A BASELINE REPORT OF WATER QUALITY AND INVERTEBRATE ASSESSMENT IN RIVER HOHWA, LAKE ALBERT

Final Report

Prepared for Environmental Assessment Consult Limited (EACL) by the National Fisheries Resources Research Institute (NaFIRRI)
October 2007

CONTACT:

P.O. BOX 343, JINJA

Tel: 043-120484/121369; Fax: 043-120192;

Email: firi@infocom.co.ug; director@firi.go.ug

Table of contents

Executive summary

Tullow Oil plc is to launch an onshore Early Production System (EPS) of oil drilling rated at 4,000 barrels of oil per day by 2009. The location of the EPS is in the Kaiso-Tonya area of Block 2 Oil Exploration Zone along Lake Albert within the Albertine graben. Tullow Oil plc contracted Environmental Resources Management (ERM) Southern Africa (Pty) Ltd in conjunction with Environmental Assessment Consult Limited (EACL) to undertake an Environmental Impact Assessment (EIA) for pre-construction and operation of the proposed EPS. ERM in association with EACL requested National Fisheries Resources Research Institute (NaFIRRI) to conduct a baseline survey of water quality and invertebrates in River Hohwa. This study was requested as part of an earlier baseline survey conducted at the Kaiso-Ngassa spit oil exploration area in Block 2. It was conducted at five selected sites (Fig. 1 & Table 1) within the Hohwa River basin in the Kaiso-Tonya Exploration Area 2. The study was pertinent because the targeted oil wells for EPS are upstream this river which drains the Kaiso-Ngassa valley into Ngassa lagoon.

The main objectives of the surveys undertaken during October 2007 were:

1. To generate baseline information on water quality status of River Hohwa and
2. Assess invertebrate species composition, diversity and relative abundance in river prior to the proposed EPS

The water quality survey component determined the following parameters:

1. Temperature, pH, dissolved Oxygen, Conductivity and oxidation reduction potential (ORP) *in situ*, just below the water surface using portable meters;
2. Total dissolved solutes (TDS)
3. Nutrients (Nitrates, Total dissolved Nitrogen (TDN), Total Nitrogen (TN) and Soluble Reactive Phosphorus (SRP), Total dissolved Phosphorus (TDP), Total Phosphorus);
4. Chlorophyll-a and Ttotal Suspended Solids (TSS)

The invertebrate survey determined the following:

1. Taxonomic composition of zooplankton and benthic macro-invertebrate communities
2. Distribution and diversity of zooplankton and macro-invertebrates
3. Abundance estimates of zooplankton and macro-invertebrates

The results of the Hohwa survey show that conductivity levels of the river water at sites 1, 3 and 4 ranged from 185 to 196 µs/cm while at sites 2 and 5, water conductivity was higher (>230 µs/cm). Site 2 was cooler (20.1^{o}C) compared to the other sites whose temperature varied within a narrow limit from 23.2 to 23.9 ^{o}C. Similarly, variations among pH were small except at sites 2 and 4 where Chl-a as well was relatively high. At site 5, concentrations of TP and TSS were higher than thsoe recorded at other sites.

Despite the nutrients especially TN and TP being abundant in the river water, Chl-a, concentrations at all the sites reflected lowproductivity within the river. Water quality results seem to indicate that River Hohwa is still close to pristine conditions, though some effects arising from human activities are suspect. Possible contamination of the river as well as the lake by different constituents during EPS may occur unless migration measures are considered. Still, more data collection from the area, especially to include dry season is recommended.

The zooplankton community composition comprised Copepoda, Cladocera and Rotifera, similar to what occurs elsewhere in the East African region. Like in other systems in Uganda, The large-bodied calanoid copepods and the cladocerans (water fleas) were scarce. Harpacticoid copepods and *Macrothrix sp.* were recovered at two sites (Hohwa 1 and 2). These are generally rare benthic organisms but in a lotic environment, they are periodically re-suspended by water current and swept downstream. In general, the zooplankton abundance estimates observed in the Hohwa river system were an order of magnitude lower than what has been recorded for sites in Lake Albert and in other lentic systems in Uganda. This is largely due to different environmental conditions associated with lotic environment where flowing water conditions are known to constrain both physical and physiological processes influencing development of biological communities. Secondly, water residence time in river systems also influences zooplankton development. However, species number and numerical density observed at Hohwa 1 were high.

The macro-benthic community of Hohwa river system contained taxa that occur widely in other aquatic environments but taxonomic/species richness and numerical abundance were much lower than those recorded elsewhere especially in the nearby Lake Albert, except at Hohwa 1. As in the case of the zooplankton community, such striking observations can at present be treated as preliminary impressions that would require confirmation from further field surveys in conjunction with studies of selected environmental factors likely to influence such phenomena. Chironominae (Diptera) and *Caenis* sp. (Ephemeroptera) were shown to occur at nearly all the study sites i.e. high frequency of occurrence of 80-100%. These taxa, and in particular, Chironominae are known to be generally hardy groups that are tolerant of a wide range of environmental conditions. Further field surveys will help to confirm their predominance or not in the system and this would be of particular interest when oil exploratory activities in the area start with the potential environmental changes that are likely to accompany such developments.

The data and information presented were collected during early October 2007 in the wet season. Subsequent periodic surveys will help to track the extent of environment changes as EPS activities unfold within the designated areas of Albertine graben of Lake Albert.

1.0 Study Area

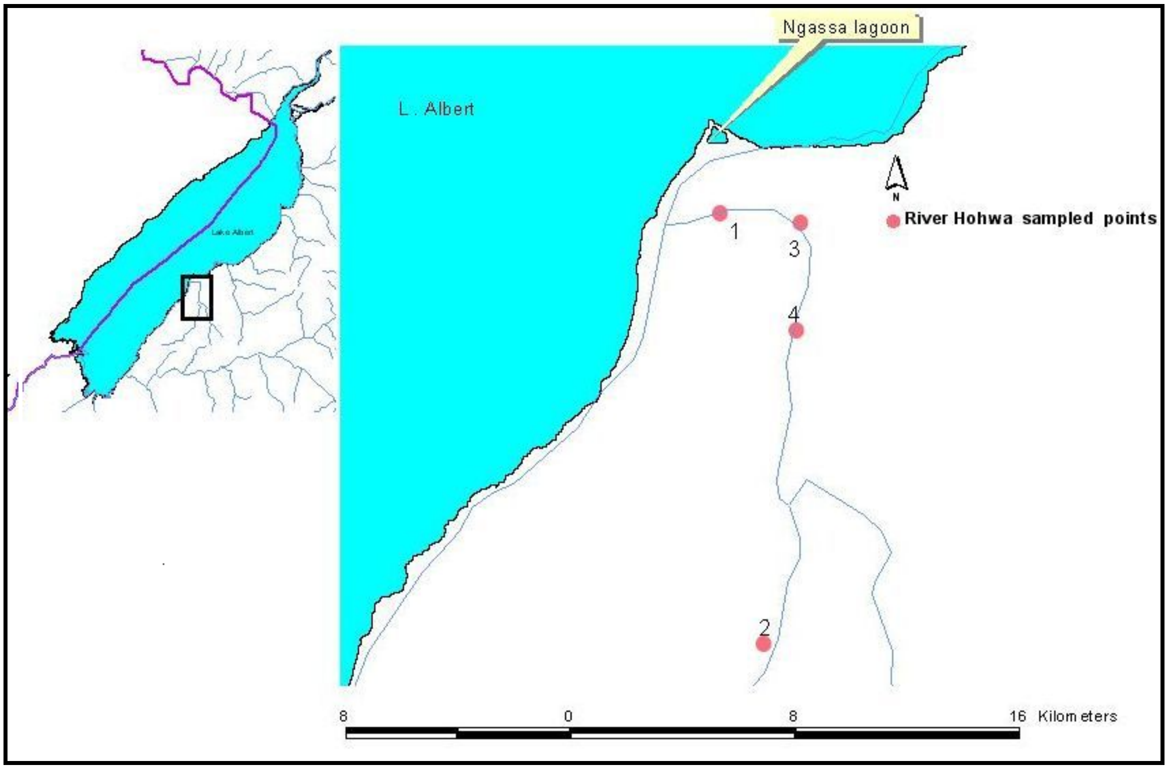

Figure 1. Portion of Albertine Graben showing the sampled points on River Hohwa

The study was conducted at five selected sites along River Hokwa (Fig. 1 & Table 1).

Table 1. Field study sites and their coordinates

Study sites	Coordinates (decimal degrees)
Hohwa 1	1.51905^0N; 30.95775^0E
Hohwa 2	1.37272^0N; 30.97161^0E
Hohwa 3	1.50734^0N; 30.98308^0E
Hohwa 4	1.47305^0N; 30.98197^0E
Hohwa 5	Could not access satellites

Site 1 was near a road/bridge, Site 2 was by the road side, with rocky bottom and characterized by numerous human activities e.g. bathing, washing, gardens, etc., and sites 3, 4 and 5 were generally covered by forests. The sites were generally shallow, ranging from about 0.3 to 1.5m.

2. 0 Water quality status of River Hohwa, October 2007

2. 1 Major objective of the study

To generate baseline information on water quality status of River Hohwa prior to the proposed Early Production System (EPS).

2.2 Specific objectives of the study

a) To determine the physical-chemical status of the waters in the selected sites (1-5) along the river as characterized by conductivity, temperature, pH and oxidation-reduction potential
b) To determine and relate nutrient and chlorophyll a (Chl-a) concentrations so as to gauge baseline biological productivity levels of the river.
c) To determine the concentrations of total suspended solids as background values prior to construction and operation activities of the EPS,
d) To delineate baseline patterns in distribution of nutrients and other constituents along the river.

2.3 Materials and methods

2.3.1 Sampling procedures

The sampling was conducted during a wet season. Water depth was estimated by a sinker tied on string. Water physical variables (conductivity (µs/cm), temperature (^oC), pH and oxidation reduction potential (ORP) at the sites were measured *in situ*, just below the water surface using standard portable meters.

For analyses of nutrients, Chl-a and total suspended solids (TSS), water samples were collected from just below the water surface using a Van Dorn sampler. Water samples were transferred from Van Dorn sampler to clean and labeled plastic sample bottles, which were then placed in cool boxes containing ice blocks. The samples were transported to NaFIRRI laboratories for analyses.

2.3.2 Sample analyses

Nutrients and chlorophyll-a (Chl-a) were analysed in accordance with standard analytical methods for freshwaters (Stainton *et al*., 1977). The analyzed nutrients were total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), total nitrogen (TN), total dissolved nitrogen (TDN) and nitrates (NO_3-N). Total suspended solids (TSS) in water were determined following the methods in Greenberg *et al*. (1992).

2.4 Results

2.4.1 Physical-chemical conditions the river

Water conductivity ranged from 185 µs/cm at site 3 to 283 µs/cm at site 5 (Table 1A). The values of about 185 µs/cm to 196 µs/cm recorded at sites 1, 3 and 4 were low as compared to the value of 233 µs/cm and 285 µs/cm, measured at sites 2 and 5, respectively. Temperatures varied between 20.1 ^oC at site 2 and 23.9 ^oC at site 4. There was no clear trend in temperature values along the stream. The pH varied between 7.0 and 8.3; the lowest being at site 1 and the highest at site 2. ORP ranged from 58 at site 1 to 91 mV at site 3.

2.4.2. Status of nutrient concentrations

The highest mean TP concentration (429.8 µg/L) was recorded at site 5 and the lowest (271.1 µg/L) at site 4 (Table 1B). At sites (2, 3, and 4), TP varied from 320.8 µg/L to 356.1 µg/L. The highest TDP (315.7 µg/L) was measured at site 2 and the lowest (259.1 µg/L) at site 4. At sites (2, 3, and 4), TDP ranged from 275.3 to 301.8 µg/L. SRP values ranged from 184.9 at site 4 to 287.6 µg/L at site 5. The trends SRP, TP and TDP along the river were similar. The values of TN were between 3347.5 µg/L at site 2 to 3804.8 µg/L at site 1. Most of the sites had comparable values of TN. TDN was highest (722.7 µg/L) at site 2 and lowest (552.0 µg/L) at site 1. Nitrate (NO_3-N) concentrations ranged from 21.4 to 37.7 µg/L, at sites 4 and 2, respectively.

Table 2: Mean concentrations of A) physical-chemical variables B), nutrients (B) and C) other constituents at the five sampling sites along River Hohwa during early October 2007.

Variables	**Sites**					**No. samples (N) at each site**
	1	**2**	**3**	**4**	**5**	**N**
A: Physical-chemicals						1
Cond. (µs/cm)	196	233	185	195	283	4
Temp (^oC)	23.6	20.1	23.5	23.9	23.2	1
pH	7.0	8.3	7.6	7.8	8.0	1
ORP (mV)	58.0	79.0	91.0	83.0	57.0	1
B: Nutrients						
TP (µg/L)	340.3	356.1	320.8	271.1	429.8	4
TDP (µg/L)	275.3	315.7	279.5	259.1	301.8	4
SRP (µg/L)	240.7	281.6	239.1	184.9	287.6	4
TN (µg/L)	3804.8	3347.5	3666	3780.2	3678.0	4
TDN (µg/L)	552.0	722.7	697.7	558.3	620.7	4
$N0_3$-N (µg/L)	30.3	37.1	25.7	21.4	31.7	4
C: Other constituents						
Chl-a (µg/L)	0.4	0.8	0.3	0.5	0.4	4

TSS (µg/L)	1075.0	3562.5	1937.5	1787.5	2300.0	4

2.4.3 Other constituents: Chlorophyll a (Chl-a) and total suspended solids (TSS)

Phytoplankton biomass measured as chlorophyll a (Chl-a) was generally low (Table 1C). The values ranged from 0.3 to 0.8 µg/L, at sites 3 and 2, respectively. The concentrations of TSS ranged from 1075.0 to 3562.5 µg/L at sites 1 and 2, respectively. More TSS was recorded downstream than upstream.

2.5 Discussion

The conductivity levels of the river water (185 to 196 µs/cm) at sites 1, 3 and 4 may be related to the geological background of the area while the higher values (>230) at sites 2 and 5, could be mainly resulting from impact of human activities (e.g. washing and bathing). The significantly higher conductivity value at site 5, probably was a result of entry of salts from the surrounding, following the rain that fell during the time of sampling at this particular site. Generally, the temperatures of the River Hohwa waters varied from 23.2 to 23.9 ^{o}C but a colder environment of 20.1^{o}C was measured at site 2. Allan (1995) reported that in a stream, the temperatures may vary seasonally, on daily time scale and along locations due to climate, elevation and vegetation cover. For example, the differences in sampling time and vegetation cover along river Hohwa could have caused such temperature differences. Small variations observed on pH values could be attributed to differences in magnitude of photosynthetic activities by the available phytoplankton biomass as shown at sites 2 and 4 where Chl-a as well as pH were relatively high (Table 1A and C). The values of ORP at all sites indicate that there was adequate dissolved oxygen that could support the various organisms and their related metabolic activities within in the river.

Higher concentrations of TP and TSS at site 5, could be attributed to the effect arising from runoff from the surrounding while TN concentrations at site 1, and TDN and NO_3-N at site 2 was probably due to human activities e.g. washing, bathing, grazing and others that were observed at these portions of the river. In general, all the nutrients listed (Table 1B) were quite abundant and these could be from vegetation material that was present along the river e.g. the forests areas of sites 3, 4 and 5. The presence of significant amounts of particular nutrients namely TDP and TDN, indicated microbial activity especially on organic materials, given the availability of dissolved oxygen mentioned above. When compared to nutrient (e.g. TP and TN) concentrations at the lagoon and the open lake (NaFIRRI 2007), the ones of River Hohwa were lower. It is probable that the nutrients that enter the lagoon from the river, accumulated as the lagoon has poor flushing. Other pollutants may also be transported and even reach the lake, especially during flooding.

The Chl-a, concentrations at all the sites reflect poor productivity within the river though there nutrients e.g. TN and TP were abundant. The shading and lotic effects in such an environment does not favour phytoplankton production and most of the metabolism depend on allochthonous organic matter, as explained in other study (Wetzel 2001). Significant value of TSS at site 2 show human impact especially road construction and gardens. This shows how suspended solid may enter the river during EPS and probably be transported downstream, if not mitigated.

2.6 Conclusion and recommendation

River Hohwa is still close to pristine conditions though some effects arising from human activities are suspect. Possible contamination of the river as well as the lake by different constituents during EPS is likely to occur unless migration measures are considered. Still, more data collection from the area, especially to include dry season is recommended.

3.0 River Hohwa Aquatic Invertebrates (zooplankton and macro-benthos) Communities, October 2007

3.1 Major objective of the study

Assess invertebrate species composition, diversity and relative abundance in river prior to the proposed EPS

3.2 Specific objectives of the study

1. To determine the taxonomic composition of zooplankton and benthic macro-invertebrate communities
2. To determine distribution and diversity of zooplankton and macro-invertebrates
3. To determine abundance estimates of zooplankton and macro-invertebrates

3.3 Materials and methods

3.3.1 Invertebrates sampling

Zooplankton were sampled with a Schindler trap of 5-litre capacity. At each sampling site nine hauls of the trap were taken (45 litres) and combined to make a composite sample. The samples were filtered through a 60 µm nitex mesh and the concentrated sample preserved with 4% formalin solution in clean, labelled sample bottles.

Macro-benthos were sampled with a Kicknet of 37X37 cm mouth area. At each site, 3 kicknet hauls were taken and combined to make a composite sample. The sample was washed through a 400 µm nitex mesh and preserved in 4% alcohol in clean, labelled sample bottles.

3.3.2 Sample analysis

In the laboratory, each zooplankton sample was diluted with clean tap water. The final dilution volume depended on the concentration of the sample. The diluted sample was vigorously agitated with a glass rod in a calibrated cylinder and 2 sub-samples of 10 ml were dispensed, each placed on a counting chamber and examined under an inverted microscope at X40 magnification. Organisms were identified to species level using taxonomic identification keys for the different groups present (copepods, cladocerans and rotifers). Organisms belonging to each category were enumerated and the count data compiled. From the latter, density data was calculated by reference to the sample dilution volume, split factor (if any) and the original sample volume.

Each macro-benthos sample was washed free of the preservative using tap water, placed on a clean plastic tray, sorted and examined under a dissecting microscope at X10 magnification. Taxonomic identity was established using appropriate keys and organisms in the different groups were enumerated. Density data was calculated by reference to the area of an open kick net mouth and the number of kick net hauls taken per site.

The count data generated were entered into Excel computer work sheets and appropriately analysed to generate data tables and figures.

3.4 Results

3.4.1 Species composition of zooplankton community

The community was composed of three broad taxonomic groups namely Copepoda, Cladocera or water fleas and Rotifera (Table 2). The Copepoda consisted of two sub-classes: Cyclopoida and Harpacticoida. The former contained three genera with two having a single species each (*Afrocyclops* sp., *Mesocyclops* sp) and one with two species (*Tropocyclops confinnis* and *Tropocyclops tenellus)*. Other copepod constituents were life cycle development stages: copepodites and nauplius larvae. Cladocera was represented by three genera each with one species: *Moina micrura*, *Macrothrix* sp. and *Chydorus* sp. Rotifera had the highest number of genera (6) with mostly a single species each. Only *Synchaeta* contained two species. Representatives of Copepoda and Rotifera were recovered at all the five study sites; but cladocerans were missing at Hohwa 3 and 5.

Table 3. Zooplankton species checklist for the five study sites along the Hohwa river course, October 2007. P means organism was present while blank space means organism was not found. **Note.** All Ps shown here were < 5 ind.L^{-1}.

Sites	Hohwa 1	Hohwa 2	Hohwa 3	Hohwa 4	Hohwa 5
COPEPODA					
Harpacticoida	P		P		
Cyclopoida					
Afrocyclops	P				
Mesocyclops sp.	P				
Tropocyclops confinnis	P				
Tropocyclops tenellus			P		
Cyclopoid copepodite	P	P	P	P	P
Nauplius larvae	P	P	P	P	P
CLADOCERA					
Chydorus spp.	P	P		P	
Macrothrix sp.	P				
Moina micrura	P				
ROTIFERA					
Brachionus angularis	P		P	P	P
Filinia opoliensis			P		
Keratella tropica	P		P		
Lecane bulla	P	P	P	P	
Platyas quadricornis			P		
Polyarthra vulgaris.	P				
Synchaeta pectinata			P	P	
Synchaeta spp.		P		P	
Trichocerca cylindrica	P		P	P	

3.4.2 Distribution and species diversity

The majority of zooplankton species regardless of the broad taxonomic grouping, exhibited discontinuous distribution across the five sample sites along the Hohwa river. Only the copepodites and naupliar larvae, and two rotiferans (*Brachionus angularis* and *Lecane bulla*) occurred nearly at all study sites. Out of the five sites, Hohwa 1 had the highest number of zooplankton species (12) followed by Hohwa 3 with 9, Hohwa 4 with 6, Hohwa 2 and Hohwa 5 both with less than 4 species. Hohwa 5 exhibited the poorest zooplankton community with a single rotiferan species *Brachionus angularis,* some copepodites and naupliar larvae.

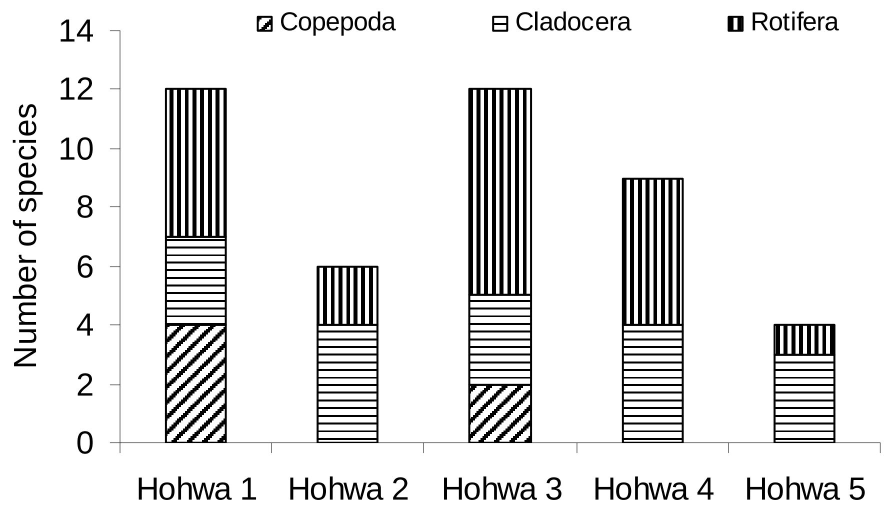

Figure 2. Species richness at different sites along the Hohwa river course, October 2007

3.4.3 Zooplankton abundance

Highest zooplankton numerical density estimate was 8 indiv. L^{-1} at Hohwa 5 while Hohwa 2 and Hohwa 5 had low density estimates of just over 1 indiv. $L^{-1.}$ Hohwa 3 and 4 exhibited intermediate abundance values of 4 and 3 ind. L^{-1} (Fig. 2). A general decreasing trend of zooplankton abundances from Hohwa 1 to Hohwa 5 was discernable

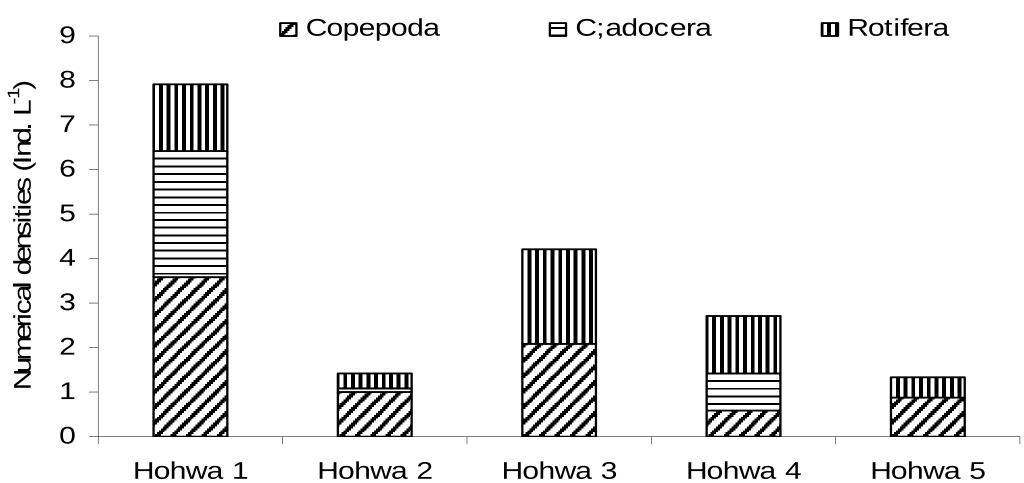

Figure 3. Zooplankton numerical abundance at different sites along the Hohwa river course, October 2007.

In the majority of cases Copepoda constituted the greater proportion of total zooplankton abundance (45-71%) except at Hohwa 4 where the highest fraction (48%) was from Rotifera (Fig. 3).

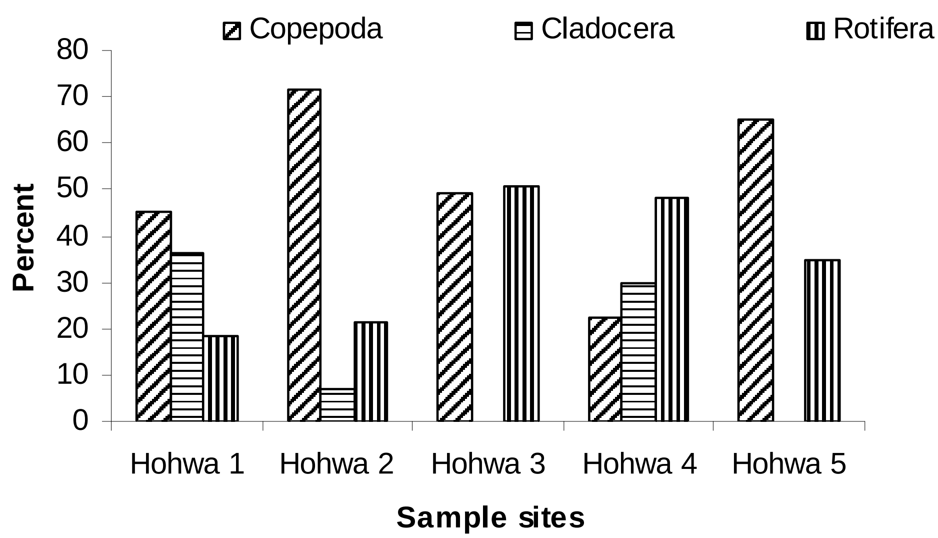

Figure 4. Percent contribution of the three broad taxonomic groups at different sites along the Hohwa river course, October 2007.

3.4.4 Taxonomic composition of macro-invertebrate community

The community was composed of 10 broad taxonomic groups across the five study sites (Table 3), namely Bivalvia and Gastropoda (Mollusca), Ephemeroptera, Odonata, Diptera, Trichoptera, Coleopteran, Hemiptera, Lepidoptera and Oligochaetae. Coleoptera, Ephemeroptera, Odonata and Diptera contained relatively high number of taxa (3-5). On the other hand, Bivalvia, Gastropoda, Hemiptera Lepidoptera and Oligochaeta had a single taxon each.

Table 4. Macro-benthos taxonomic checklist for the five study sites along the Hohwa river course, October 2007.

	Hohwa 1	Hohwa 2	Hohwa 3	Hohwa 4	Hohwa 5	% frequency of occurrence
Depth (m)	**0.4**	**0.3**	**1.5**	**1.4**	**0.1**	
Taxa:						
Bivalvia						
Pisidium victoriae	0	90	0	0	2	40
Gastropoda						
Biomphalaria sp.	0	129	0	2	0	40
Ephemeroptera						
Caenis sp	0	12	5	5	2	80
Baetidae	0	0	5	2	0	40
Leptophlebidae	0	0	5	2	0	40
Odonata						
Libellulidae (*Brechmorrhoga* sp)	0	27	0	0	0	20
Gomphidae (*Progomphus* sp.)	0	0	0	0	2	20
Protoneuridae	0	58	0	17	0	40
Diptera						
Ablabesmyia	0	2	0	0	0	20
Chironominae	66	112	19	2	7	100
Palpomyia sp.	0	0	2	0	2	40
Tipluidae	0	2	0	0	0	20
Trichoptera						
Leptoceridae	0	2	5	0	0	40
Hydropsychidae	0	10	0	0	0	20
Coleoptera						
Gyrinidae	0	0	0	2	0	20
Dytiscidae	0	2	0	0	0	20
Elmids (*Ancyronyx* sp.)	0	24	0	0	0	20
Hydrophilidae	0	2	0	0	0	20
Staphylinidae	0	2	0	0	0	20
Hemiptera						
Geriidae	0	5	0	10	0	40
Lepidoptera						
Pyralidae	0	10	0	0	0	20
Oligochaeta (*Nais* sp)	0	0	5	0	2	40

Hohwa 2 had the richest community of macro-benthos with a total of 16 taxa followed by Hohwa 4 with eight, Hohwa 3 with six, Hohwa 5 with five and Hohwa 1 with one (Figure 4.

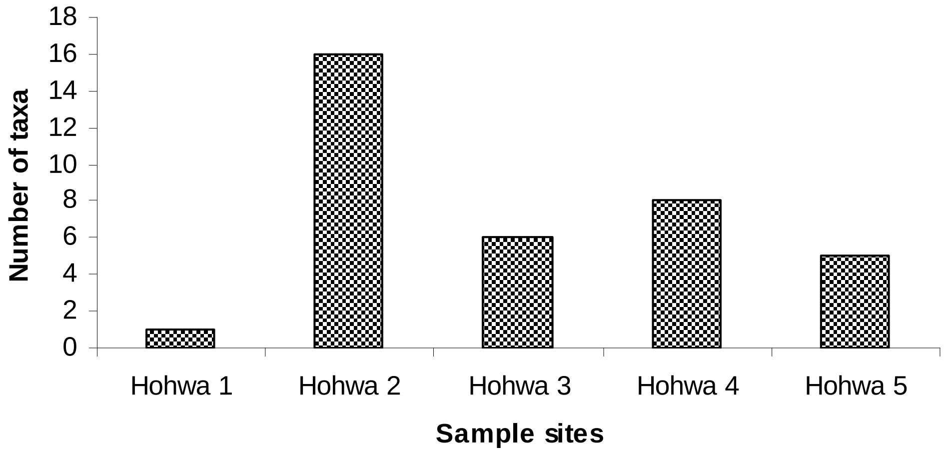

Figure 4. Total number of macro-benthos taxa at different sites along the Hohwa river course, October 2007

3.4.5 Macro-benthos abundance

Hohwa 2 had by far the greatest concentration of organisms up to 490 ind. m^{-2} (Fig. 5). The remaining 4 sites had very low organism densities (< 100 ind.m^{-2}) with Hohwa 5 having the poorest areal density of 17 ind.m^{-2}. Depth of the water column did not appear to influence the abundance of macro-benthos at the five study sites (Table 3).

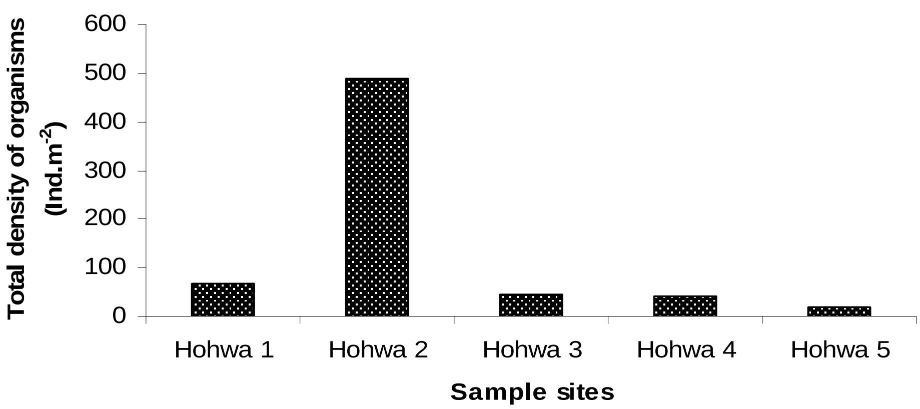

Figure 5. Macro-benthos numerical abundance at different sites along the Hohwa river course, October 2007.

3.4.6 Macro-benthos distribution and frequency of occurrence

With the exception of Chironominae (Diptera), most taxa exhibited rather discontinuous distribution across the five study sites (Table 3). The majority of taxa had a range of 20-

40% in terms of frequency of occurrence, except Chironominae which had 100% (i.e. recovered from all sample sites) and *Caenis* sp (Ephemeroptera) with 80%.

3.4.7 Relative abundance of macro-benthos

Dipteran taxa were the greatest contributors to total abundance at three of the five study sites (Hohwa 1, 3 and 5) contributing 100%, 68% and 60% of total macro-benthos respectively (Fig. 6). Odonata was prominent at Hohwa 4 (52%) and Hemiptera (30%). Bivalvia, Gastropoda, Odonata and Diptera contributed comparable proportions (19-27% of total macro-benthos) at Hohwa 4. Oligochaeta occurred in rather small proportions (13-16%) at Hohwa 3 and 5. Trichoptera was only recovered at Hohwa 3 also in small proportions (16%). Coleoptera occurred in very small proportions at Hohwa 2 and 4 (6%).

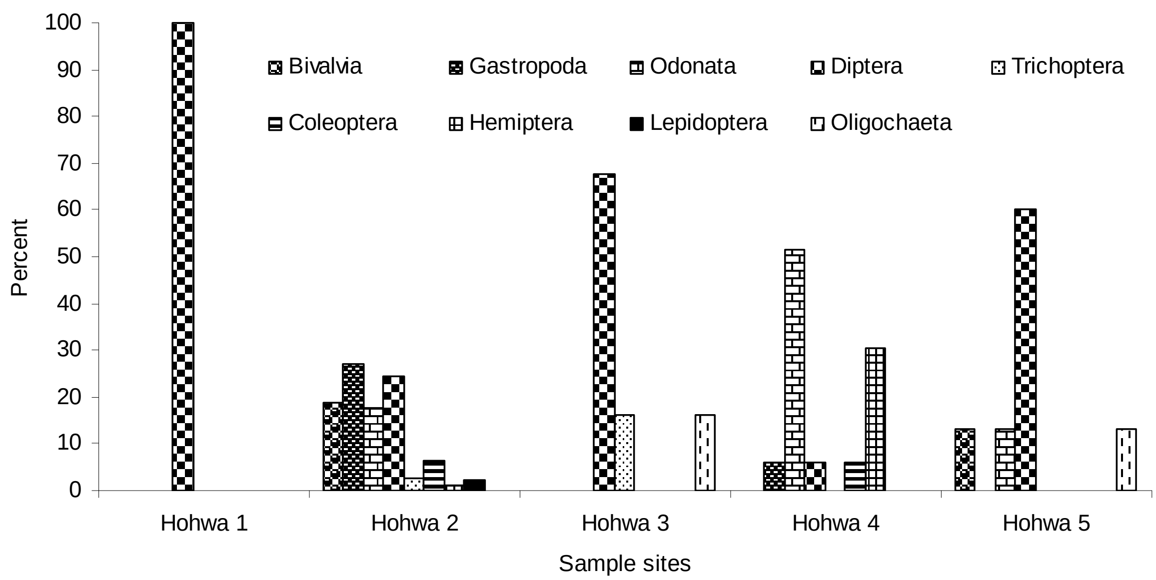

Figure 6. Percent contribution of the different macro-benthos taxonomic groups at different sites along the Hohwa river course, October 2007.

3.5 Discussion

Aquatic invertebrates are a group of small bodied organisms characterised by lack of a backbone. They can conveniently be divided into two size categories: the micro-invertebrates (hereinafter to be referred to as zooplankton) with body size ranging from several microns up to 1500 µm (1.5 mm) and macro-invertebrates or macro-benthos with body size ranging from a few to several millimetres. The zooplankton live mostly suspended in the water column and exhibit only feeble locomotion and are generally dispersed by water movements. Some of the larger macro-benthos live on sediment surface while others burrow in the sediments or are associated with roots of aquatic plants.

Invertebrates play very important ecological roles in the aquatic ecosystems. Generally they provide a food base for virtually all fish larvae and juveniles as well as adult pelagic fish species such as mukene, nkejje etc (Mwebaza-Ndawula 1998). They therefore occupy a vital position in aquatic food chains and are part and parcel of the fishery production processes in water bodies. Some invertebrates are commonly used as bio-indicators in tracking of water environmental changes and are therefore of high applied value in management of aquatic ecosystems. This ecological function is related to varying tolerances of invertebrate organisms to different levels of pollutant/toxic materials coming into the aquatic environment.

The zooplankton community composition comprising Copepoda, Cladocera and Rotifera is similar to micro-invertebrate communities occurring elsewhere in the East African region. A striking similarity to the Lake Albert zooplankton is the absence of the large-bodied calanoid copepods and the general scarcity of cladocerans (water fleas) in the community (Mwebaza-Ndawula & Kiggundu 2007 a & b). Such consistent similarity in community composition in closely connected aquatic biotopes may point to some yet unidentified environmental factor(s) that may not favour development of certain taxa that commonly occur in other systems. This area merits further investigation and with reference to environmental variables that may influence occurrence or non-occurrence of certain organisms in the environment. Harpacticoid copepods and *Macrothrix* sp. recovered at two sites (Hohwa 1 and 2) are generally rare benthic organisms which, in a lotic environment may periodically be re-suspended by water current in the river/stream water and get swept downstream.

The zooplankton species diversity is generally poor compared to the diversity observed in lentic habitats in lake sources of the River Nile (i.e. lakes Albert, Kyoga and Victoria) but was in the range of richness observed in the some sections of the Upper Victoria Nile characterised by fast current speed (Mwebaza-Ndawula et al. 2005). There is ample evidence in scientific literature linking water residence time in river systems to zooplankton development (Basu & Pick 1996). The strikingly high species number and numerical density observed at at Hohwa 1 (Figs 1 and 2) need confirmation for consistency and this will hopefully be achieved through results of subsequent surveys. It is however noted that in general terms the zooplankton abundance estimates observed in the Hohwa river system are an order of magnitude lower than those recorded for sites in the Lake Albert (Mwebaza-Ndawula & Kiggundu 2007 a & b) and in other lentic systems in Uganda (Mwebaza-Ndawula et al. 2000). This is largely due to different environmental conditions associated with lotic environment where flowing water conditions are known to constrain both physical and physiological processes influencing development of biological communities (Mwebaza-Ndawula *et al*. 2005).

The macro-benthic community of Hohwa river system also contains taxa that occur widely in other aquatic environments. However, notable differences are seen in the much lower taxonomic/species richness and numerical abundance (Figs. 4 and 5). The markedly richer macro-benthic community at Hohwa 1 is probably an indication of differences in environmental variables at this site relative to the rest of the study sites. As in the case of the zooplankton community, such striking observations can at present be treated as preliminary impressions that would require confirmation from further field surveys in conjunction with studies of selected environmental factors likely to influence such phenomena. Nonetheless, it is to be noted that that estimates of both the taxonomic richness and numerical abundance of macro-benthos of the Hohwa system are much lower that those recorded elsewhere especially in the nearby Lake Albert (Sekiranda & Kalogo 2007a & b) and other systems in Uganda.

Chironominae (Diptera) and *Caenis* sp. (Ephemeroptera) are shown to occur at nearly all the study sites i.e. high frequency of occurrence of 80-100% (Fig. 6; Table 3). These taxa, and in particular, Chironominae are known to be generally hardy groups that are tolerant of a wide range of environmental conditions. Further field surveys will help to confirm their predominance or not in the system and this would be of particular interest when oil exploratory activities in the area start with the potential environmental changes that are likely to accompany such developments.

3.6 Conclusions

The zooplankton and benthic community compositions of the Hohwa river system bear striking similarity with communities commonly encountered in other aquatic systems in Uganda. However, the taxonomic/species richness and numerical abundances are an order of magnitude lower than those recorded elsewhere in Lake Albert and other aquatic systems in Uganda. This observation may be explained by environmental differences bearing on lotic and lentic conditions also observed elsewhere between the Upper Victoria Nile and Lake Victoria. The high zooplankton and macro-benthic numerical abundances at Hohwa 1 and 2 require confirmation through further surveys that should preferably couple with a study of selected environmental variables. These surveys should also establish the true status of what appear to be prominent taxa such as the dipteran Chironominae and *Caenis* sp.

References

Allan J. D. (1995) Stream ecology, structure and function of running waters. Kluwer Academic Publishers, 388pp.

Basu, B.K. & F.R. Pick 1996. Factors regulating phytoplankton and zooplankton biomass in temperate rivers. *Limnol, Oceanogr* 41: 1572-1577.

Greenberg A. E. C., Lenore L. S., and Eaton A. D. (1992) Standard methods for examination of water and waste water.

Mwebaza-Ndawula, L. & V. Kiggundu 2007a. Zooplankton studies. Technical report from the field visit to the central part of Lake Albert, January 2007

Mwebaza-Ndawula, L. & V. Kiggundu 2007b. Zooplankton studies. Technical report from the field visit to the southern part of Lake Albert, May 2007

Mwebaza-Ndawula, L. 1998. Distribution and abundance of zooplankton and *Rastrineobola argentea* (Pisces: Cyprinidae) and their trophic interactions in northern Lake Victoria, East Africa. P.hD Thesis, University of Vienna, Austria.

Mwebaza-Ndawula, L. S.B.K. Sekiranda & V. Kiggundu 2005. Variability of zooplankton community alonfa section of the Upper Victoria Nile, Uganda. *Afr. J. Ecol*. 43:251-257.

Mwebaza-Ndawula, L. V. Kiggundu & H. Ochieng 2000. Invertebrate communities in northern Lake Victoria with reference to their potential for fishery production. Victoria 2000 International Conference, Jinja, Uganda

NaFIRRI (2007). A baseline survey of water and sediment quality, fisheries and invertebrates at Ngassa spit, Kaiso, Lake Albert. A Report prepared for Environmental Resources Management Southern Africa (Pty) Ltd (ERM) in association with Environmental Assessment Consult Ltd (EACL), 71pp.

Sekiranda, S.B.K. & P. Kalogo 2007a. Macro-benthos studies. Technical report from the field visit to the central part of Lake Albert, January 2007.

Sekiranda, S.B.K. & P. Kalogo 2007b. Macro-benthos studies. Technical report from the field visit to the central part of Lake Albert, May 2007.

Stainton M. P., Capel M. J. and Armstrong F. A. J. (1977) The Chemical Analysis of Fresh Waters, 2nd Edition. Misc. Spec. Publ. Environment Canada 25,166pp.

Wetzel R. G. (2001) Limnology, Lake and River ecosystems, Structure and productivity of aquatic systems, pp 130.