Diversity and abundance of plankton species in the Hardap Dam, Mariental District- Hardap Region

BY:

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A report in the Department of Fisheries and Aquatic Sciences, Faculty of Agriculture and Natural Resources

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DECLARATION

I hereby declare that this work is the product of my own research efforts, undertaken under the supervision of Mr. F.P. Nashima and has not presented elsewhere for the award of the degree. All the sources have been duly and appropriately acknowledged.

Candidate Signature: ………………………………… Date: ……………………..

ARNOLD DE KLERK (200807591)

CERTIFICATION

This is to certify that this report has been examined and approved for the award of the degree of Bachelor of Science in Fisheries and Aquatic Science of the University of Namibia.

External supervisor………………………………………………………………………….

Internal supervisor…………………………………………………………………………

Head of Department………………………………………………………………………

ACKNOWLEDGEMENT

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DEDICATION

This work is dedicated to Naomi Jacobs and friends that helped and supported me during the course of my studies.

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ABSTRACT

Species diversity and abundance of plankton were investigated in Hardap Dam, Mariental district, southern part of Namibia. Samples of zooplankton and phytoplankton were collected at different depths (0m-20) for a period of 3 months from three sites, representing the inlet inflow of the river into the dam, middle of the dam and the outlet which is the discharge of the dam. Sampling followed a systematic design at each identified site and a Kruskal Wallis test was used to test for significant differences in species diversity and abundance of plankton species non-parametric one sample independent test was used to test significant differences between sites. A total of about 8 zooplankton species and 7 phytoplankton species were encountered in this study. Environmental factors such as dissolved oxygen and pH were determined by the use of a pH meter while temperature of the water was measured using a thermometer whereas nitrate in collected water samples was determined in the laboratory using a spectrometer. Results indicated non-significant differences in means of zooplankton species diversity and abundance. With regards to environmental factors in relation to zooplankton diversity no significant relationship was observed. Zooplankton abundance resulted in a significant relationship and positive linear correlation with temperature and oxygen. Furthermore, insignificant differences in the means of phytoplankton species diversity and abundance with sites were observed. Phytoplankton species diversity showed a non-significant relationship (d.f=4; F=0.300; p>0.05) with environmental parameters. However, a significant relationship (d.f=4; F=0.047.; p<0.05) and positive linear correlation was concluded between phytoplankton species abundance and temperature in the Hardap dam. No significant differences in species diversity and abundance of plankton at each site might be a result that species richness in both zooplankton and *phytoplankton was equal at both sites. At each site 8 zooplankton species and 7 phytoplankton species was identified. It was concluded that environmental parameters in Hardap dam there is no significant linear relationship with diversity since plankton diversity is more influenced by biotic factors, competition, food and predation than environmental factors. A significant relationship was observed between temperature and oxygen with plankton abundance since it was founded that temperature was the most important factor that influence abundance.*

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 General introduction

According to Grahame (1987), the word plankton comes from the Greek planktos, a wanderer. This refers to the fact that planktonic organisms are drifters rather than powerful swimmers and their horizontal distribution is more governed by currents than by the outcome of their own efforts. Planktonic organism can be divided into two groups according to how they obtain their food source, they include photoautotrophs and heterotrophs. Photoautotrophs are also known as phytoplankton that uses light and carbon dioxide to make food for them. Photosynthesis and growth, phytoplankton need to be maintain in the euphotic zone though they do not need to spend all their time there; a cell permanent out of the euphotic will not survive indefinitely unless it is capable of heterotrophy (Grahame, 1987).

Heterotrophic plankton is known as zooplankton, the animal portion of the plankton. They obtain their energy by feeding on phytoplankton. Zooplankton inhibits all layers of aquatic bodies and constitutes a major link between primary production and higher trophic levels in aquatic ecosystems (Falkowski and Raven, 2007). An intriguing behavior of zooplankton is their vertical movement within water column, known as Dial Vertical Migration. Zooplankton moves to deeper darker sometimes anoxic waters during daytime and move upwards to surface water during night time; however some zooplankton may not exhibit migratory behavior at all (Reynolds, 2002).

The abundance and distribution of plankton is influenced by various parameters within the water column such as pH, temperature, nutrients, turbidity, and dissolve oxygen and furthermore by the presence of some zooplankton species example rotifers *Brachionus angularis, Trichocerca cylindrical* which are indicators of heavy polluted waters and are known as bio-indicators of water quality (Saksena, 2006). Since these factors plays a vital role on plankton diversity and abundance this study have assessed the plankton diversity and abundance in the Hardap dam in order to understand why the dam is so rich in fish species and its potential for aquaculture.

1.2 Justification of the study

Partially, a study of this nature was done previously by the Ministry of Fisheries and Marine Resource, Hardap Freshwater Institute in 1985, and ever since no new study has been conducted to demonstrate changes in the dam constituents. Therefore it is important for this study to give current information about the dam and also give an indication on the species diversity and abundance of plankton in the dam. It is evident that no previous study was conducted to assess the plankton diversity and abundance of species in the dam. Significantly, information to be obtained from this study will be helpful in the sense that it is necessary to understand what constitute to the dam. The Ministry of Fisheries and Marine Resources at Hardap Institute only monitor a section of the water quality of the dam and only tests certain water quality parameter except the nutrient content of the Thus, a complete plankton inventory within the dam will be helpful since an aquaculture practice is already taking place at the Ministry.

1.3 General project objective

The aim of this study is to determine the diversity and abundance of plankton species in the Hardap Dam.

1.3.1 Specific research objectives

1. To determine and compare the diversity and abundance of plankton species in the Hardap Dam.
2. To determine the influence of environmental factors on plankton diversity and abundance.

1.3.2 The specific research questions

1. Are there significant differences in diversity and abundance of plankton species in the Hardap Dam?
2. Do environmental factors influence the diversity and abundance of plankton species?

1.3.3 Research Hypothesis

1. There is a significant difference in plankton diversity and abundance in Hardap Dam
2. There is a significant influence of environmental factors on plankton diversity and abundance.

1.4 Literature review

Zooplankton play an important ecological role in lakes and rivers, feeding on non- living organic matter, phytoplankton and bacteria and in turn being eaten by secondary consumers such as fish (Ayodele, 2005). The physic-chemical parameters of an aquatic ecosystem are very important in assessing the composition of any aquatic biota and also there sensitivity to pollution (Taylor *et al.,* 2000*)*. Therefore a major interest in zooplankton investigation is to understand environmental factors that influence their diversity.

According to Boyd (2000), the aquatic system is very diverse and includes many thousands of species. These include planktonic algae (phytoplankton) that are microscopic and suspended in water. However, phytoplanktons are the most biological active plants in aquatic ecosystems, and they generally have a greater influence on water quality than other plants. Green algae are almost totally of fresh water distribution as they are mainly found in fresh water than any other kind of algae that include red and brown (Boyd, 2000). The phytoplankton species diversity and composition is not equivalent in two different water bodies and the diversity and composition will vary overtime in the same water body.

The ability of certain phytoplankton species to dominate a water body is because of favorable conditions to them and while others are not because of the same condition is not suitable for them suggested by (Reynolds, 2002). Furthermore the study Stoichiometry and Nutrition of Plant Growth in Natural Communities also examine why certain phytoplankton species may show analogous adaptation to similar conditions but have yet to be found simultaneously at the same localities. In addition *Cylindrospermopsis* and *Anabaena minutissima* show similar antennal properties and nitrogen fixation capacities that suit them to turbid, nitrogen- deficiency water column but they have not been found in mutual association in the same location (Reynolds, 2002). Phytoplankton can be differentiate on the basis of specialist adaptation and requirement such as having a high affinity for phosphorus or carbon dioxide at low external concentration, or of requiring skeleton silican, or of being a good light antenna.

According to the study conducted by Arimoro and Oganah (2010), at Orogodo river southern Nigeria, explain that zooplankton distribution and abundance are effected by local environmental conditions (i.e. temperature, flow velocity, depth, dissolve oxygen, alkalinity and conductivity) and they account for 69% of variation in zooplankton assemblage. The study revealed that most of the zooplankton encounters example rotifer families Brachionidae, Testudinellidea, and crustacean families; Diaptomidae, Bosminidae in the study area appears to be normal inhabitants of lakes, pond streams and artificial impoundments in tropic and subtopic regions. The rotifers constitute the largest group of zooplankton recorded at all the sites due to their ability to undergo vertical migration, and parthenogenesis reproduction patter and short development rates under favorable conditions in most fresh water systems (Arimoro and Oganah, 2010). In addition, it was stated that zooplankton communities respond to change in water quality meaning sensitive species normally disappears as water becomes too polluted while tolerant species survive example rotifers.

Phytoplankton community composition profoundly affects the biogeochemical chemical cycling of many elements, such as carbon, nitrogen, and phosphorus, because major functional groups have different requirements and modes of acquisition of these elements (Reynolds, 2002). Many cyanobacteria are able to fix atmosphere nitrogen and increase nitrogen availability in the water column (Reynolds, 2002). Diatoms have a greater efficiency of carbon sequestration into the deep ocean, because their heavily silica frustules make them sink faster than other groups of phytoplankton (Reynolds, 2002). Phytoplankton groups also differ in their edibility and their nutritional value for higher tropic levels (Reynolds, 2002). Many phytoplankton species can produce toxins that negatively affect water quality and higher trophic levels (Reynolds, 2002).

Phytoplankton community composition impact the functioning of aquatic ecosystems, it is important to understand what facts govern phytoplankton communities, assembly and dynamics.

It has been widely accepted that predation play a key role in diurnal vertical migration, Zaret and Suffern (1970), were the first to provide experimental support for the predatory avoidance hypothesis, and they urged that diurnal vertical migration was a way for zooplankton to avoid visual predators like fish. Although this behaviour is wide spread it is subjected to the considerable modification depending upon development stage and season (Grahame, 1987).

According to a study done by Jung *et al* (2009), on the ecology of freshwater phytoplankton state that in winter, the growth of phytoplankton is reduced by cold temperature, low light intensity, and short day length. However some phytoplankton (*Stephanodiscus* species) blooms repeatedly in winter, these blooms can be attributed to anthropogenic eutrophication. Furthermore, the reintroduction of nutrients at low temperatures and eutrophic condition could help *Stephanodiscus* species to respond quickly and increase in number again.

It is well known that predation (top-down forces) and resource supply (bottom-up forces) are important in the regulation of population dynamics and community structure in freshwater plankton (Sommer, 1989). Many previous studies have found that individual numbers or biomasses of organisms in aquatic systems are sensitive to changes in both resource supply and abundance of their natural enemies (Carpenter *et al.*, 1987). Schalau *et al.*, (2008), argued that one should seek specific or dominant conditions or factors that determine the regulation of plankton population dynamics and community structure. Furthermore, Schalau *et al.*, (2008), and Straile (2000), suggested that temperature and not food is the dominant factor driving inter annual variability of zooplankton population dynamics especially *Daphnia* species during spring.

Rotifers are one of the most important constituents of freshwater zooplankton communities. Regulation of the seasonal variation of rotifers population has been attributed to both abiotic factors, including temperature, pH, dissolve oxygen (DO) and biotic factors such as food resource, competition, and predation (Dumont, 1977; Hofmann, 1977). Temperature was the most important factor that influences the different parameters in a rotifer experimental population (Xi and Huang, 2004).

CHAPTER TWO

MATERIALS AND METHODS

2.1. Study area

The study area is located in Mariental, Hardap dam. The dam is the biggest man-made constructed dam in Namibia. The Hardap dam is situated in the Fish river catchment area and it serves as a recreational area and also provides fresh water to the Municipality of Mariental and for the Hardap irrigations scheme (Ministry of Agriculture, Water and Rural Development Republic of Namibia, 1992). Significantly, the dam supports numerous bird species as their breeding area. In addition, having a game park and having hosted a variety of species of game such as kudu, gemsbok, springbok, steenbok, mountain zebra and ostriches hence catchment area of the Hardap dam is characterized by dwarf shrubs savannah vegetation.

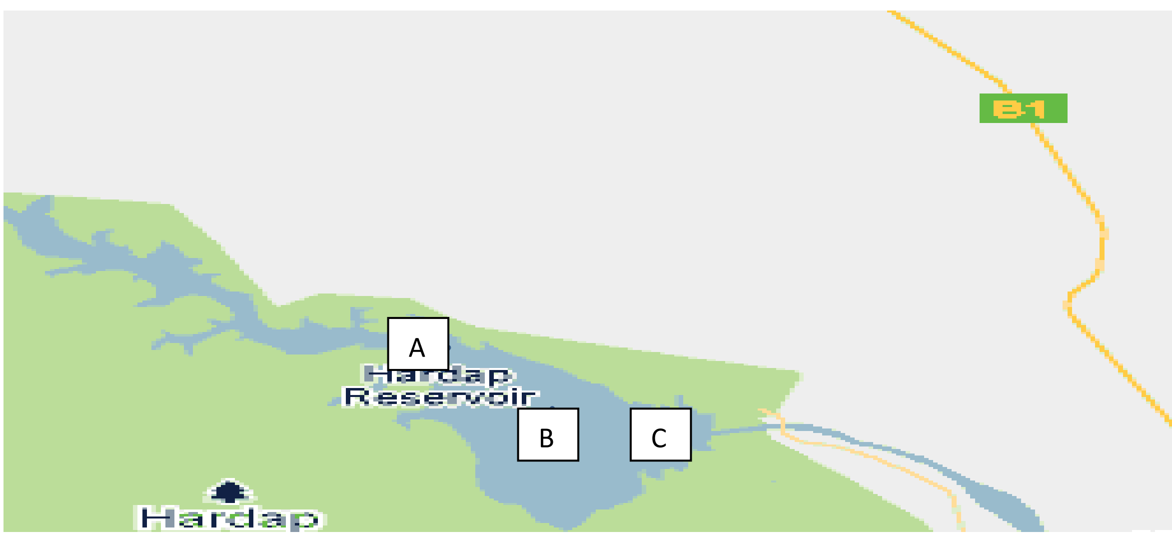

Figure 1: The map of Hardap dam (Source: Google Earth, 2010). The letters indicates the sampling sites: The inlet (A), middle (B) and the outlet (C).

2.2. Study Design

Three sampling sites were sampled in the dam and the sites include: the inlet, the middle and the outlet. At each sampling sites different depth within the water column was sampled and the depths include multiples of two 0 m, 2m, 4m, 6m, 8m, 10m, 12m, 14m ,16m, 18m, 20m.

2.3. Data collection

Sampling was conducted during the period between May and August, 2011. A Ski-boat was used for sampling in the dam. Niskin bottle was used for collecting water samples at different depths of the three selected sites. Water samples collected were stored in bottles for later analyzing of water parameter nitrate. Temperature, pH and dissolve oxygen were measured on site using pH meter and mercury thermometer. Plankton at surface was collected using plankton net and placed in bottles.

2.4. Laboratory Analysis

The samples were analyzed within a period of not more than 10 days after sampling as keeping the samples longer in the laboratory makes identification difficult. Samples from the three different sites, a drop of the samples was taken from the bottle and put on a Haematocytometer with a volume of $0.00025mm^3$ where it was observed using the light microscope at magnification of 200X.

The numbers of individuals identified in the Haematocytometer were multiplied by 1000 to account for the 250ml where the sample was taken. Guide to Identification of Freshwater Microorganisms by (Maths/Science Nucleus, 2004), and Field Guide to Zambian Fishes, Plankton and Aquaculture (Utsugi and Mazingaliwa, 2002) were used to identify plankton species level. The number of species was recorded on a sheet (*See Appendix 1, 2).* Microphotography of the species identified was taken for reference (*See Appendix 3, plates 1, 2, 3, 4 and 5*). Nitrate samples were analyzed in the laboratory using spectrometer instrument.

2.5. Data manipulation and analysis

PRIMER 5.0 for Windows was used to analyze species diversity of plankton in Hardap dam and was calculated using the Shannon – Weiner Index of diversity. Kruskal Wallis Test was used to test for significant differences in species diversity and abundance of plankton species; this was carried out using SPSS 16.0.

A Multiple Linear Regression (MLR) was used to determine the relationship between environment factors and species diversity and abundance; this was carried out using GENSTART statistical package.

CHAPTER THREE

RESULTS

3.1 Diversity and abundance of zooplankton species

A total of 8 zooplankton species were investigated during the present study. No 'new' zooplankton species were recorded during this study. The results show that there are non-significant differences in means of species diversity and abundance in zooplankton as observed at different sites (inlet, middle and outlet) within the dam.

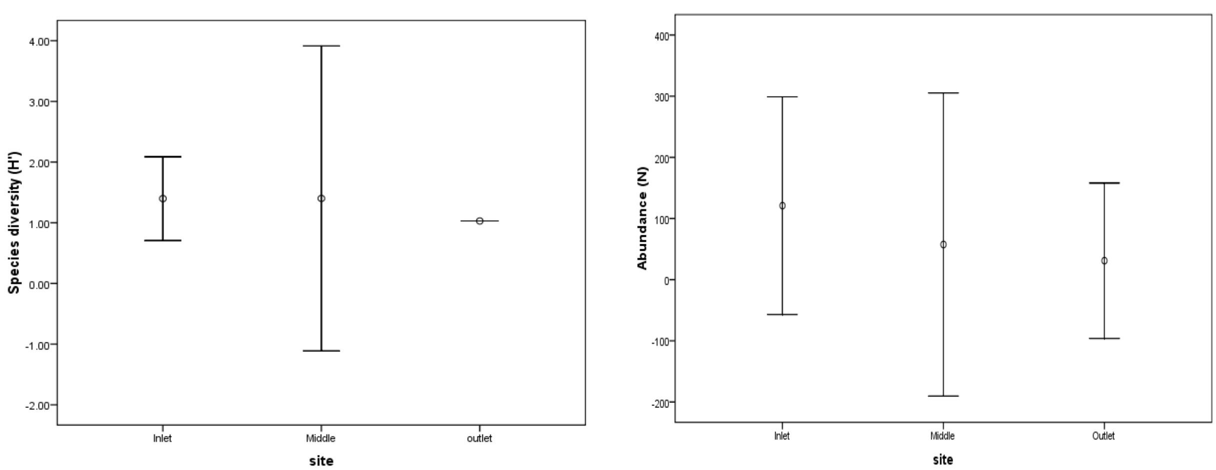

Figure 2: Comparison of means species diversity and abundance of zooplankton at three sites in the Hardap dam. Error bars indicate 95% confidence interval of the mean.

Zooplankton species diversity at inlet was *H*' = 1.39 whereas at middle and outlet location were *H'* = 1.44 and 1.22, respectively. The comparison of means in zooplankton species diversity and abundance indicated non-significant differences between location with *d.f*=2; *F*=0.250; $p>0.05$ and *d.f*=2; *F*=0.148; $p>0.05$, respectively. The general trend observed in figure 2 shows that the average species diversity and abundance was quite high in the middle relative to the other sites.

3.2 Influence of environmental factors on zooplankton species diversity

The result showed no significant relationship (*d.f*=4; *F*=0.246; $p>0.05$) between environmental factors (Temperature, oxygen, pH and nitrate) and zooplankton species diversity (table 1). The fitted and observed relationship yield a regression model; y= 1.733 + 0.3326X1 + 0.0095X2 + 0.0529X3 + 0.0143X4 shows a non significant linear relationship between nitrateX1, dissolve oxygenX2, pHX3, temperatureX4 and y (figure: 3, 4, 5, and 6).

Table 1: **Summary for Regression Analysis of Variance for zooplankton diversity**

Source of Variation	D.F	SS	MS	p-Value
Regression	4	0.064	0.0159	0.246
Residual	1	0.002	0.0018	
Total	5	0.066	0.0131	

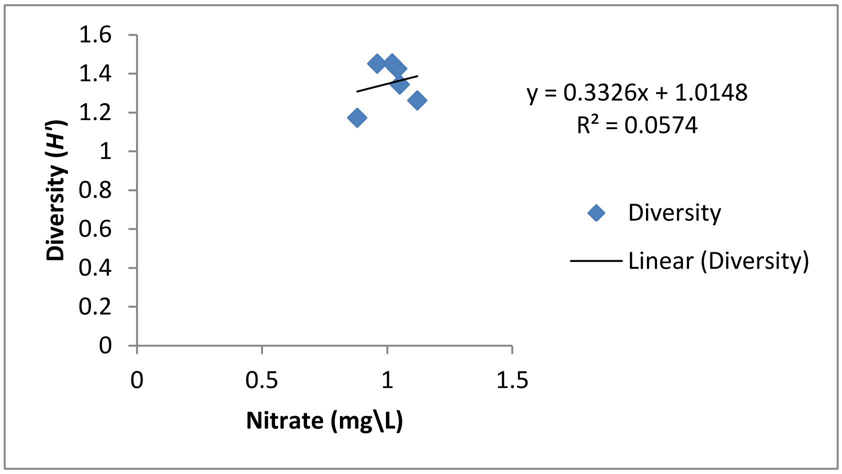

Figure 3: The Relationship between Nitrate and zooplankton species diversity

Figure 3 above indicate the relation between zooplankton species diversity and nitrate concentration with the line of best fit and a low percentage coefficient variance (R^2=0.0574) regression model (y= 1.0148 + 0.3326X) (zooplankton species diversity= 1.0148 + 0.3326 nitrate).

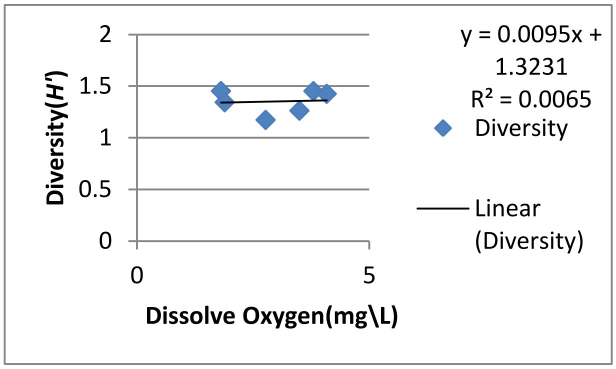

Figure 4: The Relationship between dissolved oxygen and zooplankton species diversity

As observed above in figure 4 showing a low percentage coefficient variance (R^2= 0.0065) between dissolve oxygen and zooplankton species diversity and yielding a regression model (y=1.3231 + 0.0095X) (zooplankton species diversity= 1.3231 + 0.0095) not good model.

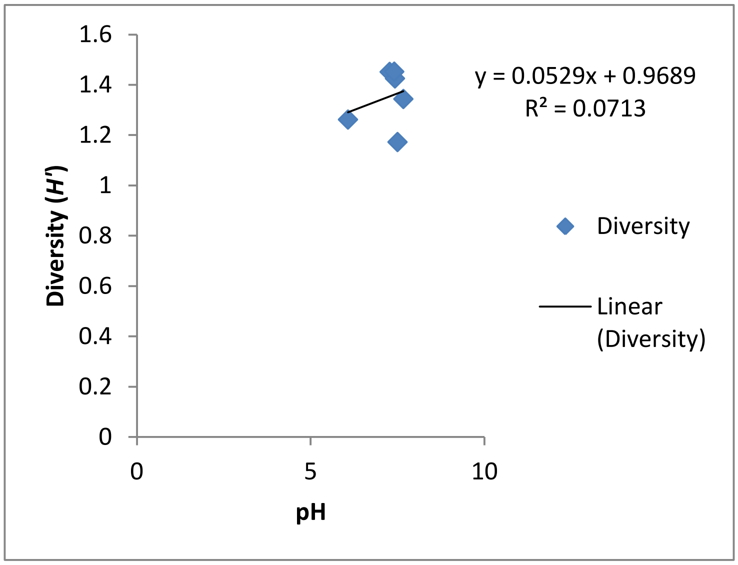

Figure 5: Relationship between pH and zooplankton species diversity

Figure 5 above indicate the line of best fit for zooplankton species diversity and pH with a low coefficient percentage variance; model (y= 0.9689 + 0.0529X). The regression model (y= 0.0529X + 0.9689) shows a linear correlation between diversity and ph.

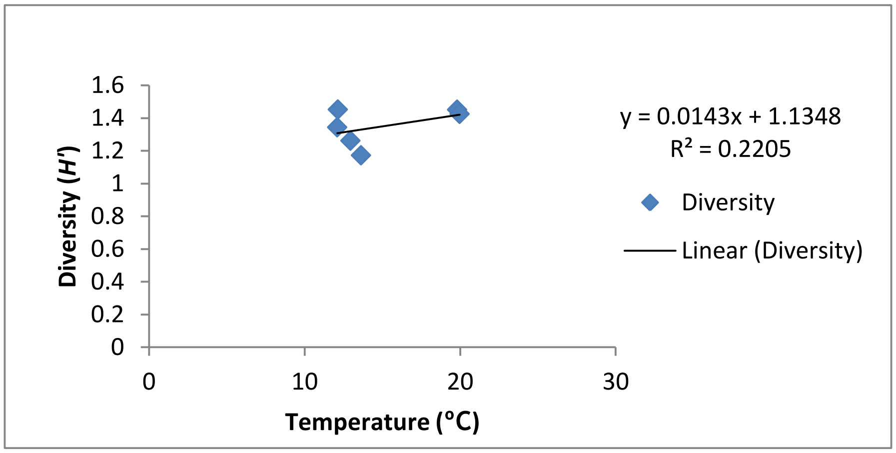

Figure 6: The Relationship between temperature and zooplankton species diversity

It is evident from figure 6 showing zooplankton species diversity and temperature with a line of best fit resulted in a low percentage coefficient variance (R^2=0.2205); model (y= 1.13231 + 0.0143X). The regression model (y= 0.0143X + 1.13231) shows a linear correlation between diversity and temperature.

3.3 Influence of environmental factors on zooplankton abundance

The result showed no significant relationship between environmental factors pH and nitrate (*d.f*=4; *F*=0.694; *p*>0.05) and (*d.f*=4; *F*=0.486; *p*>0.05) respectively. The result showed a significant relationship between environmental factors temperature and oxygen (*d.f*=4; *F*=0.006.; *p*<0.05) and (*d.f*=4; *F*=0.044; *p*<0.05) respectively, (figure: 7, 8, 9 and 10) and (appendix: 5, 6, 7, and 8).

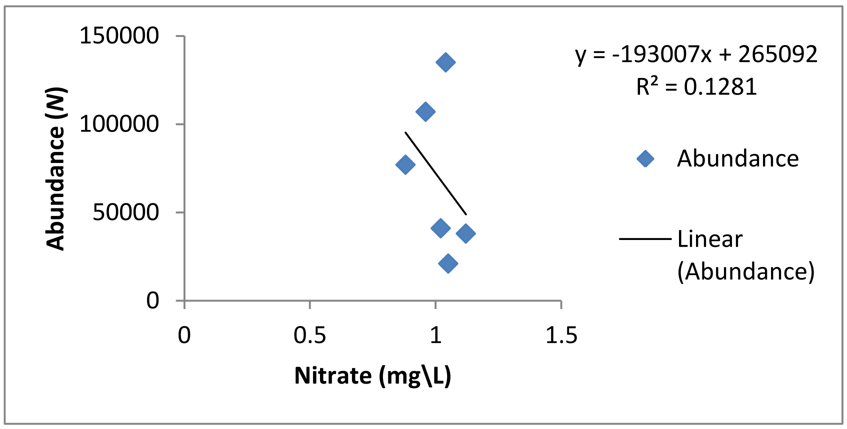

Figure 7: The Relationship between nitrate and zooplankton species abundance

Figure 7 above shows a low coefficient (R^2=0.1281) percentage variance for nitrate and zooplankton species abundance; model (y=265092 – 193007X). The regression model (y= -193007X + 265092) shows a non-linear correlation between abundance and nitrate.

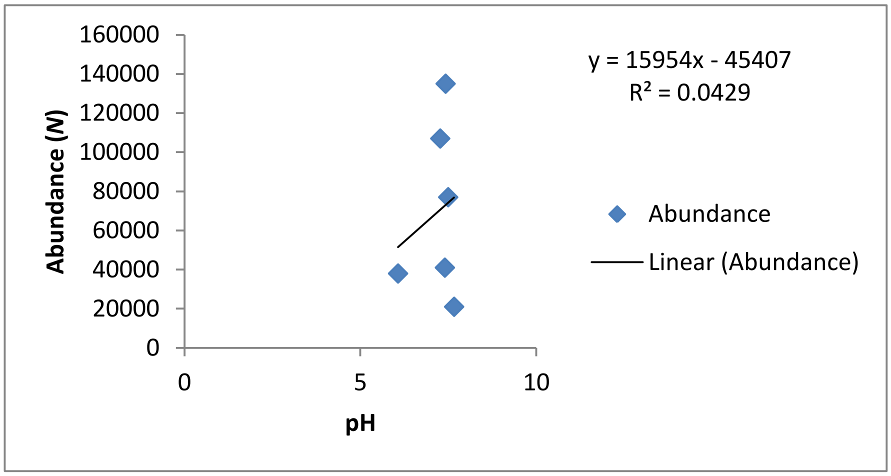

Figure 8: The Relationship between pH and zooplankton species abundance

Figure 8 depicts above the line of best fit for changes in pH with zooplankton abundance and a low coefficient percentage variance (R^2= 0.0429); model (y= -45407 + 15954X). The regression model (y= 15954X - 45407) shows a linear correlation between abundance and ph.

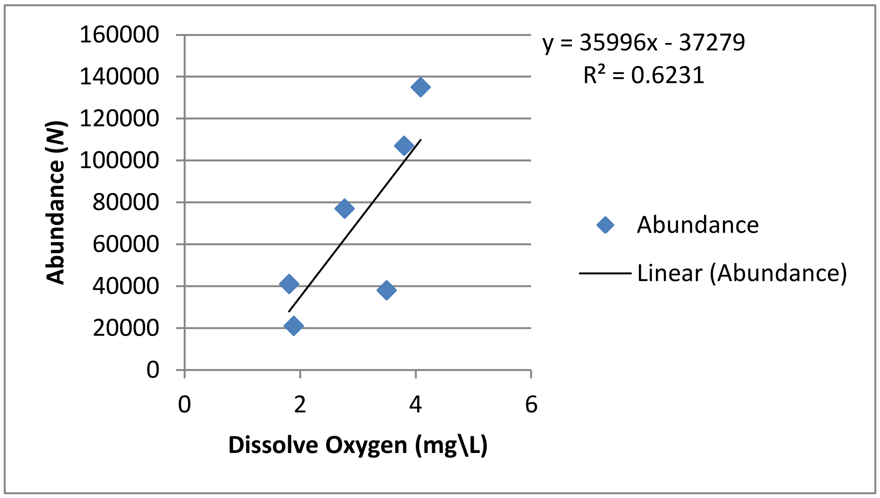

Figure 9: The relationship between dissolve oxygen and zooplankton species abundance

It is evident from figure 9 that zooplankton species abundance was changing with changes in dissolve oxygen. The line of best fit were fitting some data points linearly resulting in an above moderate coefficient (R^2=0.6231) percentage variance; moderate regression model (y= -37279 + 35996X). The regression model (y= 35996X - 37279) shows a positive linear correlation between abundance and dissolve oxygen.

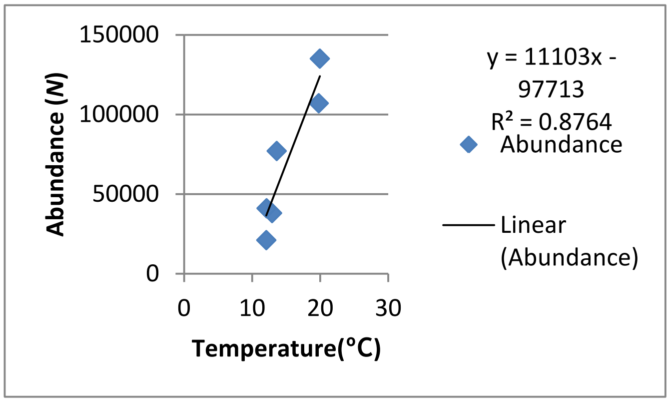

Figure 10: The relationship between temperature and zooplankton species abundance

As observed from figure 10 that zooplankton species abundance was changing with changes in temperature. The line of best fit were fitting some data points linearly and a high coefficient of percentage variance (R^2=0.8764) can be observed between temperature and zooplankton abundance, meaning an increase in temperature leads to an increase in abundance; model (y= -97713 + 11103X). The regression model (y= 11103X + 97713) shows a positive linear correlation between abundance and temperature.

3.5 Species diversity and abundance of phytoplankton species

A total of 7 phytoplankton species were investigated during the present study. No 'new' phytoplankton species were recorded during this study. The results show that there are non-significant differences in means of species diversity and abundance in zooplankton as observed at different sites (inlet, middle and outlet) within the dam.

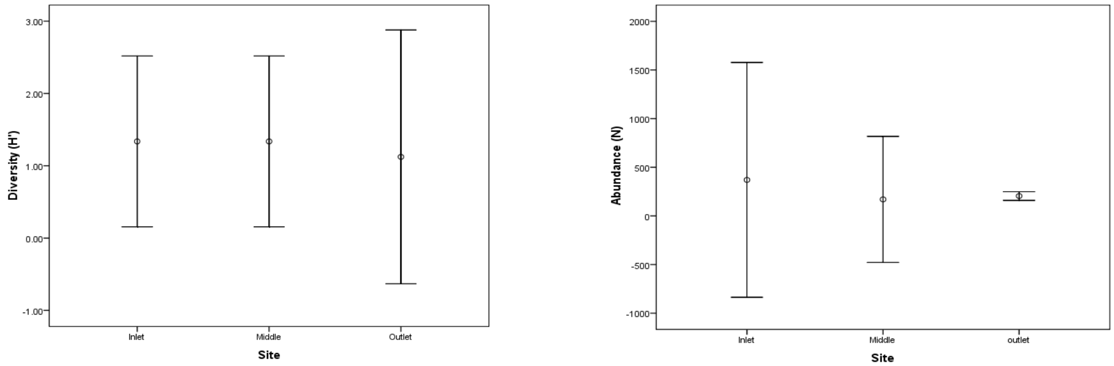

Figure 11: Comparison of means species diversity and abundance of phytoplankton at three sites in Hardap Dam. Error bars indicate 95% confidence interval of the mean.

Phytoplankton species diversity at inlet was *H*' = 0.90 whereas at middle and outlet sites were *H'* = 0.71 and 1.18 respectively. The comparison of means in phytoplankton species diversity and abundance indicated non-significant differences between sites with $d.f=2$; $F=0.156$; $p>0.05$ and $d.f=2$; $F=0.180$; $p>0.05$, respectively. The general trend observed in figure 11 indicates that the average species diversity was quite high at outlet and abundance inlet was highest relative to the other locations.

3.4 Influence of environmental factors on phytoplankton diversity

The result showed no significant relationship (d.f=4; F=0.300; p>0.05) between environmental factors (Temperature, oxygen, pH and nitrate) and phytoplankton species diversity table 2. The fitted and observed relationship yield a regression model; y= 1.000 + 0.3326X1 + 0.1018X2 + 0.0065X3 - 0.166X4 shows a non-significant linear relationship between nitrateX1, dissolved oxygenX2, temperatureX3 while non-linear for pHX4 between y (figure: 12, 13, 14 and 15).

Table 2: **Summary for Regression Analysis of Variance for phytoplankton species diversity**

Source of Variation	D.F	SS	MS	p-Value
Regression	4	0.158	0.0396	0.356
Residual	1	0.063	0.0630	
Total	5	0.221	0.0443	

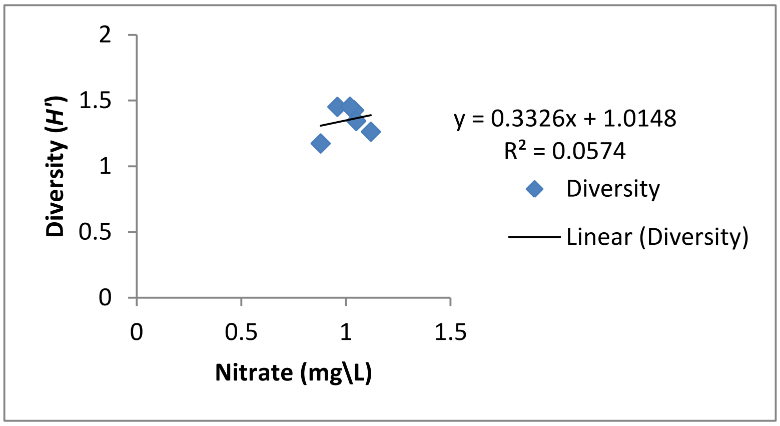

Figure 12: The relationship between nitrate and phytoplankton species diversity

Figure 12 demonstrate phytoplankton species diversity and nitrate with a line of best fit resulting a low percentage coefficient variance (R^2=0.0537); model (phytoplankton species diversity= 1.0148 + 0.3326 nitrate). The regression model y= 0.3326X + 1.0148 shows a linear correlation between diversity and nitrate.

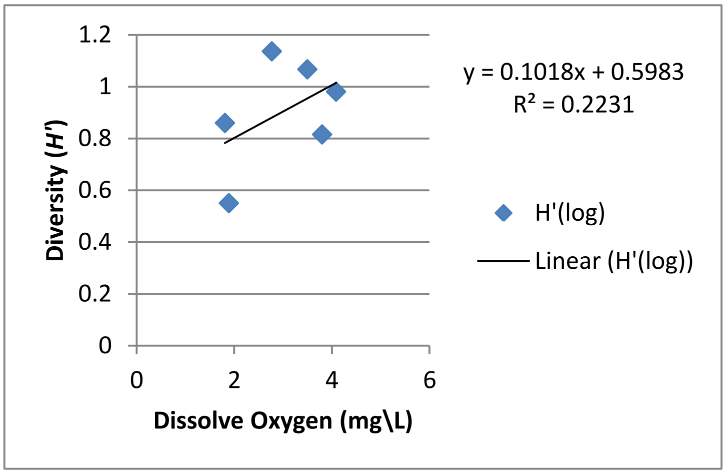

Figure 13: The relationship between dissolve oxygen and phytoplankton species diversity

The above figure 13 depict the line of best fit with a low coefficient percentage variance (R^2= 0.2231) for dissolve oxygen and phytoplankton species diversity; model (y= 0.5983 + 0.108X). The regression model y= 0.0108X + 0.5983 shows a linear correlation between diversity and dissolve oxygen.

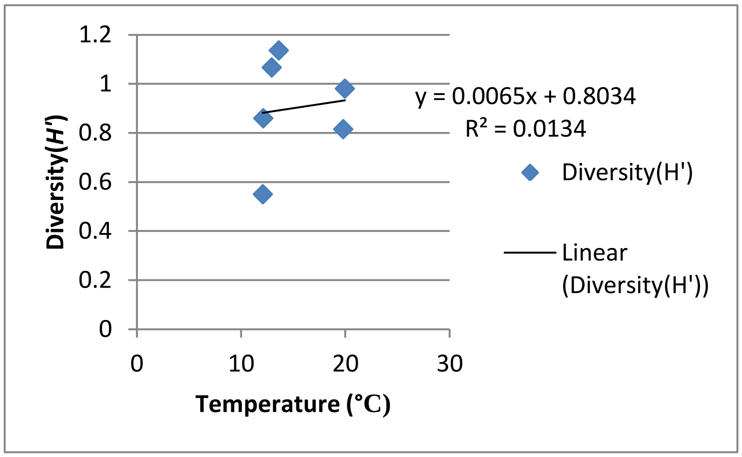

Figure 14: The relationship between temperature and phytoplankton species diversity

It is evident from figure 14 that a low coefficient percentage variance (R^2= 0.0134) observed with the line of best fit between temperature and phytoplankton species diversity; regression model (y=0.8034 + 0.0065X). The regression model (y= 0.0065X + 0.8034) shows a linear correlation between diversity and temperature.

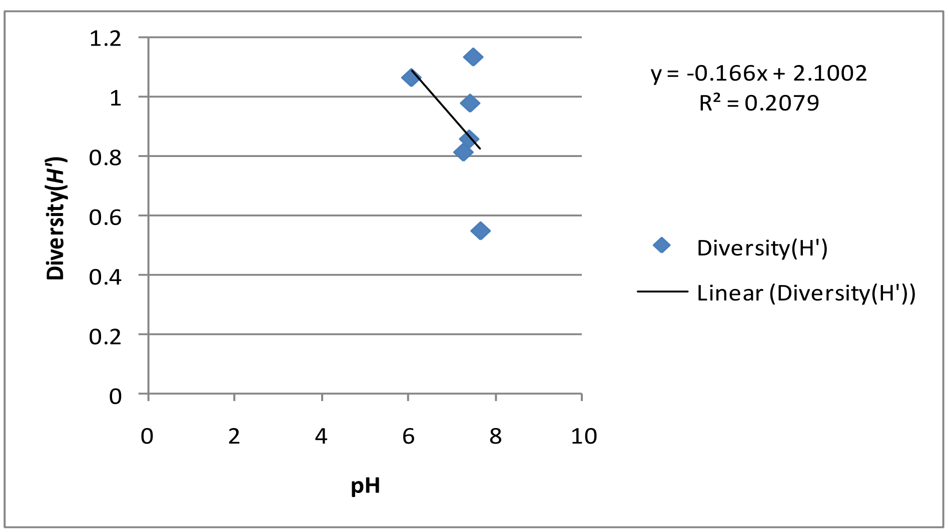

Figure 15: The relationship between pH and phytoplankton species diversity

Figure 15 show the line of best fit for phytoplankton species diversity and pH with low coefficient percentage variance (R^2= 0.2079); regression model (y=2.1002 - 0.166x) (phytoplankton species diversity= 2.1002 -0.166 pH). The regression model (y= -0.166X + 2.1002) shows a non-linear correlation between diversity and ph.

3.6 Influence of environmental factors on phytoplankton abundance

The result showed no significant relationship between environmental factors pH (*d.f*=4; *F*=0.346; *p*>0.05), nitrate (*d.f*=4; *F*=0.767; *p*>0.05), dissolve oxygen (*d.f*=4; *F*=0.288; *p*>0.05) and phytoplankton abundance. A significant relationship between environmental factor temperature (*d.f*=4; *F*=0.047.; *p*<0.05) and phytoplankton diversity, (figure: 16, 17, 18 and 19) and (appendix: 9, 10, 11 and 12).

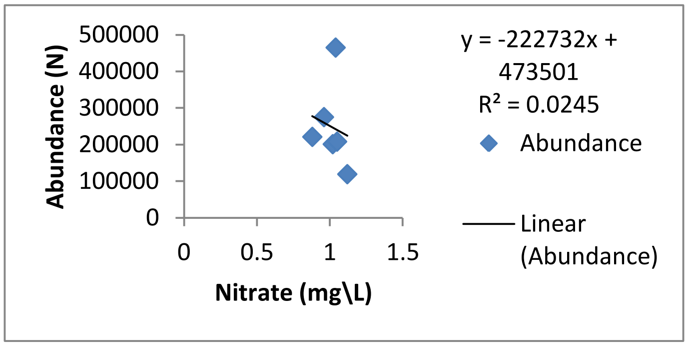

Figure 16: The relationship between nitrate and phytoplankton species abundance

Figure 16 clearly shows changes in nitrate with phytoplankton species abundance having a low coefficient percentage variance (R^2=0.0245); model (y= 473501 - 22732X). The regression model (y= -22732X + 473501) shows a non-linear correlation between abundance and nitrate.

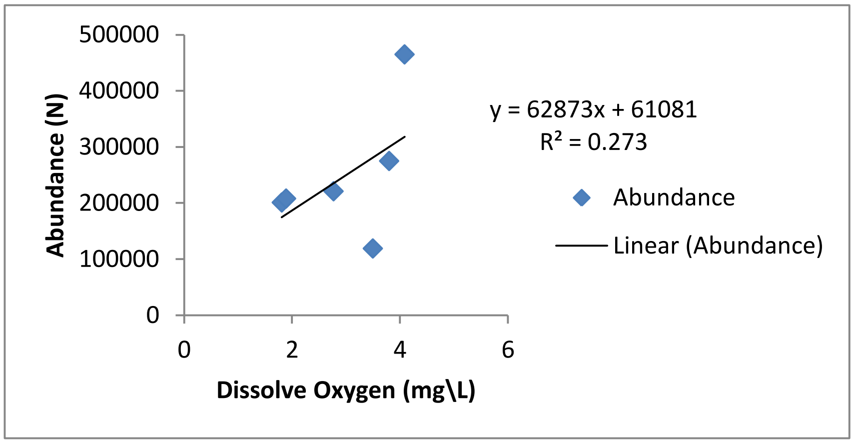

Figure 17: The relationship between dissolve oxygen and phytoplankton species diversity

As observed from figure 17 changes in dissolved oxygen and phytoplankton species abundance with a low coefficient percentage variance (R^2= 0.273) and line of best fit; model (y= 61081 +62873X). The regression model (y= -61081X + 62873) shows a non-linear correlation between abundance and dissolve oxygen.

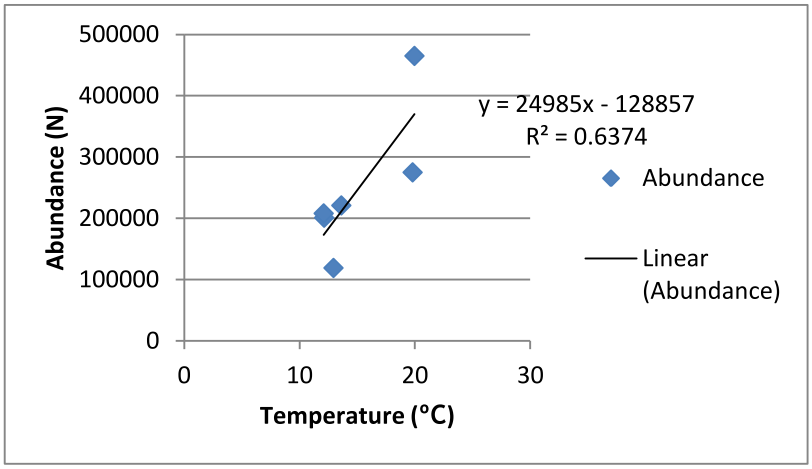

Figure 18: The relationship between temperature and phytoplankton species abundance

The above figure 18 shows as temperature increase phytoplankton abundance increase resulted in an above moderate coefficient percentage variance (R^2= 0.6374) and a line of beat fit; model (y= -128857 + 24985X). The regression model (y= 24985X - 128857) shows a positive linear correlation between abundance and temperature.

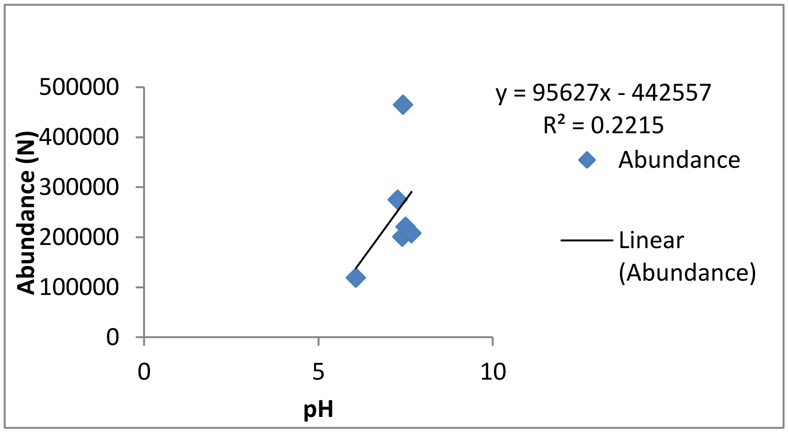

Figure 19: The relationship between pH and phytoplankton species abundance

Figure 19 displays a low coefficient percentage variance (R^2= 0.2215) between change in pH and phytoplankton species abundance; model (y= -0.442557 + 95627x). The regression model (y= 95627X – 0.442557) shows a linear correlation between abundance and ph.

CHAPTER FOUR

DISCUSION AND CONCLUSION

4.1 Diversity and Abundance of zooplankton species

This study was aimed to compare species diversity and abundance of zooplankton and phytoplankton between the three different sites (inlet, middle, and outlet) at Hardap Dam in Mariental district. Similarly, environmental parameters were also measured to assess their relationship with species diversity and abundance of planktons. At the different sites (inlet, middle and outlet) ROTIFERS, CLADOCERA and CYCLOPOID COPEPODS were identified. Different species of ROTIFERS (*Keratella valga, Brachinonus buda pestinensis, Brachinonus calyciff, Brachinonus caudatus, Synchaeta pectinata)* and CLADOCERA (*Diaphanasoma excisum)* and CYCLOPOID COPEPODS (*Cyclopoid nauplii*, *Cyclopoid copepodites)* were identified at all the three sites. The results of the comparison in zooplankton species diversity and abundance showed a non-significant difference between sites ($p > 0.05$).

The general trend observed in figure 2 showed that the average species diversity and abundance was quite high at the middle of the dam. The bird island located at the middle site might have contributed to high diversity and abundance of zooplankton; this is because of bird faeces in the water that can result in an increase of nutrients content leading to an increase in primary production. Furthermore, zooplankton communities respond to changes in water quality and availability of food thus these factors determine species diversity and abundance (Arimoro and

Oganah, 2010). In addition species richness in zooplankton was equal at both sites since 8 zooplankton species were identified at each site.

Most of the zooplankton species encountered in the dam appears to be normal inhabitants of natural lakes, ponds, streams and artificial impoundments in tropics and subtropics (Maruthanayagam *et al*., 2003; Ogbeibu, 1998; Ward, 1992). The abundance of rotifers species identified was the highest followed by the CYCLOPOID COPEPODS recorded at all the sites within the dam. The domination by rotifers might be due to their ability to undergo vertical migration, and parthenogenetic reproduction pattern and short development rates under favorable conditions in most fresh water systems (Arimoro and Oganah, 2010). *Synchaeta pectinata* was the most dominant species observed in all three sites. For the CYCLOPOID COPEPODS, *Cyclopoid Nauplii* was the dominant species observed. This might be due to the fact that cyclopoid copepod are small in size and relatively faster growth rates and variety of sensory capabilities which allow them to detect prey or predators from water flow around its body (Durbaum and Kunnemenn,1997) and this might contribute to the successful survival and its dominance.

4.2 Diversity and abundance of phytoplankton species

There are no-significant differences observed in the mean species diversity with sites (inlet, middle and outlet). Various species of phytoplankton observed in the dam at all sites are such as *Chlorella* species, *Closterium* species, *Volvox* species, *Carteria* species, *Cosmarium* species, *Pediastrum* species and *Sphaeropleates* species. The general trend that can be observed in figure 11 shows that the average species diversity and abundance was quite high at the outlet and inlet respectively. Phytoplankton species identified at the inlet was also present at the middle and outlet site, since environmental conditions such as temperature, oxygen, pH and nitrate was similar at all three sites. Furthermore no significant diversity can be as a result of weak inflow from river brining in species and different conditions into the dam. In addition species richness in phytoplankton was equal at all three sites. The *Sphaeropleates* species were the most dominant phytoplankton species at all of the three sites (inlet, middle and outlet) followed by the Carteria species. Reynolds (2002), explain that certain phytoplankton species tend to dominate a water body because of favorable conditions to them and while others phytoplankton species are not dominant because the same conditions are not suitable for them.

4.3 Environmental factors relationship with plankton diversity and abundance

The findings revealed non-significant relationship between the environmental parameters (i.e. nitrate, dissolve oxygen, temperature and pH) for plankton species diversity. However, a significant relationship was observed between zooplankton abundance with temperature and dissolve oxygen while for phytoplankton, a significant relationship was only with temperature. . The results clearly indicate that for both zooplankton and phytoplankton diversity a low coefficient percentage was observed in result. This implies that the models generated from diversity and environmental factors are not good enough since the coefficient measure the effectiveness of the model (Lampert, 2009). Thus, it can be concluded that changes in environmental parameters are not sufficient enough to account for changes in diversity.

The relationship of zooplankton abundance and temperature resulted in a very good model since the coefficient percentage variance was very high (R^2 =0.8764). Therefore, a change in temperature is sufficient enough to account for a change in zooplankton abundance. Schalau *et al., (*2008) stated that temperature of the water is one of the most dominant environmental factor driving inter annual variability and abundance of zooplankton population especially *Diaphanasoma species* population. Regulation of the seasonal variation of rotifers population has been attributed to both abiotic factors, including temperature, pH, dissolve oxygen (DO) and biotic factors such as food resource, competition, and predation (Dumont, 1977; Hofmann, 1977). Phytoplankton abundance relationship with temperature resulted a slightly above moderate coefficient percentage variance (R^2 =0.6374) means the model is not that good but it can be said that changes in temperature will result in changes of phytoplankton abundance. Jung *et al.*, (2009) conclude that on the ecology of freshwater phytoplankton in winter, the growth is reduced by cold temperature, low light intensity, and short day length meaning there exist a relationship between temperature and phytoplankton abundance

According to King, (1989) the oxygen level in the environment is important to organisms because it’s required for cellular respiration. Thus, the reduction in the level of dissolved oxygen in water may be critical for aquatic animals like zooplankton living in rivers, streams, lakes and even ponds. Such being the case, there should be a high percentage coefficient of variance be for dissolved oxygen with zooplankton species diversity and abundance. In addition, a significant linear relationship was observed and implies that as dissolve oxygen increase so does zooplankton abundance increase.

The pH of water in aquatic environments is a condition that can exert a powerful influence on the diversity and abundance of aquatic organisms (Begon *et al.*, 2006). They further argued that low or high pH may affects organisms directly by upsetting osmoregulation, enzyme activity and gaseous exchange across respiratory surfaces. However a low coefficient percentage variance (R^2=0.0425) and (R^2=0.0713) was observed with pH and zooplankton diversity and abundance respectively. Nitrate resulted in a low coefficient percentage variance (R^2=0.0574) with phytoplankton diversity and abundance. However Becker, (2007) suggested that due to high nitrate and phosphate levels or direct sunlight can result in a high growth for phytoplankton especially *Chlorella* species.

4.4 Conclusion

The aim of the study was to examine if there were significant differences in plankton diversity and abundance among the three sites and whether there is a significant linear relationship with environmental factor and plankton diversity and abundance. The results concluded that there was no significant difference in the mean plankton diversity and abundance since species richness in both zooplankton and phytoplankton was equal at both sites. At each site 8 zooplankton species and 7 phytoplankton species was identified. With regards to environmental parameters, no significant relationship with nitrate, temperature, oxygen, and pH with plankton diversity was observed. Furthermore since plankton diversity is more influenced by biotic factors, competition, food and predation than environmental factors. There was a significant relationship observed between plankton abundance with temperature and oxygen. Therefore conclude that any changes in temperature and dissolve oxygen will have an effect on plankton abundance resulting in an increase or decrease in the number of plankton species. However the result found cannot necessarily deduce the long-term biological events and processes of the dam. Since the study was done in a period of three months which is not sufficient for concluding the results.

4.5 Contribution to Knowledge

This study has impacted knowledge in the sense that the investigator has gained in depth understanding of conducting an independent research. Knowledge gained includes research design, data collection, analysis and interpretation. The skills of critic and synthesize other authors' work cannot be left without mentioned. Let alone this research can be used as a basis for establishing an inventory for zooplankton diversity in the two dams.

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APPENDICES

Appendix 1: Environmental Data Collection Sheet

Time	Month	Site	Depth	Water Parameters				
				Temperature (^oC)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
M	May	Inlet	0	19	2.66	7.555	1.2	1
M	May	Inlet	5	18.5	2.51	7.549	1.1	1
M	May	Inlet	10	18.9	2.47	6.08	1.25	1
M	May	middle	0	20.3	3.64	7.462	0.1	1
M	May	middle	5	20.3	3.29	7.468	0.6	1
M	May	middle	10	20.3	3.48	7.463	1.3	1
M	May	Outlet	0	21	4.04	7.397	1	1
M	May	Outlet	10	20.3	4.32	7.35	1.2	1
M	May	Outlet	20	19.9	7.80	7.12	0.9	1
A	May	Inlet	0	20.7	2.92	7.71	0.3	1
A	May	Inlet	5	18.4	2.21	7.625	1.0	1
A	May	Inlet	10	18.1	3.92	7.402	2.2	1
A	May	middle	0	20.7	4.04	7.394	1.1	1
A	May	middle	5	20.4	3.54	7.436	0.9	1

Time	Month	Site	Depth	Water Parameters				
				Temperature (^oC)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
A	May	middle	10	20.3	3.54	7.444	0.7	1
A	May	Outlet	0	20.7	4.08	7.403	1.8	1
A	May	Outlet	10	20.3	5.87	7.222	0.4	1
A	May	Outlet	20	20.1	6.65	7.186	1	1
M	June	Inlet	0	12	2.87	6.542	0.5	2
M	June	lnlet	2	13	2.83	6.555	2.8	2
M	June	lnlet	4	13	2.66	6.576	0.6	2
M	June	lnlet	6	13	2.38	6.602	0.5	2
M	June	lnlet	8	13	2.30	6.624	1.3	2
M	June	middle	0	14.0	3.33	6.386	1.6	2
M	June	middle	2	14.0	3.39	6.518	1.2	2
M	June	middle	4	13.0	2.54	6.598	2.3	2
M	June	middle	6	13.0	3.8	6.416	1.4	2
M	June	middle	8	13.0	3.97	6.403	1.0	2
M	June	middle	10	12.5	3.95	6.37	1.2	2
M	June	middle	12	12.5	2.89	6.501	1.4	2
M	June	Outlet	0	14	4094	6.254	0.5	2

Time	Month	Site	Depth	Water Parameters				
				Temperature (^{o}C)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
M	June	Outlet	2	13.5	8.7	5.000	0.2	2
M	June	Outlet	4	13.5	9.59	5.018	1.3	22
M	June	Outlet	6	13.5	7.38	5.082	0.2	2
M	June	Outlet	8	13.5	1.68	5.811	1.5	2
M	June	Outlet	10	12	3.13	5.599	0.9	2
M	June	Outlet	12	12	1.74	5.789	1.3	2
M	June	Outlet	14	12.5	2.1	5.727	1.3	2
M	June	Outlet	16	12.5	1.91	5.718	1.3	2
M	June	Outlet	18	12.5	1.63	5.787	1.3	2
M	June	Outlet	20	12	1.59	5.793	0.2	2
A	June	Inlet	0	14.9	2.94	7.89	0.9	2
A	June	Inlet	2	13.6	2.6	7.585	1.0	2
A	June	Inlet	4	13.1	2.76	7.519	1.2	2
A	June	Inlet	6	13.3	2.54	7.543	0.4	2
A	June	Inlet	8	13.2	6.71	5.184	1.6	2
A	June	middle	0	13.8	2.36	7.631	0.9	2
A	June	middle	2	13.7	4.8	7.276	1.0	2

Time	Month	Site	Depth	Water Parameters				
				Temperature (^oC)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
A	June	middle	4	13.6	2.23	7.651	0.7	2
A	June	middle	6	13.4	2.3	7.638	0.7	2
A	June	middle	8	13.2	2.46	7.545	0.6	2
A	June	middle	10	13.2	2.25	7.65	0.8	2
A	June	middle	12	13.2	2.32	7.634	0.9	2
A	June	Outlet	0	14.7	2.03	7.692	0.5	2
A	June	Outlet	2	14.7	2.14	7.694	1.1	2
A	June	Outlet	4	13.6	2.4	7.628	0.9	2
A	June	Outlet	6	13.6	2.49	7.608	1.2	2
A	June	Outlet	8	13.6	2.2	7.658	1.2	2
A	June	Outlet	10	13.6	2.49	7.606	0.2	2
A	June	Outlet	12	13.4	2.66	7.575	1.3	2
A	June	Outlet	14	13.4	2.33	7.569	0.6	2
A	June	Outlet	16	13.5	2.53	7.596	0.6	2
A	June	Outlet	18	13.4	2.49	7.591	1.4	2
A	June	Outlet	20	13.6	3.38	7.495	1.6	2
M	August	Inlet	0	12	3.63	7.44	1.2	3

Time	Month	Site	Depth	Water Parameters				
				Temperature (^oC)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
M	August	Inlet	2	12	5.61	7.251	0.8	3
M	August	Inlet	4	12	2.3	7.638	1.3	3
M	August	Inlet	6	12	2.28	7.642	0.1	3
M	August	Inlet	8	13	2.03	7.692	0.8	3
M	August	middle	0	11	3.07	6.758	1.1	3
M	August	middle	2	12	2.28	7.047	0.2	3
M	August	middle	4	12	1.20	7.021	2.8	3
M	August	middle	6	12	1.42	6.839	2.5	3
M	August	middle	8	12	1.80	7.054	0.2	3
M	August	middle	10	12	1.86	7.018	4.2	3
M	August	middle	12	13	1.75	7.064	1.0	3
M	August	Outlet	0	14	1.04	6.983	0.1	3
M	August	Outlet	2	13	1.05	6.979	0.6	3
M	August	Outlet	4	12	1.00	6.969	0	3
M	August	Outlet	6	12	1.06	6.956	0.6	3
M	August	Outlet	8	12	1.14	6.962	2.7	3
M	August	Outlet	10	12	1.12	6.938	2.1	3

Time	Month	Site	Depth	Water Parameters				
				Temperature (^oC)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
M	August	Outlet	12	12	1.16	6.917	0.5	3
M	August	Outlet	14	11	1.24	6.91	0.1	3
M	August	Outlet	16	12	1.31	6.868	0.2	3
M	August	Outlet	18	12	1.17	6.935	0.1	3
A	August	Outlet	20	12	1.00	7.015	0.4	3
A	August	Inlet	0	14	1.32	7.872	0.9	3
A	August	Inlet	2	12	2.01	7.704	0.1	3
A	August	Inlet	4	12	2.03	7.582	0.1	3
A	August	Inlet	6	12	2.14	7.687	1.2	3
A	August	Inlet	8	11	1.83	7.573	0.9	3
A	August	middle	0	14	1.86	7.719	1.8	3
A	August	middle	2	11	1.78	7.745	0.1	3
A	August	middle	4	12	2.1	7.719	2.2	3
A	August	middle	6	12	1.75	7.719	0.6	3
A	August	middle	8	11	1.90	7.718	0	3
A	August	middle	10	12	1.96	7.687	1.3	3
A	August	middle	12	12	1.99	7.705	0.2	3

Time	Month	Site	Depth	Water Parameters				
				Temperature (^{o}C)	Oxygen (mg/L)	pH	Nitrate (mg/L)	Replicate
A	August	Outlet	0	15	1.16	7.944	1.0	3
A	August	Outlet	2	12	1.85	7.728	1.6	3
A	August	Outlet	4	12	1.91	7.702	2.4	3
A	August	Outlet	6	12	1.80	7.764	0.3	3
A	August	Outlet	8	12	2.13	7.630	0.3	3
A	August	Outlet	10	12	1.81	7.740	0.1	3
A	August	Outlet	12	12	1.88	7.720	1.0	3
A	August	Outlet	14	11	2.12	7.673	0.0	3
A	August	Outlet	16	11	2.13	7.671	2.7	3

Appendix 2: Laboratory Data Collection Sheet for Zooplankton

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
5/11/2011	Inlet	1	0	*Cyclopoid copepodites*	9000	32000	0	41000	1.451
5/11/2011	Inlet	1	0	*Cyclopoid Nauplii*	16000	13000	0	29000	
5/11/2011	Inlet	1	0	*Keratella valGa*	1000	3000	0	4000	
5/11/2011	Inlet	1	0	*Brachinonus buda*	10000	1000	0	11000	
5/11/2011	Inlet	1	0	*Brachinonus calyciff*	4000	12000	0	16000	
5/11/2011	Inlet	1	0	*Brachinonus caudatus*	1000	0	0	1000	
5/11/2011	Inlet	1	2		0	0	0		
5/11/2011	Inlet	1	4		0	0	0		
5/11/2011	Inlet	1	6		0	0	0		
5/11/2011	Inlet	1	8		0	0	0		
5/11/2011	Middle	1	0	*Cyclopoid copepodites*	6000	5000	0	11000	
5/11/2011	Middle	1	0	*Keratella valGa*	0	7000	0	7000	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
5/11/2011	Middle	1	0	*Brachinonus buda*	0	0	0		
5/11/2011	Middle	1	0	*Brachinonus calyciff*	5000	6000	0	11000	
5/11/2011	Middle	1	0	*Brachinonus caudatus*	4000	0	0	4000	
5/11/2011	Middle	1	2		0	0	0		
5/11/2011	Middle	1	4		0	0	0		
5/11/2011	Middle	1	6		0	0	0		
5/11/2011	Middle	1	8		0	0	0		
5/11/2011	Middle	1	10		0	0	0		
5/11/2011	Middle	1	12		0	0	0		
5/11/2011	Outlet	1	0	*Cyclopoid copepodites*	6000	6000	0	12000	0
5/11/2011	Outlet	1	0	*Keratella valGa*	0	0	0	0	0
5/11/2011	Outlet	1	0	*Brachinonus buda*	4000	0	1000	5000	0
5/11/2011	Outlet	1	0	*Brachinonus calyciff*	0	1000	0	1000	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
5/11/2011	Outlet	1	0	*Brachinonus caudatus*	0	0	0	0	0
5/11/2011	Outlet	1	2		0	0	0		
5/11/2011	Outlet	1	4		0	0	0		
5/11/2011	Outlet	1	6		0	0	0		
5/11/2011	Outlet	1	8		0	0	0		
5/11/2011	Outlet	1	10		0	0	0		
5/11/2011	Outlet	1	12		0	0	0		
5/11/2011	Outlet	1	14		0	0	0		
5/11/2011	Outlet	1	16		0	0	0		
5/11/2011	Outlet	1	18		0	0	0		
5/11/2011	Outlet	1	20		0	0	0		
6/29/2011	Inlet	2	0	*Cyclopoid copepodites*	1000	7000	0	6000	1.425
6/29/2011	Inlet	2	0	*Cyclopoid Nauplii*	9000	3000	0	6000	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Inlet	2	0	*Keratella valGa*	2000	0	0	2000	
6/29/2011	Inlet	2	0	*Brachinonus buda*	0	0	0	0	
6/29/2011	Inlet	2	0	*Brachinonus calyciff*	0	0	0	0	
6/29/2011	Inlet	2	0	*Brachinonus caudatus*	0	0	0	0	
6/29/2011	Inlet	2	0	*Synchaeta pectinata*	1000	18000	0	19000	
6/29/2011	Inlet	2	2		0	0	0		
6/29/2011	Inlet	2	4		0	0	0		
6/29/2011	Inlet	2	6		0	0	0		
6/29/2011	Inlet	2	8		0	0	0		
6/29/2011	Middle	2	0	*Cyclopoid copepodites*	1000	1000	0	2000	0
6/29/2011	Middle	2	0	*Cyclopoid Nauplii*	2000	9000	0	11000	0
6/29/2011	Middle	2	0	*Keratella valGa*	0	0	0	0	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Middle	2	0	*Brachinonus buda*	0	0	0	0	0
6/29/2011	Middle	2	0	*Brachinonus calyciff*	0	0	0	0	0
6/29/2011	Middle	2	0	*Brachinonus caudatus*	0	0	0	0	0
6/29/2011	Middle	2	0	*Synchaeta pectinata*	2000	1000	0	3000	0
6/29/2011	Middle	2	2		0	0	0		
6/29/2011	Middle	2	4		0	0	0		
6/29/2011	Middle	2	6		0	0	0		
6/29/2011	Middle	2	8		0	0	0		
6/29/2011	Middle	2	10		0	0	0		
6/29/2011	Middle	2	12		0	0	0		
6/29/2011	Outlet	2	0	*Cyclopoid copepodites*	3000	5000	0	8000	
6/29/2011	Outlet	2	0	*Keratella valGa*	6000	0	0	6000	
6/29/2011	Outlet	2	0	*Brachinonus buda*	0	0	0	0	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Outlet	2	0	*Brachinonus calyciff*	0	0	0	0	
6/29/2011	Outlet	2	0	*Brachinonus caudatus*	0	0	0	0	
6/29/2011	Outlet	2	0	*Synchaeta pectinata*	39000	19000	0	58000	
6/29/2011	Outlet	2	2		0	0	0		
6/29/2011	Outlet	2	4		0	0	0		
6/29/2011	Outlet	2	6		0	0	0		
6/29/2011	Outlet	2	8		0	0	0		
6/29/2011	Outlet	2	10		0	0	0		
6/29/2011	Outlet	2	12		0	0	0		
6/29/2011	Outlet	2	14		0	0	0		
6/29/2011	Outlet	2	16		0	0	0		
6/29/2011	Outlet	2	18		0	0	0		
6/29/2011	Outlet	2	20		0	0	0		
8/6/2011	Inlet	3	0	*Cyclopoid copepodites*	5000	2000	0	7000	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Inlet	3	0	*Cyclopoid Nauplii*	4000	17000	0	21000	1.261
8/6/2011	Inlet	3	0	*Keratella valGa*	8000	5000	0	13000	
8/6/2011	Inlet	3	0	*Brachinonus buda*	0	0	0	0	
8/6/2011	Inlet	3	0	*Brachinonus calyciff*	0	0	0	0	
8/6/2011	Inlet	3	0	*Synchaeta pectinata*	25000	29000	6000	54000	
8/6/2011	Inlet	3	0	*Diaphanasoma excisum*	9000	0	0	9000	
8/6/2011	Inlet	3	2			0	0		
8/6/2011	Inlet	3	4			0	0		
8/6/2011	Inlet	3	6			0	0		
8/6/2011	Inlet	3	8			0	0		
8/6/2011	Middle	3	0	*Cyclopoid copepodites*	5000	5000	0	10000	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Middle	3	0	*Cyclopoid Nauplii*	2000	4000	0	6000	0
8/6/2011	Middle	3	0	*Keratella valGa*	2000	8000	0	10000	0
8/6/2011	Middle	3	0	*Brachinonus buda*	0	0	0	0	0
8/6/2011	Middle	3	0	*Brachinonus calyciff*	0	0	0	0	0
8/6/2011	Middle	3	0	*Synchaeta pectinata*	8000	25000	0	33000	0
8/6/2011	Middle	3	0	*Diaphanasoma excisum*	3000	9000	0	12000	0
8/6/2011	Middle	3	2		0	0	0		
8/6/2011	Middle	3	4		0	0	0		
8/6/2011	Middle	3	6		0	0	0		
8/6/2011	Middle	3	8		0	0	0		
8/6/2011	Middle	3	10		0	0	0		
8/6/2011	Middle	3	12		0	0	0		

Date	**Site**	**Replicate**	**Depth**	**Zooplankton**	**Subsample**			**N**	**H'**
					1	2	3		
8/6/2011	Outlet	3	0	*Cyclopoid copepodites*	4000	2000	0	6000	0
8/6/2011	Outlet	3	0	*Cyclopoid Nauplii*	8000	12000	0	20000	0
8/6/2011	Outlet	3	0	*Keratella valGa*	6000	5000	0	11000	0
8/6/2011	Outlet	3	0	*Brachinonus buda*	0	0	0	0	0
8/6/2011	Outlet	3	0	*Brachinonus calyciff*	0	0	0	0	0
8/6/2011	Outlet	3	0	*Synchaeta pectinata*	15000	10000	0	25000	0
8/6/2011	Outlet	3	0	*Diaphanasoma excisum*	3000	0	0	6000	0
8/6/2011	Outlet	3	2		0	0	0		
8/6/2011	Outlet	3	4		0	0	0		
8/6/2011	Outlet	3	6		0	0	0		
8/6/2011	Outlet	3	8		0	0	0		

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Outlet	3	10		0	0	0		
8/6/2011	Outlet	3	12		0	0	0		
8/6/2011	Outlet	3	14		0	0	0		
8/6/2011	Outlet	3	16		0	0	0		
8/6/2011	Outlet	3	18		0	0	0		
8/6/2011	Outlet	3	20		0	0	0		

Appendix 3: Laboratory Data Collection Sheet for Phytoplankton

Date	**Site**	**Replicate**	**Depth**	**Zooplankton**	**Subsample**			**N**	**H'**
					1	2	3		
5/11/2011	Inlet	1	0	*Chlorella sp,*	9000	32000	0	41000	1.451
5/11/2011	Inlet	1	0	*Closterium sp*	16000	13000	0	29000	
5/11/2011	Inlet	1	0	*Volvox sp*	1000	3000	0	4000	
5/11/2011	Inlet	1	0	*Carteria sp*	10000	1000	0	11000	
5/11/2011	Inlet	1	0	*Cosmarium sp*	4000	12000	0	16000	
5/11/2011	Inlet	1	0	*Pediastrum sp*	1000	0	0	1000	
				Sphaeropleates sp					
5/11/2011	Inlet	1	2		0	0	0		
5/11/2011	Inlet	1	4		0	0	0		
5/11/2011	Inlet	1	6		0	0	0		
5/11/2011	Inlet	1	8		0	0	0		
5/11/2011	Middle	1	0	*Chlorella sp,*	6000	5000	0	11000	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
5/11/2011	Middle	1	0	*Closterium sp*	5000	0	0	5000	
5/11/2011	Middle	1	0	*Volvox sp*	0	7000	0	7000	
5/11/2011	Middle	1	0	*Carteria sp*	0	0	0		
5/11/2011	Middle	1	0	*Cosmarium sp*	5000	6000	0	11000	
5/11/2011	Middle	1	0	*Pediastrum sp*	4000	0	0	4000	
5/11/2011	Middle	1	0	*Sphaeropleates sp*					
5/11/2011	Middle	1	2		0	0	0		
5/11/2011	Middle	1	4		0	0	0		
5/11/2011	Middle	1	6		0	0	0		
5/11/2011	Middle	1	8		0	0	0		
5/11/2011	Middle	1	10		0	0	0		
5/11/2011	Middle	1	12		0	0	0		
5/11/2011	Outlet	1	0	*Chlorella sp,*	6000	6000	0	12000	0
5/11/2011	Outlet	1	0	*Closterium sp*	10000	2000	0	12000	0
5/11/2011	Outlet	1	0	*Volvox sp*	0	0	0	0	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
5/11/2011	Outlet	1	0	*Carteria sp*	4000	0	1000	5000	0
5/11/2011	Outlet	1	0	*Cosmarium sp*	0	1000	0	1000	0
5/11/2011	Outlet	1	0	*Pediastrum sp*	0	0	0	0	0
5/11/2011	Outlet	1	0	*Sphaeropleates sp*					
5/11/2011	Outlet	1	2		0	0	0		
5/11/2011	Outlet	1	4		0	0	0		
5/11/2011	Outlet	1	6		0	0	0		
5/11/2011	Outlet	1	8		0	0	0		
5/11/2011	Outlet	1	10		0	0	0		
5/11/2011	Outlet	1	12		0	0	0		
5/11/2011	Outlet	1	14		0	0	0		
5/11/2011	Outlet	1	16		0	0	0		
5/11/2011	Outlet	1	18		0	0	0		
5/11/2011	Outlet	1	20		0	0	0		

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Inlet	2	0	*Chlorella sp,*	1000	7000	0	6000	1.425
6/29/2011	Inlet	2	0	*Closterium sp*	9000	3000	0	6000	
6/29/2011	Inlet	2	0	*Volvox sp*	2000	0	0	2000	
6/29/2011	Inlet	2	0	*Carteria sp*	0	0	0	0	
6/29/2011	Inlet	2	0	*Cosmarium sp*	0	0	0	0	
6/29/2011	Inlet	2	0	*Pediastrum sp*	0	0	0	0	
6/29/2011	Inlet	2	0	*Sphaeropleates sp*	1000	18000	0	19000	
6/29/2011	Inlet	2	2		0	0	0		
6/29/2011	Inlet	2	4		0	0	0		
6/29/2011	Inlet	2	6		0	0	0		
6/29/2011	Inlet	2	8		0	0	0		
6/29/2011	Middle	2	0	*Chlorella sp,*	1000	1000	0	2000	0
6/29/2011	Middle	2	0	*Closterium sp*	2000	9000	0	11000	0
6/29/2011	Middle	2	0	*Volvox sp*	0	0	0	0	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Middle	2	0	*Carteria sp*	0	0	0	0	0
6/29/2011	Middle	2	0	*Cosmarium sp*	0	0	0	0	0
6/29/2011	Middle	2	0	*Pediastrum sp*	0	0	0	0	0
6/29/2011	Middle	2	0	*Sphaeropleates sp*	2000	1000	0	3000	0
6/29/2011	Middle	2	2		0	0	0		
6/29/2011	Middle	2	4		0	0	0		
6/29/2011	Middle	2	6		0	0	0		
6/29/2011	Middle	2	8		0	0	0		
6/29/2011	Middle	2	10		0	0	0		
6/29/2011	Middle	2	12		0	0	0		
6/29/2011	Outlet	2	0	*Chlorella sp,*	3000	5000	0	8000	
6/29/2011	Outlet	2	0	*Closterium sp*	25000	15000	0	40000	
6/29/2011	Outlet	2	0	*Volvox sp*	6000	0	0	6000	
6/29/2011	Outlet	2	0	*Carteria sp*	0	0	0	0	
6/29/2011	Outlet	2	0	*Cosmarium sp*	0	0	0	0	

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
6/29/2011	Outlet	2	0	*Pediastrum sp*	0	0	0	0	
6/29/2011	Outlet	2	0	*Sphaeropleates sp*	39000	19000	0	58000	
6/29/2011	Outlet	2	2		0	0	0		
6/29/2011	Outlet	2	4		0	0	0		
6/29/2011	Outlet	2	6		0	0	0		
6/29/2011	Outlet	2	8		0	0	0		
6/29/2011	Outlet	2	10		0	0	0		
6/29/2011	Outlet	2	12		0	0	0		
6/29/2011	Outlet	2	14		0	0	0		
6/29/2011	Outlet	2	16		0	0	0		
6/29/2011	Outlet	2	18		0	0	0		
6/29/2011	Outlet	2	20		0	0	0		
8/6/2011	Inlet	3	0	*Chlorella sp,*	5000	2000	0	7000	
8/6/2011	Inlet	3	0	*Closterium sp*	4000	17000	0	21000	1.261

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Inlet	3	0	*Volvox sp*	8000	5000	0	13000	
8/6/2011	Inlet	3	0	*Carteria sp*	0	0	0	0	
8/6/2011	Inlet	3	0	*Cosmarium sp*	0	0	0	0	
8/6/2011	Inlet	3	0	*Pediastrum sp*	25000	29000	6000	54000	
8/6/2011	Inlet	3	0	*Sphaeropleates sp*	9000	0	0	9000	
8/6/2011	Inlet	3	2			0	0		
8/6/2011	Inlet	3	4			0	0		
8/6/2011	Inlet	3	6			0	0		
8/6/2011	Inlet	3	8			0	0		
8/6/2011	Middle	3	0	*Chlorella sp,*	5000	5000	0	10000	0
8/6/2011	Middle	3	0	*Closterium sp*	2000	4000	0	6000	0
8/6/2011	Middle	3	0	*Volvox sp*	2000	8000	0	10000	0
8/6/2011	Middle	3	0	*Carteria sp*	0	0	0	0	0
8/6/2011	Middle	3	0	*Cosmarium sp*	0	0	0	0	0
8/6/2011	Middle	3	0	*Pediastrum sp*	8000	25000	0	33000	0

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Middle	3	0	*Sphaeropleates sp*	3000	9000	0	12000	0
8/6/2011	Middle	3	2		0	0	0		
8/6/2011	Middle	3	4		0	0	0		
8/6/2011	Middle	3	6		0	0	0		
8/6/2011	Middle	3	8		0	0	0		
8/6/2011	Middle	3	10		0	0	0		
8/6/2011	Middle	3	12		0	0	0		
8/6/2011	Outlet	3	0	*Chlorella sp,*	4000	2000	0	6000	0
8/6/2011	Outlet	3	0	*Closterium sp*	8000	12000	0	20000	0
8/6/2011	Outlet	3	0	*Volvox sp*	6000	5000	0	11000	0
8/6/2011	Outlet	3	0	*Carteria sp*	0	0	0	0	0
8/6/2011	Outlet	3	0	*Cosmarium sp*	0	0	0	0	0
8/6/2011	Outlet	3	0	*Pediastrum sp*	15000	10000	0	25000	0
8/6/2011	Outlet	3	0	*Sphaeropleates sp*	3000	0	0	6000	0
8/6/2011	Outlet	3	2		0	0	0		

Date	Site	Replicate	Depth	Zooplankton	Subsample			N	H'
					1	2	3		
8/6/2011	Outlet	3	4		0	0	0		
8/6/2011	Outlet	3	6		0	0	0		
8/6/2011	Outlet	3	8		0	0	0		
8/6/2011	Outlet	3	10		0	0	0		
8/6/2011	Outlet	3	12		0	0	0		
8/6/2011	Outlet	3	14		0	0	0		
8/6/2011	Outlet	3	16		0	0	0		
8/6/2011	Outlet	3	18		0	0	0		
8/6/2011	Outlet	3	20		0	0	0		

Appendix 4: Samples in the laboratory and organisms identified

Plate 1: Samples in the Laboratory

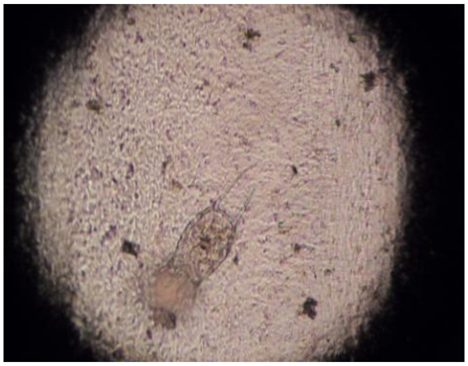

Plate 2: *Keratella valGa*

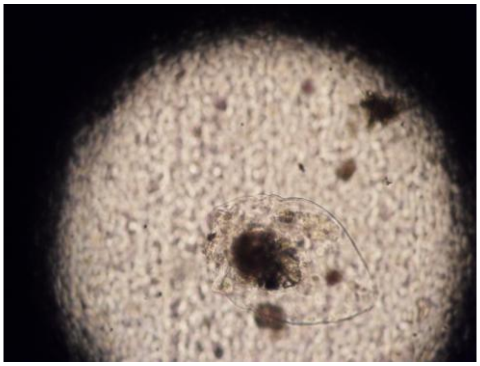

Plate 3: *Synchaeta pectinata*

Plate 4: *Cyclopoid copepodites*

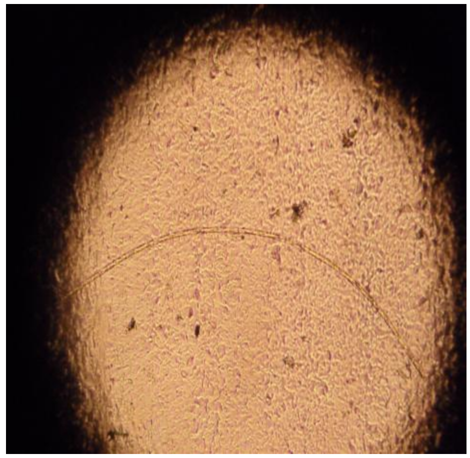

Plate 5: *Sphaeropleates sp*