concern for the survived animals.

In 2008, about 250 000 people in this densely populated central northern part of Namibia or Owambo as it is popularly known, were reported to have been affected by flooding with many areas that could only be reached by Helicopter (NWRMR 2008).

Approximately 42 people, children and elders, were reported to have drowned in the flood water in the basin (Reuters AlertNet 2008). Cholera, a waterborne disease, outbreaks were reported in Ohangwena region during the flood period with a few other cases reported in Kunene Region (, Dr Hamhata Op. cit. 2008, NWRMR 2008).

1.2 Biomonitoring of the flora and fauna of wetlands

The Cuvelai Drainage system is characterized by open, grassy drainage channels known as oshanas. The area can be divided into several distinct habitats, each with distinguishing biodiversity (Kolberg *et. al.* No date); which needs to be conserved or protected. Assessments of biodiversity can be done using different tools of which biological monitoring is one.

Biological Monitoring for wetlands is a relatively a new tool to monitor the health of wetlands. It uses macroinvertebrates as useful indicators of wetland health. In 1992 in the US Minnesota, the MPCA (Minnesota Pollution Control Agency) began the process of developing an Index of Biological Integrity (IBI) as a tool for monitoring wetland health using macroinvertebrates. This methodology was applied to monitor the health of lakes and other wetlands in the United States and elsewhere (www.pca.state.mn.us/water/biomonitoring). In wetlands, invertebrates are found in the entire spectrum of available aquatic wetland habitats and conditions just like in streams. They are found in the sediments, in the water column and on and amongst submerged and emergent vegetation (Gerber and Gabriel 2002).

Macroinvertebrates in wetlands are somewhat different from their counterparts in streams (Danielson 1998, Gerber and Gabriel 2002), because wetlands' ones greatly tolerate the lower dissolved oxygen concentrations; however they are still sensitive to a variety of physical and chemical factors. The invertebrate community is negatively impacted by unnaturally high levels of nutrients such as phosphorus and chemicals like chloride. Unstable hydrology and lack of invertebrate habitats can also have negative impacts on this community (Burton no date).

Hand held dipnets are used to sample the invertebrate community. In addition, traps are used to collect very fast swimming and nocturnal organisms. They are identified to genus level or even beyond and the relative abundance of the different taxa are given scores according to their sensitivity. The invertebrate community data can be used for various wetland management needs and decisions. These include, condition monitoring (status and trends in the wetland), problem investigation monitoring, wetland mitigation effectiveness monitoring, permit issuance, etc (Burton no date).

In South Africa, a method called SASS version 4 (South African Scoring System has been developed to monitor streams (Chutter 1994, 1998 in Palmer and Taylor 2004) and research studies are ongoing to develop a tool to monitor other wetlands (Taylor 1999, Dallas and Day Pers. Comm 2008). SASS tool works by giving invertebrates different scores depending on their sensitivity to impacted waters. Since, the invertebrates found in streams are similar to the ones found in other wetlands, one can use similar sensitivity scales but also to consider the number of species found to draw reasonable conclusions. Namibia also developed its scoring system built on SASS with inclusion of invertebrates only found in Namibia and not in South African rivers and exclusion of those not found in Namibia. This version is known as NASS 2 (Namibian Scoring System Version two (Palmer and Taylor 2004).

1.3 Basin Management Committees

Basin management committees (BMC's) in Namibia were or may be established for the purpose of proper management of the water resources of the basins (Water Resource Act 2004). The Iishana Sub-basin Management Committee is one of the functional BMCs in the larger Cuvelai basin. This project will be tested in the Iishana Sub-basin and carried out in other basins in future time.

BMCs are made up of different stakeholders both at community and institutional levels who are dealing with water and land issues. Hence, their functions are to "protect, develop, conserve, manage and control water resources within its water management area (Water Resources Act 2004).

Some traditional authorities like the Oukwambi Traditional Authority in the basin already manage the resources by having restrictions on times when to harvest grass, to allow animals to graze on certain areas and to catch fish to avoid water disturbance and over harvesting (Anguku. pers. comm). However some traditional authorities do not yet have those restrictions and everybody can use wetland resources as they please. With this project, we will be looking at places which are biodiversity hotspots so that they are protected in future.

The Water Ecology section of the Directorate of Resources Management is striving "to monitor and collect data on wetlands and environmental water use in Namibia, maintain these data and interpret them so as to provide information for sustainable water management", for instance to Basin Management Committees. Therefore, this study is looking at enhancing that and also to publish results and disseminate information on Namibian wetlands and promote awareness on wetlands and their resources.

1.4 Objectives

1. To establish a system or framework to monitor the health of the natural aquatic environment of the oshanas, at selected sites, in the Iishana Basin (IB); for the BMCs to use as part of their annual water resource reporting.

a) To collect physical data of wetlands such as wetland width and depth, water temperature, pH, and conductivity from the onset of the rain season throughout to the end.
b) To sample fauna and flora of wetlands during the rain season (from January to May).
c) To measure species diversity of crustaceans and insects in these wetlands.
d) To study the succession of crustaceans with insects.

2. To compare the results of this study with Clarke's study on the flora and fauna of the Cuvelai Drainage System in 1996 as he provided baseline data on aquatic invertebrates and plants.

3. To make recommendations to the Iishana Sub-basin Management Committee (IBMC) on the aquatic plants and animals of the system and propose ways to manage the water resources.

2 Study area

The study was conducted in 11 selected shallow watercourses or Oshanas and also in deeper pool or Ondombe in the now called Iishana Sub-basin of the main Cuvelai Basin, see figure 1. These sites are the same as the ones Dr N.V. Clarke studied in 1996-1997 with an additional two new sites, Shanandjaba and Shanalumono. The sites are as follows: - Shashimwaku, Ogongo, Ogongo East, Lashivanda, Sheenkombo, Shashuuli, Elim junction, Oshikuku and Ehangano, See figure 2. These are all situated along main roads, Engela-Outapi road, Oshakati-Outapi road, Oshakati-Okahao road as shown in figure 1. These sites are all shallow watercourses or oshanas, except for Ehangano, Shanandjaba and Lashivanda which have deeper pools or ondombes alongside the oshanas. For both previously sampled and added sites, a site visit was done on the 20-21 December 2007; to view the sites and be familiar with the place before the start of the study in January 2008. The sites were selected according to their accessibility during flood, therefore all sites close to good roads.

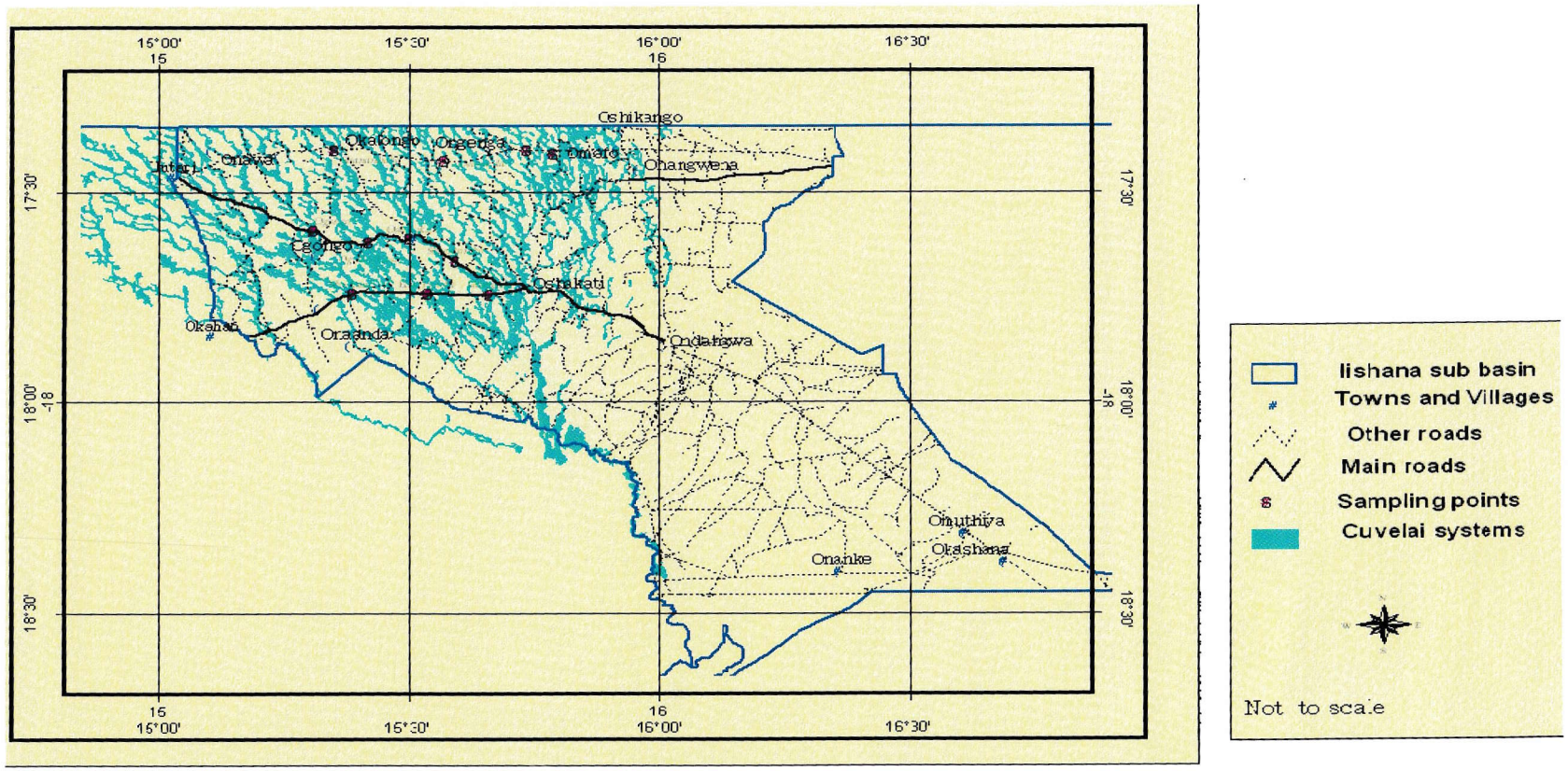
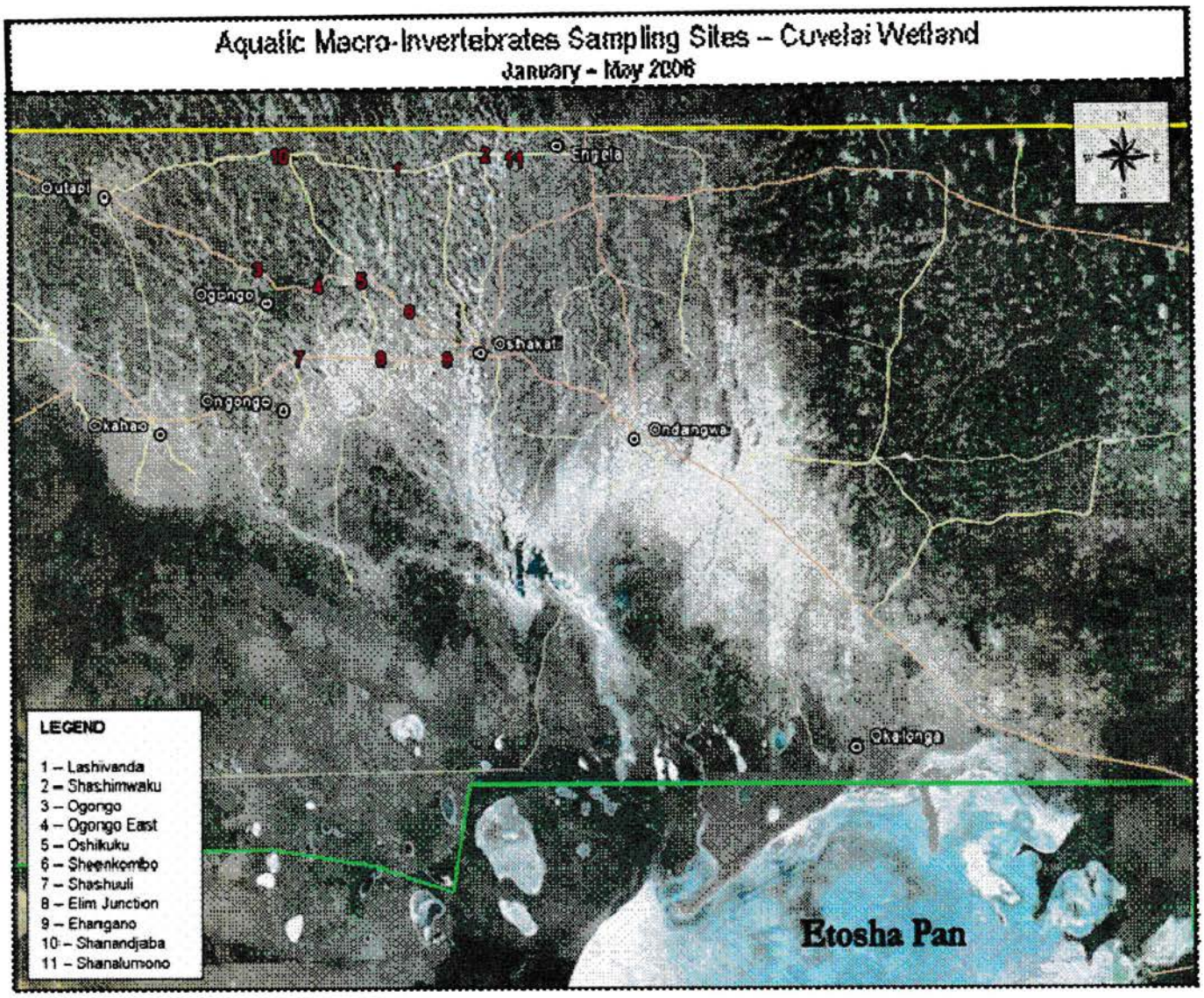


Figure 1.The map showing the lishana Sub-basin in the Cuvelai system with major and minor roads, towns and villages.



2.1 Materials and Methods

A GPS (Garmin 7) navigation system was used to confirm the selected sites as they had already been taken by Dr Clarke during his study in 1996-1997.

2.1.1 Fauna

During the rain season of 2008, a total of 10 oshana and ondombe sites were sampled in the Iishana Sub-basin of the Cuvelai Drainage system. Of these sites, three were classified as ondombes or deeper pools and seven as oshanas or shallow watercourses. Sampling was done once a month from January and continued until the end of May.

2.1.2 Sampling in the Ondombe

For every ondombe, water samples were taken from each distinct habitat type; and these habitat types are Deep Area of the pool and Marginal Vegetation. A scoop net was used to collect the invertebrates from the wetland for 30 seconds per sweeping in order to collect invertebrates inhabiting the water column and those attached to the aquatic vegetation. This process was repeated 3 times for each habitat type providing three replicates. For each habitat type, water depth using a 3m measuring tape, of each habitat and wetland width were also measured. The HI 9810 portable pH/EC/TDS Meter was used to measure pH and conductivity and the temperature was deduced from these readings.

2.1.3 Sampling in the oshana

In Oshana, aquatic invertebrates were sampled at each selected habitat type, in this case Open Water (OW) and Aquatic Vegetation (AV), within the site. The same method as for sampling in Ondombe was employed at a distance of 100m from the bridge both north and south of the bridge. A scoop net was used to collect the invertebrates from the wetland at distance of 10m which is equivalent to sampling for 30 seconds used for Ondombe. The water depth of each habitat was recorded using a 3m measuring tape and wetland width was estimated using criteria highlighted in table 3.

For sites that were totally filled with water in the first period of sampling, no samples were taken e.g. Ogongo. Similarly, sites which were covered in grass and sedges, the alternative to the open water habitat type was found and in this case, Oshikuku whereby substratum and aquatic vegetation were sampled instead.

Sites found with no vegetation within the 100m distance from the bridge, only OW habitat type was sampled e.g. Ehangano, at which OW samples were taken from the northern side and AV from the southern side; as there was no vegetation on the former and full vegetation cover on the latter.

Lashivanda oshana and Oshikuku have their southern sides developed into shops or houses, and the water was found approximately 500m from the road or bridge. Samples were only taken from the northern side within 100m. At Shanalumono, no samples were taken during the sampling period as the roads to the site were destroyed by floods and the researcher could not get access to this site.

Throughout the sampling period, fishing activities were observed with most sites attracting fishers who slept at the sites catching, selling, cooking and drying fish e.g. Shashuuli, Sheenkombo, Shanandjaba, Ogongo and Ogongo East. The pictures of all sites from the onset of rain till the end have been taken.

Collected samples were then sieved with a 500µm sieve and specimens collected were field preserved in 70% ethanol. They were brought to the Laboratory at the Water Ecology Section at the Head Office in Windhoek for processing and identification.

The majority of collected specimens were identified at least to genus level (e.g. Anostraca and some groups like Crustacea (e.g. Cladocera, Notostraca and Copepoda) were identified to species. Some taxonomic groups, however, were not identified past family level, e.g. families in these orders: Coleoptera, Trichoptera, Diptera, and Odonata. Identifications were made using the taxonomic keys found in Davies & Day (1998), Day *et. al.* (1999), Day *et. al.* (2001), Gerber & Gabriel (2002) and de Moor *et. al.* (2003).

2.1.4 Flora

The Grasses and sedges were collected from the banks and instream (submerged) of the wetland sites where the invertebrates were collected. They were collected from March (the high water level month and most plants were abundant).

Vegetation collected were dried up first and then placed in the specimen bags for identification in the Laboratory in Windhoek. They were identified using Clarke (1998a), Oudtshoorn (2004) and Van Eck (2007).

2.2 Criteria: wetland size

Wetland sizes were determined in percentage using the following formula:
Number of wetlands of a specific size/total number of wetlands sampled * 100%. See table 4 for the results.

2.3 Physical data

There was not much change in the temperature readings. This may not be useful in this study as they were only taken when the equipment was available. The HI 9810 pH meter (for recording pH and conductivity) was borrowed from IBMC since the one we had was not working, and only when it was not being used by the IBMC staff.

3 Results

3.1 Fauna

A total of 34 invertebrate taxa were collected via scoop net sampling during the January – May from 10 (excluding Shanalumono) wetland sites, with the total broken down by major taxonomic groups; orders as follows: Crustacea, Insecta, Mollusca and Annelida as shown in table 1. In Insecta, hemipterans dominated the invertebrates' community in terms of species richness, recording seven families; of which Notonectidae topped the list of species abundance. Dipterans (6 families) and Coleopterans (4 families) came second and third respectively, with Chironomids and Dytiscids recorded in large numbers. The rest recorded below four families and these include Ephemeropterans, Trichopterans, Odonata (Zygoptera and Anisoptera), Hydracarina and Gastropods as illustrated in table 1.

In terms of Crustaceans, Cladocera was the most rich and abundant; recording 3 families and 6 species. Of which *Daphnia barbata* and *Diaphanosoma exsicum* were more abundant from nearly all sites. Although a single species, *Lovenula falcifera*, was recorded from Class Calanoida of Copepoda, its number was the highest amongst all taxa recorded from all sites (both oshanas and ondombes). The pictures of invertebrates found in the oshanas are shown in figure 3 (for crustaceans) and 4 (insects and snails) below.

a) b)

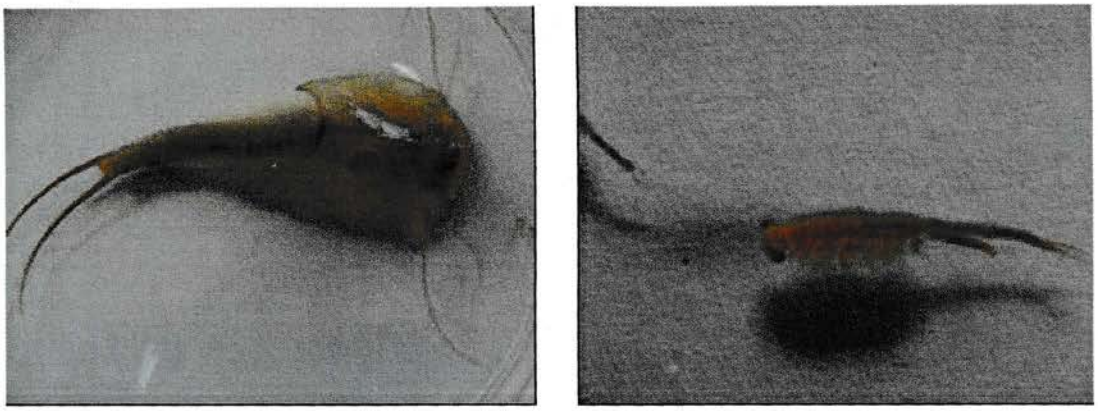


Figure 3: a) Crustaceans: Notostraca, Triops granarius found in the Cuvelai wetlands, plenty at the onset of the wet season. b) An Anostracan (shrimp), *Branchiopodopsis spp*, found in masses throughout the wet season especially in pools.

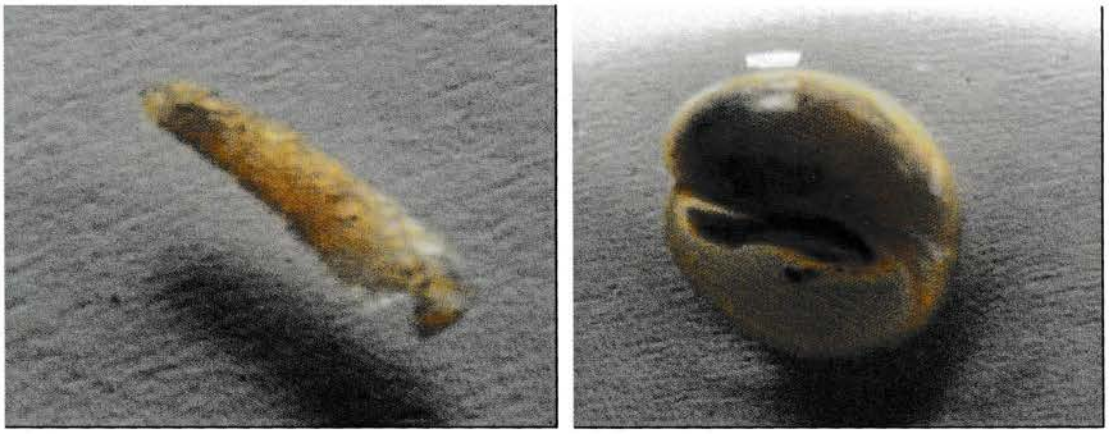


Figure 4: a) Insects: Trichoptera, Leptoceridae. b) Gastropods (snails), Planorbidae. The former was found from the fourth month towards the end of the wet season and the later was found throughout the wet season.

Table 1. Freshwater invertebrates in the oshanas and ondombes of the Iishana Sub-Basin in the Cuvelai system.

Taxon
A. Crustaceans **1. Cladocera (Water fleas)** **-Daphnidae** *Daphnia barbata* *Simocephalus exspinosa* *Simocephalus serrulatus* **-Sididae** *Diaphanosoma excisum* *Diaphanosoma perrmatum* **-Macrothricidae** *Macrothrix spinosa*
2. Copepoda **-Calanoida** *Lovenula falcifera*
3. Notostraca *Triops granarius*
4. Anostraca **-Streptocephalidae** *Streptocephalus spp.* **-Branchipodidae** *Branchipodopsis wolfi* *Branchipodopsis tridens*
5. Conchostraca **-Leptestheriidae** *Leptestheria spp.* **-Cyclestheriidae** *Cyclestheria hislopi*
B. Insecta **1. Ephemeroptera** **-Baetidae** **-Caenidae** **Telogonidae**
2. Hemiptera **-Notonectidae** **-Gerridae** **-Corixidae**

-Belostomaidae -Nepidae -Veliidae -Naucoridae
3. Coleoptera -Dytiscidae -Elmidae -Hydraenidae -Hydrophilidae
4. Trichoptera -Leptoceridae
5. Plecoptera -Notonemouridae
6. Zygoptera -Coenagrionidae -Lestidae
7. Anisoptera -Aeshnidae -Libellulidae
8. Diptera -Ceratopogonidae -Chironomidae -Culidae -Dixidae -Tabanidae -Simuliidae
9. Hydracarina
C. Mollusca 1. Gastropoda -Planorbidae
D. Arachnida 1. Annelida -Oligochaeta

Invertebrates tolerate water quality in the system differently; some are more tolerant to survive in polluted waters than others. As outlined in the South African Scoring System version 4 and 5 and the Namibian Scoring System version 2 for rivers, the sensitivity differs between taxa. Using the sensitivity scale for these scoring systems, it was found that four families were very sensitive, 10 families were moderately sensitive and 19 families were tolerant as illustrated in table 3. Ephemeroptera, Diptera, Trichoptera and Plecoptera were the very sensitive orders. Order Hemiptera dominated the tolerant list, followed by Diptera and Coleoptera.

Table 2. The sensitivity to water quality of aquatic invertebrates found in the wetlands of the Cuvelai System.

Taxon
Very Sensitive Taxa (scores of 10 to 15)
Baetidae > 2 spp
Dixidae
Notoneumoridae
Telogonidae
Moderately Sensitive Taxa (scores of 6 to 9)
Baetidae 2 spp
Caenidae
Leptoceridae
Elmidae
Hydraenidae
Hydracarina
Aeshnidae
Lestidae
Naucoridae
Oligochaeta
Tolerant Taxa (scores of 1 to 5)
Baetidae 1 spp
Dytiscidae
Gyrinidae
Belostomatidae
Hydrophilidae
Ceratopogonidae
Corixidae
Gerridae
Nepidae
Notonectidae

Veliidae
Libellulidae
Coenagrionidae
Planorbidae
Chironomidae
Culicidae
Simuliidae
Tabanidae
Belostomatidae

The ranges or changes of invertebrate species found in the oshanas and ondombes through the season per site and habitat are shown in figure 5 for ondombe at Shanandjaba; and figure 6 for ondombe at Lashivanda. For oshanas, figure 7 shows changes in invertebrates' species at Shashimwaku. In March, the number of invertebrates has increased drastically and it went down in April when the water level (see appendices) dropped towards end of the wet season. Some habitats were not sampled in May as the sampling sites had dried up; e.g. marginal vegetation at Shanandjaba and Lashivanda.

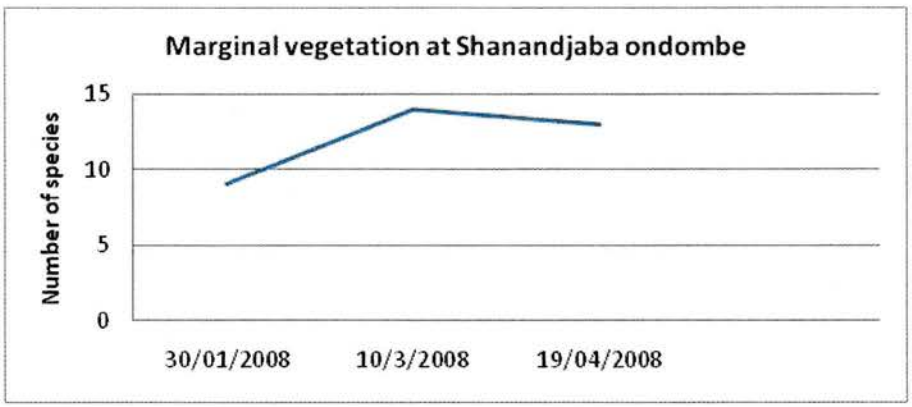


Figure 5: The number of species collected and identified from Marginal Vegetation habitat at Shanandjaba (ondombe).

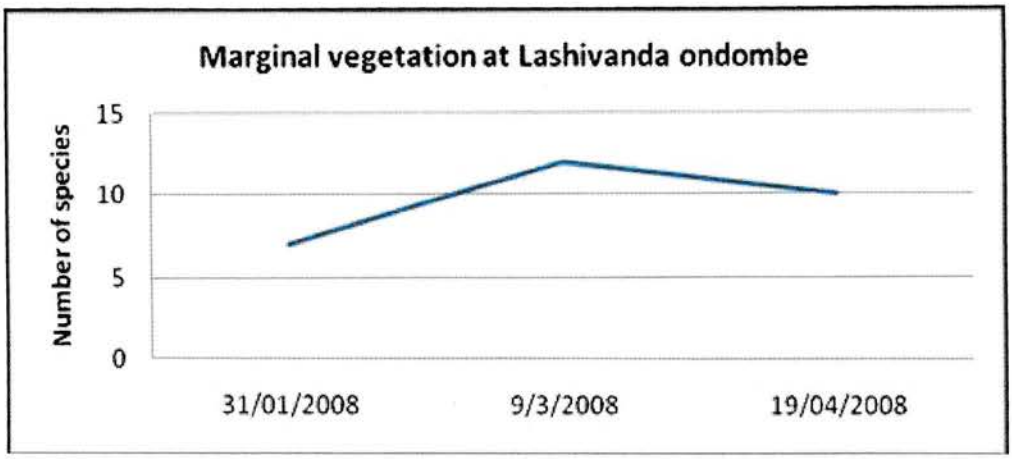


Figure 6: The number of species from the marginal vegetation habitat at Lashivanda (Ondombe). This habitat disappeared during the last sampling month (May).

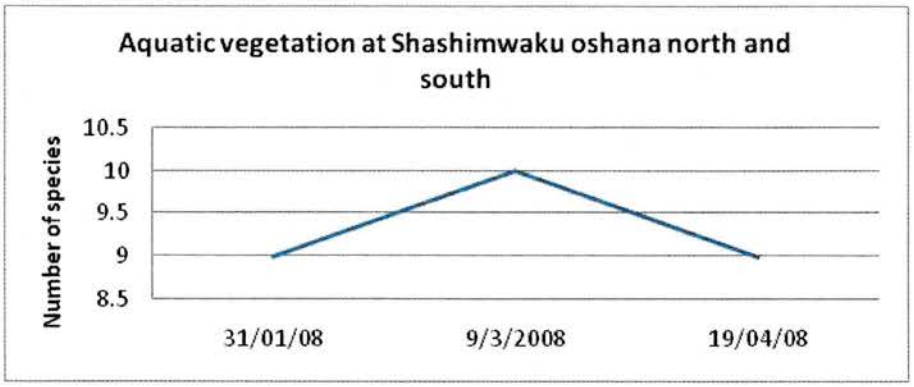


Figure 7: The number of identified species from aquatic vegetation at Shashimwaku (oshana). This habitat disappeared in the last sampling month (May).

3.2 Flora

The following grasses, sedges, shrubs and trees, shown in table 4, were collected and identified from the 10 wetland sites sampled for this project. Most of them, if not all, were identified to species level.

Table 3. Wetland vegetation identified in the Cuvelai System from the sampled sites.

Plant species
Grasses
1. *Echinochloa spp*
2. *Echinochloa stagnina*
3. *Diplachne ambonensis*
4. *Diplachne cuspidate*
5. *Eragrostis rotifer*
6. *Cynodon dactylon*
7. *Elytrophorus globularis*
8. *Panicum coloratum*
9. *Panicum repens or Branchiaria deflexa*
10. *Dactyloctenium aegyptium*
11. *Cholris virgata*
12. *Eragrostis cylindriflora*
13. *Sporobolus spicatus*
14. *Sporobolus fimbriatus*
15. *Oryzidium barnardii*
16. *Brachiaria deflexa*
17. *Wilkommia sarmentosa*
Sedges
1. *Cyperus spp*
2. *Cyperus procerus*
3. *Fuirena angolensis*
4. *Cyperus compressus*
5. *Schoenoplectus senegalensis*
6. *Cyperus schinzii*
7. *Cyperus procerus*
8. *Pycreus chrysanthus*
9. *Cyperus articulates*
10. *Cyperus difformis*
11. *Monandrus squarrosus or Courtoisina cyperoides*
Herbs or floating vegetation
1. *Ipomea aquatic*
2. *Marsilea spp*
3. *Nymphea nouchali*
4. *Burnatia enneandra*

5. *Geigeria ornativa*
Trees
1. *Acacia hebeclada*
2. *Colophospermum mopane*
3. *Ziziphus mucronata*
4. *Combretum imberbe*
5. *Diospros mespiliformis*
6. *Hyphaene petersiana*
Shrubs
1. *Pechuel-Loeschea leubnitziae*

3.2.1 Occurrence of plants species over the wet season

The number of plant species was highest in end of February and beginning of March, with 80% grass cover. Sedges and herbs such as Cyperus *spp* and were abundance and highest with high height in March.

3.3 Physical Data of the wetlands

3.3.1 Water level

However, the water level was highest in February and March for all sites and reduced from April, but Ogongo north has still recorded about 44cm in May for oshanas and Shanandjaba 57cm (deep area) for ondombes. Ondombe at Ehangano completely dried up in May while other sites recorded less than 5cm if not just mud. See Appendices (table 5) for all sites water level.

3.3.2 Temperature, pH and Conductivity

There was a bit of a problem with equipment (ministerial are old and not working anymore) for recording these parameters, especially in the first (January-February 2008) and second sampling period (March 2008). The records available are only for April and May. It is not easy to draw conclusions from available data. However, the temperature ranged from 20^0C to 25^0C as deduced from pH calibrations, pH ranges from 6.3 to 8.3; same for conductivity between 0.02 (µS/cm) and 0.38 (µS/cm). Some sites were sampled in the mornings while others in the afternoons; hence the variation in the recordings. See Appendices in table 5 for all the sites temperature, pH and conductivity.

3.4 Criteria for wetland size

Fifty percent of the sampled oshanas were greater than 20 ha and the other 50 percent went to those between 5ha and 20ha; and those less than 5ha as presented in table 4.

Table 4. Criteria for wetland sizes classification

Score	Measure	% wetland
3	Area >20 ha	50
2	Area > 5 ha and ≥ 20 ha	25
1	Area < 5 ha	25

4 Discussion

4.1 Fauna and Flora

In the first sampling periods, i.e. January to March, crustaceans such as Copepods, Cladocera, Conchostracans, Anostracans and Notostracans dominated in all oshanas with Lashivanda and Shashimwaku recording the highest number of Anostracans (*Branchiopodopsis spp.*) compared to insects. Ephemeral wetlands are known to house more crustaceans than rivers which are dominated by insects (Day 1990). Although, insects were found in smaller numbers from the beginning, their number increased from April to May with Hemipterans dominating. Notonectidae and Corixidae were more abundant in almost all oshanas.

Sites that were impacted by their adjacent land-use had a less diverse invertebrate community and were dominated by chironomids (midges) and corixids (water boatmen) (Burton no date). These species were recorded from oshanas and were not in significant numbers to determine the impact of adjacent land use; but it could be the sign that can be looked into in future e.g. Ogongo East. It could be that the ephemeral nature and low productivity of these sites may result in a characteristically depauperate invertebrate community.

Since aquatic organisms are indicators of impacted water quality or other major changes to the wetlands, for future monitoring purposes, the same sites can be used. They are all divided by tarred roads with many paths going almost at all directions for people living nearby these sites to reach their homes. They are also grazing grounds for livestock in the basin due to their sizes and abundant vegetation. Furthermore,

they are prone to overfishing and overharvesting of the grass since they keep water for much longer. They are good monitoring sites, such that if there are any significant changes to the system, it can be picked up from these sites. Only Oshikuku, close to Oshikuku town, is threatened by pollution. Shashuuli, Ogongo East and Ogongo are near by the sheebens, which is not much of a threat to the system in terms of water pollution.

These types of vegetation e.g. *Pechuel-Loeschea leubninitziae and Geigeria ornativa* are associated with overgrazing and disturbance (Clarke 1999) and were recorded from Lashivanda and Ogongo East. This could indicate that some sort of overgrazing in these areas has taken place. Grasses like *Eragrotis viscosa* dominates areas of soil compaction (Clarke 1999) but were (not) recorded in this study. This could be a flaw on the researcher's side as she is still acquainting herself with plant species and not necessary that it is not present.

The abundance of species like *Cynodon dactylon, Cyperus compressus, C. difformis*, may be good indicators of wetland disturbance as it was recorded from all sites. At Ogongo East, about 60% of the sampled area was covered by *C. compressus*.

Iishana Sub-basin Management Committee, in collaboration with the Water Environment Division of DWAF, may take the lead to make sure that these wetlands are not negatively impacted by human activities. They may as well train people to carry out such studies in future, perhaps once in every two years.

4.2 Succession of crustaceans by insects

It was observed that from the third sampling period (March to May), the number of insects increased compared to crustaceans. The *Triops spp,* which were collected from Jan and Feb decreased until they disappeared towards the end of the wet season. They are typical temporal habitat organisms. However, the number of crustaceans (anostaracans, copepods, cladocerans) was relatively high at Lashivanda ondombe and oshana, Shashimwaku oshana and Shanandjaba ondombe) throughout the wet season than insects. Whilst, the rest of the sites were dominated by insects towards the end of the wet season in the ratio of 1:3.

4.3 Species richness and abundance

Branchipodopsis spp, Daphnia spp, Lovenula falcifera and notonectids recorded the highest in the terms of abundance with Cladocerans topping the list of species rich taxa with three families and six species. However, this conclusion could not be made

for plants as they were not extensively sampled; i.e. invertebrates were the major aspect of this study.

Although, sensitivity scores used were taken from SASS/NASS methods, they could not be used to draw conclusion as the SASS/NASS methods was not designed for still waters but for rivers and streams only. The scores were used just to get an overview of tolerance for families found in these wetlands.

4.4 Comparison between this study and Dr Clarke's

- All invertebrate species collected in this study were also found by Dr Clarke in his 1996/7 study, although not all of them. This could be attributed to this year wet season that started late and the flood which flowed immediately at the onset of rainy season.
- There was only one family of Ephemeroptera, Telogonidae, which was identified in this study and not in Dr Clarke's. According to literature (Gerber and Gabriel 2002), these are very sensitive organisms in terms of water quality and are only known to be occurring in the mountain acidic water of Western and Southern Cape. This specimen needs to be identified further by other specialists for confirmation.
- The same goes with the plant species collected. Dr Clarke identified a large number of plant species compared to this study. There was not much of vegetation in the wetlands due to the level of water and those that were found were the most tolerant ones.
- By this, one may say that the health of the wetlands in terms of water quality is relatively good. No major changes were detected in this study as compared to the 1996/7 study. However, about 58% of the taxa collected ranked tolerant, 30% moderately tolerant and 12% very sensitive to impacted water.

4.5 General observation by the researcher

Overexploitation of water resources and overfishing were also some of the big concerns that pose a big threat to the resources of the wetlands. It is clearly stated in the (Inland Fisheries Resources Act of 2003), that "a person may not engage in fishing in any inland waters by means of any unregulated fishing gear- without being the holder of a fishing licence issued by the Minister or designated officer authorizing fishing by means of a particular type of regulated fishing gear which the person is using or intends using".

Some fishing methods are prohibited in inland waters such as using chemicals, poison or any other injurious substance, electrical devices, lights to lure fish etc. If using nets, a person is not allowed to use nets within 100m of a bridge, culvert when water is flowing through such structures. This was not the case as most observed nets were deployed at a distance of less than 10m from the bridge and even at the entrance of the culverts. Fishers were using any fishing gear, and mosquito nets were also observed in fishing. Mosquito nets were catching any organisms that could not escape from them. Significant numbers of Conchostraca (E.g. *Leptesthria spp.*), Notostraca (*Triops spp*), Anostraca (E.g. *Branchiopodopsis spp* and *Streptocephalus spp*) and Odonata (E.g. Aeshnidae) were found dumped (or exposed on the sun instead of being returned back to the water) on the edge of oshanas after fishers have selected what they wanted from the catch. Even small fish and unwanted Kapenta were just left to dry in the sun. This is abuse of resources perhaps due to lack of knowledge that other organisms may be returned back in the water and continue as feed for other organisms or fish can grow to a favourable size for their next catches.

5 Recommendations

Floods negatively affect people, by destroying roads, residential properties, businesses (shops), schools, hospitals, cut communication networks, fields which results in poor harvesting or no harvesting at and even death of people and animals. Flood waters can also carry vectors that transmit water borne diseases such as cholera and malaria. Some of these effects could be mitigated by doing the following.

5.1 General Recommendations

- Avoid constructing residential and business properties on flood prone areas - would reduce construction pressure on wetlands and save the aquatic resources found.
- Proper site selection could also be conducted in the case of building schools and hospitals. Under circumstances where these are already carelessly constructed, safer bridges could be erected to avoid cut off during floods. It was not easy for the research team to access some place when it was heavily raining, e.g. gravel roads from Engela to Ombalantu.
- Roads, especially those passing through oshanas, must be flood friendly. Meaning they should have culverts big enough to let huge amounts of water to pass through them to prevent damming, destruction and cut offs.

5.2 Recommendations to IBMC

- IBMC, Water Environment Division of DWAF and Inspectorate Division of the MFMR need to work together with the traditional authorities and MHSS to protect wetlands on the Cuvelai Drainage system; through similar studies to assess dominant species which can be used to determine changes to the system. This could be done biannually if possible as doing it annually is impractical. To cut cost and time, in future, emphasis can be on indicators species that Dr Clarke had identified. This will require speedy and effective training to other people who may not be aquatic scientists.
- Inhabitants of such areas must be well informed about the dangers of drinking polluted water and learn to boil it before drinking, how to protect themselves from cholera outbreaks as was experienced in Ohangwena and Kunene regions during this rain season. They must also stop using mosquito nets as fishing gears and rather use them to protect themselves from mosquitoes and prevent malaria.
- The public needs to be educated on the importance of having these small aquatic organisms in the water and they need to be protected by all means;

as they filter water and clear it from pollutants, they are food to other aquatic organisms such fish and frogs. People must first be taught about their environment to understand the concepts of conservation and sustainable use of aquatic and other terrestrial resources.

- Proper information must be communicated to people in flood prone areas of the IBMC, so that people could evacuate to high ground with their belongings and animals in time to avoid loss of life and property.
- MFMR needs to inspect fishing activities during the rain season and fine guilty parties and send a clear message that they are serious about enforcing their regulations in the Inland Fisheries Resources Act of 2003.
- Oukwambi Traditional Authority has already management actions on the table, specifically on fish and grass harvesting and grazing areas, it is just a matter of enforcement.

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7 Appendices

Table 5. The sampling sites, other physical parameter readings, the number of species identified from each site throughout the sampling period in the wetlands off the Cuvelai System. n/a means that readings were not taken due to malfunctioning equipment.

Site	Habitat type	Date	Bridge side	Wetland size (ha)	Depth (cm)	No. of species	Temp (°C)	pH	EC (µS/cm)
Ehangano oshana	Aquatic vegetation	28/01/2008	South	>20 ≤ 100	27	11	n/a	n/a	n/a
Ehangano oshana	Open water	28/01/2008	North	>20 ≤ 100	27	4	n/a	n/a	n/a
Ehangano ondombe	Deep Area	28/01/2008	Ondombe	<20	35	10	n/a	n/a	n/a
Ehangano ondombe	Marginal vegetation	28/01/2008	Ondombe	<20	33	11	n/a	n/a	n/a
Ehangano oshana	Open water	7/3/2008	North	>20 ≤ 100	28	9	n/a	n/a	n/a
Ehangano oshana	Aquatic vegetation	7/3/2008	South	>20 ≤ 100	16	10	n/a	n/a	n/a
Ehangano ondombe	Deep Area	7/3/2008	Ondombe	<20	29	14	n/a	n/a	n/a
Ehangano ondombe	Marginal vegetation	7/3/2008	Ondombe	<20	17	20	n/a	n/a	n/a
Ehangano oshana	Open water	17/04/2008	North	>20 ≤ 100	13	4	22	7.3	0.24
Ehangano ondombe	Deep Area	17/04/2008	Ondombe	<20	14	7	20	7.5	0.81
Ehangano oshana	Open water	22/05/2008	North	>20 ≤ 100	23	3	22	7.3	0.32
Elim Junction oshana	Open water	28/01/2008	N + S	>100	67 (N) + 53 (S)	11	n/a	n/a	n/a

Elim Junction oshana	Aquatic vegetation	28/01/2008	N + S	>100	67 (N) + 53 (S)	11	n/a	n/a	n/a
Elim Junction oshana	Open water	7/3/2008	North	>100	54	5	n/a	n/a	n/a
Elim Junction oshana	Aquatic vegetation	7/3/2008	South	>100	45	8	n/a	n/a	n/a
Elim Junction oshana	Aquatic vegetation	7/3/2008	North	>100	54	9	n/a	n/a	n/a
Elim Junction oshana	Open water	17/04/2008	South	>100	36	5		6.7	0.06
Elim Junction oshana	Open water	17/04/2008	North	>100	24	7		6.7	0.06
Elim Junction oshana	Aquatic vegetation	17/04/2008	South	>100	36	3		6.7	0.06
Elim Junction oshana	Aquatic vegetation	17/04/2008	North	>100	37	5		6.7	0.06
Elim Junction oshana	Aquatic vegetation	22/05/2008	North	>100	24	6		6.8	0.38
Shashuuli oshana	Open water	28/01/2008	North	>100	37	6	n/a	n/a	n/a
Shashuuli oshana	Open water	28/01/2008	South	>100	50	11	n/a	n/a	n/a
Shashuuli oshana	Aquatic vegetation	28/01/2008	North	>100	37	11	n/a	n/a	n/a
Shashuuli oshana	Aquatic	28/01/2008	South	>100	50	10	n/a	n/a	n/a

	vegetation								
Shashuuli oshana	Open water	7/3/2008	South	>100	43	4	n/a	n/a	n/a
Shashuuli oshana	Open water	17/04/2008	North	>100	24	3		7.7	0.05
Shashuuli oshana	Open water	17/04/2008	South	>100	30	4		8.3	0.05
Shashuuli oshana	Aquatic vegetation	17/04/2008	South	>100	30	7		8.3	0.05
Shashuuli oshana	Open water	22/05/2008	South	>100	17	3		7.2	0.15
Sheenkombo oshana	Open water	29/01/2008	North	>100	70	5		7.1	0.05
Sheenkombo oshana	Open water	29/01/2008	South	>100	40	7		7.1	0.05
Sheenkombo oshana	Aquatic vegetation	29/01/2008	South	>100	40	5		7.1	0.05
Sheenkombo oshana	Aquatic vegetation	29/01/2008	North	>100	70	7		7.1	0.05
Sheenkombo oshana	Open water	8/3/2008	South	>100	23	5	n/a	n/a	n/a
Sheenkombo oshana	Aquatic vegetation	8/3/2008	North	>100	75	12	n/a	n/a	n/a
Sheenkombo oshana	Open water	18/04/2008	North	>100	54	7		6.7	0.14
Sheenkombo oshana	Aquatic vegetation	18/04/2008	North	>100	54	12		6.7	0.14
Sheenkombo oshana	No sampling	22/05/2008					n/a	n/a	n/a
Ogongo East oshana	Open water	30/01/2008	South	>100	50	9	n/a	n/a	n/a
Ogongo East oshana	Aquatic vegetation	30/01/2008	North	>100	56	11	n/a	n/a	n/a

Ogongo East oshana	Open water	8/3/2008	North	>100	51	4	n/a	n/a	n/a
Ogongo East oshana	Open water	8/3/2008	South	>100	37	5	n/a	n/a	n/a
Ogongo East oshana	Aquatic vegetation	8/3/2008	South	>100	37	17	n/a	n/a	n/a
Ogongo East oshana	Aquatic vegetation	8/3/2008	North	>100	51	10	n/a	n/a	n/a
Ogongo East oshana	Open water	18/04/2008	North	>100	20	9		6.8	0.09
Ogongo East oshana	Open water	18/04/2008	South	>100	17	7		6.3	0.09
Ogongo East oshana	Aquatic vegetation	18/04/2008	North	>100	20	10		6.8	0.09
Ogongo East oshana	Aquatic vegetation	18/04/2008	South	>100	17	11		6.3	0.09
Ogongo East oshana	Open water	22/05/2008	North	>100	25	5		6.6	0.02
Ogongo oshana	No sampling	29/01/2008							
Ogongo oshana	No sampling	8/3/2008							
Ogongo oshana	Open water	18/04/2008	North	>100	65	4		6.9	0.05
Ogongo oshana	Open water	18/04/2008	South	>100	33	6		6.6	0.04
Ogongo oshana	Open water	22/05/2008	South	>100	13	3		6.8	0.08
Ogongo oshana	Open water	22/05/2008	North	>100	44	4		6.5	0.1
Oshikuku oshana	Substratum	31/01/2008	North	>20 ≤ 100	60	9		6.7	0.05
Oshikuku oshana	Aquatic vegetation	31/01/2008	North	>20 ≤ 100	60	10		6.7	0.05
Oshikuku oshana	Aquatic	8/3/2008	North	>20 ≤ 100	52	15			

	vegetation								
Oshikuku oshana	Open water	18/04/2008	North	>20 ≤ 100	47	7		7.1	0.05
Oshikuku oshana	Aquatic vegetation	18/04/2008	North	>20 ≤ 100	47	11		7.1	0.05
Oshikuku oshana	Open water	22/05/2008	North	>20 ≤ 100	41	4		6.7	0.12
Shanandjaba ondombe	Deep Area	30/01/2008	Ondombe	<20	80	5	n/a	n/a	n/a
Shanandjaba ondombe	Marginal vegetation	30/01/2008	Ondombe	<20	60	9	n/a	n/a	n/a
Shanandjaba ondombe	Marginal vegetation	10/3/2008	Ondombe	<20	27	14	n/a	n/a	n/a
Shanandjaba ondombe	Deep Area	10/3/2008	Ondombe	<20	80	12	n/a	n/a	n/a
Shanandjaba ondombe	Deep Area	19/04/2008	Ondombe	<20	68	7		6.7	0.05
Shanandjaba ondombe	Marginal vegetation	19/04/2008	Ondombe	<20	24	13		6.7	0.05
Shanandjaba ondombe	Deep Area	23/05/2008	Ondombe	<20	57	4		6.7	0.09
Lashivanda ondombe	Deep Area	31/01/2008	Ondombe	<20	76	8		7.1	0.2
Lashivanda ondombe	Marginal vegetation	31/01/2008	Ondombe	<20	38	7		7.1	0.2

Lashivanda oshana	Aquatic vegetation	31/01/2008	North	<20	32	4	n/a	n/a	n/a
Lashivanda oshana	Open water	9/3/2008	North	<20	49	8	n/a	n/a	n/a
Lashivanda ondombe	Marginal vegetation	9/3/2008	Ondombe	<20	41	12	n/a	n/a	n/a
Lashivanda ondombe	Deep Area	9/3/2008	Ondombe	<20	55	8	n/a	n/a	n/a
Lashivanda oshana	Open water	19/04/2008	North	<20	42	8		6.7	0.15
Lashivanda ondombe	Marginal vegetation	19/04/2008	Ondombe	<20	37	10		7.5	0.07
Lashivanda ondombe	Deep Area	23/05/2008	Ondombe	<20	17	8		6.7	0.11
Lashivanda oshana	Open water	23/05/2008	North	<20	34	7		7.2	0.22
Shashimwaku oshana	Open water	31/01/2008	North	>100	75	8	n/a	n/a	n/a
Shashimwaku oshana	Aquatic vegetation	31/01/2008	South	>100	60	9	n/a	n/a	n/a
Shashimwaku oshana	Open water	9/3/2008	South	>100	56	8	n/a	n/a	n/a
Shashimwaku oshana	Aquatic vegetation	9/3/2008	North	>100	80	10	n/a	n/a	n/a
Shashimwaku oshana	Open water	19/04/2008	South	>100	37	4	n/a	7.1	0.2

Shashimwaku oshana	Aquatic vegetation	19/04/2008	South	>100	37	9	n/a	7.1	0.2
Shashimwaku oshana	Open water	23/05/2008	South	>100	21	4	n/a	6.7	0.31