THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Effects of Water Quality on Spatio-Temporal Diversity of Benthic Macro-Invertebrate Species along the Selected Shores of Lake Victoria, Homa-Bay County, Kenya

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Abstract:
Human-induced landscape alterations impact the ecological integrity of water resources by adversely affecting fresh water ecosystems, water-quality, habitat structure, flow regime, and biotic interactions. For instance fresh-water Lake Victoria continues to be affected by massive discharge of waste-waters and other pollutants from the surrounding basin which interfere with the ecological balance leading to adverse impact on benthic macro-invertebrates especially along the lake shores. The objective of this study was to investigate the effect of water quality on the diversity of benthic macro-invertebrates along the shores of Lake Victoria in Homa-Bay County, Kenya. Samples were taken at various beaches including Oluch Kimira River Mouth, Homa Bay Sewage discharge point and Mbita East of course way shoreline and examined for water quality parameters and the species diversity of benthic macro-invertebrates at monthly intervals between September 2019 and Feb 2020. The study was conducted during dry and wet seasons to help determine any changes in waste water discharges, water quality and benthic macro-invertebrates' characteristics. The results showed significant differences between various sites along the 3 different sites. During both wet and dry periods, Oluch Kimira and Homa Bay recorded low DO levels (4.0±0.46 to 6.2±0.19) MgL-1, while Mbita East of the course way throughout the period recorded DO level of (5.6±0.23 to 7.7±0.17) MgL-1. The mean concentration of Ammonia,NH4(μgL^{-1}) during the dry season was (6.32 ±.3.55 to 8.79±3.02) and during the wet season 12.16± 0.92 to 22.50 ± 0.52. The county government should implement the findings of this study, which provides baseline data for evaluating the trends in water quality and related changes in benthic-macro invertebrates biodiversity in Lake Victoria shorelines in Homa Bay County. The findings will also help in making policy decisions in order to support environmental protection in Lake Victoria.

Keywords: *Water quality, benthic macro-invertebrates, Lake Victoria shore, Homa Bay County*

1. Background Information

Globally, among the resources provided by nature, water is one of the most important and indispensable resource for life for human and other organisms. At the same time water is the backbone of growth and prosperity for mankind, (National Water Service Strategy- GOK, 2007). According to World Health Organization (WHO, 2012) the slogan water is life, underscores the importance of water in all aspects and spheres of life. World Health Organization (WHO, 2012) also affirmed the importance of water as essential necessity after oxygen. Anything that disturbs water provision and supply tends to disrupt the very survival of humanity and other living organisms. Water is a habitat for aquatic organisms and also supports terrestrial life. Benthic macro-invertebrates depend absolutely on water in various ways including habitat, breeding site and life support in general. Contamination and/or pollution of water not only interfere with human beings but also severely affect the aquatic lives. Degradation of water quality may come as a result of a number of factors such as farming, poor waste disposal, soil erosion, poor fishing methods among others. When water is contaminated, the lives of aquatic organisms are directly interfered with. The level of dissolved oxygen goes down, the water may become acidic, biological oxygen demand increases and these interfere with the normal body functioning of the aquatic biota including macro-invertebrates UNDP (2006).

Anthropogenic induced eutrophication continues to be a major threat to lake ecosystems, despite efforts to reduce nutrient inputs into lakes. Many fresh-water lakes still receive substantial inputs of phosphorus (P) and nitrogen (N) from urban and agricultural land use (Behrendt, 2006; Carpenter *et al*., 2007; Sanyanga and Hlanga, 2004) and atmospheric deposition (Vitousek*et al*., 2009). Regardless of the source, inputs of nutrients can substantially alter the ecological function of fresh water bodies such as lakes. According to Devon *et al*. (2015), it has been evidenced that increased nutrients, especially phosphorus, often result in increased pelagic primary production and algal blooms, which may inhibit the growth of submerged macrophytes and benthic primary production as was also asserted by Vadeboncoeur*et al*., Egertson*et al*., 2004 and 2003 and Chandra *et al*., 2005). Moreover, decomposition of algal biomasses may result in anoxic conditions in profundal habitats, adversely affecting community composition. Wibowo and Santoso (2017) revealed the strong relationship between Dissolved Oxygen (DO) concentration and the composition of profundal macro-invertebrate communities. In their view, dissolved oxygen concentration directly influences the well-being of profundal macro-invertebrate communities. They contended that at a lower concentration of DO, activities of these macro-invertebrates are impaired. This was also established by Langdon *et al*., (2006) who got inspired to classify the trophic status of lakes based on the previous studies.

According to Odinga (2015), aquatic organisms' structure and function normally reflect change with increased human influence and physical or chemical conditions. Mary and Macrina (2012) contended that aquatic organisms tend to be controlled mainly by temperature regimes, substratum types and hydraulic variables. In view of Ngodhe*et al*. (2014), a number of factors such as colonisation, stochastic processes of recruitment, dispersal, and local extinction majorly control the macro-invertebrate communities of wetlands and lake shores, particularly those in areas of variable climate. These factors affect the macro-invertebrates themselves and the macrophyte beds that provide much of their habitat. Ram and Deep (2013) also established temperature, turbidity, discharge and specific conductivity as the main physical factors that affect aquatic environments.

Renata*et al.* (2011) perceived temperature to be having the most significant influences effect on living aquatic resources. This is because it directly affects the organisms' physical, biological and chemical functions. According to Teferi*et al.* (2013), temperature's ecological significance is manifested on its influence on the structure of riverine communities. For example, through combined influences on dissolved oxygen and metabolic activity, temperature has critical effects on species' distributions (Rostgaard and Jacobsen, 2005) and density. Temperature and oxygen levels usually fluctuate seasonally and aid in the structuring of benthic communities, which varies from species to species (Shieh and Yang, 2000). Temperature influences primary production, decomposition and litter processing with consequences for stream energetics (Shieh and Yang, 2000).

The Lake Victoria is a major source of water supply for domestic and industrial purposes and supports a valuable fishery that supplies fish protein and cash five for the five East African partner states and the countries which lie along the Nile Basin and European Union countries e.g. Israel, Australia, U.S.A through Exports (Muli, 1996). The lake and its resources are crucial for the livelihood of the people living in Lake Victoria Basin and the benthic macro invertebrates e.g. insects, mollusks, oligochaetes and fresh water prawns.

Human population in Homa Bay County has been increasing over the years (HCDP 2013), and hence the increase in activities required to sustain it such as fishing, farming among other activities which have caused changes in various water quality parameters, increased pollution, enhanced nutrient load and water hyacinth *(Eichormiacrassipes*) invasion which may adversely lead to changes in characteristics of benthic-macro-invertebrates in numerous ways as well as increase in water related health problems e.g. cholera.

The interdependency between water quality and macro-invertebrates and other organisms in the lake's ecosystem is vital and anything that affects their ecological balance may impact on the entire lake ecosystem. Homa Bay County has the longest lake shore in Kenya with a wide range of human activities that could negatively impact on the various characteristics of benthic macro-invertebrates in various ways. There are limited studies that could reveal such negative impacts in this part of the lake. Even as rapid economic growth, urbanization and high population growth rate continues in this county and targets the use of lake's water resources, research on such impacts are still lagging behind and corresponding data on the impact of these trends on benthic macro-invertebrates is scarce. Therefore, this study considered investigating the effect of water quality on the diversity, abundance and distribution of benthic macro-invertebrates along the shores of Lake Victoria in Homa-Bay County, Kenya.

2. Materials and Method

2.1. Study Area and Location

The study was conducted in Homa-Bay County which lies between latitude 0°15' South and 0°52' South, and between longitudes 34° East and 35° East. The county covers an area of 4,267.1 Km^2 including water surface area of 1,227 km^2. The county is located in South Western Kenya along Lake Victoria (County Integrated Development Plan 2013-2017).

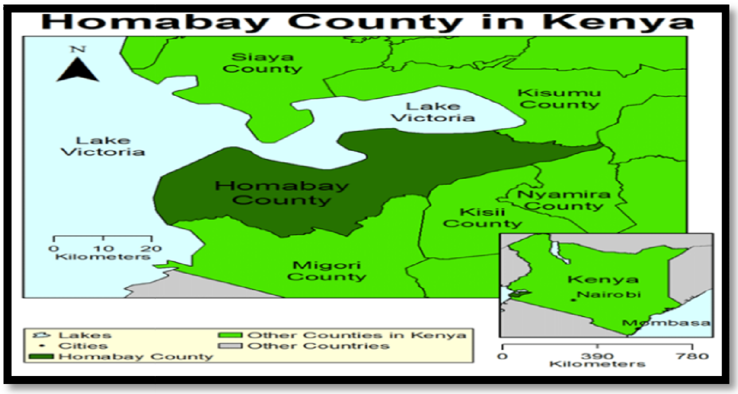

Figure 1: Map of Homa-Bay County in Kenyan Context

2.2. Experimental Sites and Sampling Technique

The study was conducted at three stations; Mbita East shoreline, Homa Bay Sewage discharge point and OluchKimira river Bay. The three micro-habitats were identified according to Jeffries and Mills (1990) as cited in Renet*aet al.* (2011). To avoid bias in spatial variations or patchiness, three samples were randomly collected from each of the three microhabitats as follows: a transect was established at each sampling reach in a station with four equally spaced points and a sampling location determined from the points using random numbers. This procedure was replicated three times for each micro-habitat (9 samples per reach). The replicate samples were identified and analysed separately for each station.

2.3. Data Collection Procedure

2.3.1. Macro-Invertebrate Sample Collection Procedure

The Macro invertebrates within the literal zones and macrophytes bed were scooped using D frame dip nets of 500μm mesh size with 0.4m diameter. A total of 20 jabs were taken at each habitat, resulting in sampling an area of approximately 3m^2. The macro-invertebrates were washed through a 300 μm mesh size sieve, hand sorted and preserved in 70 % alcohol in labelled vials. Ekman dredge grabber (a bottom sampling 3.5 litre device) was used in areas of deep water, or soft bottom sediments. The Ekman dredge (dimensions 152mmX152mmX152mm) scoops an area of 0.231m^2 per jab, and was used at a distance of 200 m from the Lake shore

2.3.2. Water Sample Collection Procedure

The water samples were collected at the sites of macro invertebrate sampling, and at the same time, at a depth of 10m below water surface level. Water samples were collected using Vandon water sampler, and transferred to high density polyethylene (HDPE) sample bottles. The samples were analysed using APHA, 1989 & Wetzel *et al* 1991 standard methods. The parameters analysed included: nutrients such as nitrite, nitrate, ammonium, silicate, SRP, total phosphorous, total nitrogen. Other physico- chemical parameters like total alkalinity and total hardness were determined titrimetrically using Standard method procedure and field in situ measurements taken using YSI meter

3. Results and Discussion

3.1. Benthos Macro-Invertebrate Species Diversity along Lake Victoria Shoreline

During the dry season in the months of September 2019 to November 2019, 14 macro-invertebrate species were identified along the Mbita East of the course way shoreline, 8 Species along Homabay sewage discharge point and 19 macro-invertebrate species along OluchKimira river mouth whereas 12, 14 and 8 species were identified inshore along Mbita, Homabay and OluchKimira respectively (Figure 2). The result indicates that the species richness of benthic macro-invertebrates increased along OluchKimira river mouth and Mbita East of the course way shoreline; however, the species richnessdeclined along Homabay sewage discharge point shoreline, compared to species diversity of benthic macro-invertebrate inshore at the same study sites. This result suggests that changes in water quality in terms of physico-chemical parameters and nutrients loads during the dry season in the months of September 2019 to November 2019 had positive influenceon species richness at the shoreline of Mbita and OluchKimira and negative influence on species richness at Homabay sewage discharge point shoreline. The decline in species richness along Homabay shoreline could be attributed to the relatively high average water temperatures and low dissolved oxygen concentration levels causing inhabitable ecosystem for survival of most benthic macro invertebrate species.

Some of the most common species identified alongMbita shoreline included *Spaniodoma, PaleomonetesPaladosus, Lethocerusamericanus, Hydropsyche and Cleon simile* with diversity indices of 1, 1, 1.03, 1.05, 1.02 and 0.95 while inshore*Uniopictorum, Rhogoveliaobesta* and *Baetis*sp each had a diversity index of 0.28, 0.28 and 0.11 respectively. In Homabay, the most common speciesobserved were *Anadondacygnae, Corixids*sp, *Polycentropus*sp and *Sphaerium*sp, each with a diversity index of 1 whereas *TubifexSphaeriid* and *Physasayi* had the least diversity index of 0.68 and 0.75 respectively. Yet, in OluchKimira river mouth, the species with the highest diversity index were *Chironomidae, Hirudidae* and *Caenidae*with diversity indices of 0.78, 0.75 and 0.64 respectively and the least in diversity was *Palemonidae* with a diversity index of 0.12. The presence of *Chironomidae*is bioindicative of polluted mesotrophic waters along

OluchKimirariver mouth shoreline (Patang, Soegianto&Hariyanto, 2018). Equally, availability of *TubifexHaryanto* was indicating that water quality along Homabay shoreline had low oxygen concentration and sewage sludge since they exhibit negative aerotaxis (Smith, 2001) and the low diversity of *Baetis*sp was a reflection that along Mbita East shoreline the waters had low levels of organic matter contamination.

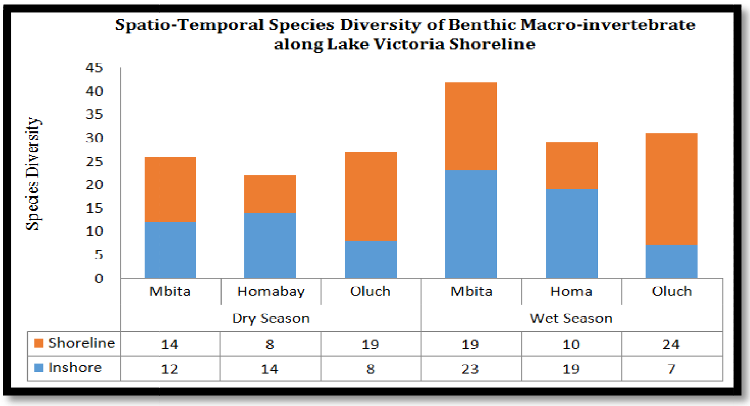

Figure 2: Spatio-Temporal Species Diversity for Benthic Macro-Invertebrates along Lake Victoria Shoreline

During the wet season in the months of December 2019 to February 2020, the study identified 19 macro-invertebrate species along Mbita East shoreline, 10 speciesalongHomabay shoreline at sewage discharge pointand 24 species at oluchKimira river mouth shoreline while 23, 19 and 7 species were identified inshore at Mbita, Homabay and OluchKimira respectively. The result shows that spatio-temporal species diversity increased along the shoreline at OluchKimira river mouth, however, declined along the shorelines at Mbita and Homabay sewage discharge point compared with the corresponding inshore statistics (Figure 2). Therefore, suggesting that changes in water quality parameter in terms of physico-chemical properties and nutrient loads had positive influence onspecies richness of benthic macro-invertebrate at the shoreline of OluchKimira river mouth and negative influence on species richness of benthic macro-invertebrate along Mbita East of the course way and Homabay sewage discharge point shorelines during the wet season. The species with the highest diversity indices in Mbita East were *Melanoidestuberculata, hydropsyche*sp, cleonsimile and Baetissp with diversity indices of 1.06, 0.99, 0.99, and 0.99 respectively and the species with the least diversity included *Sphaetium, Polycentropus, Physasayi* and *Agrionspledens* with diversity indices of 0.28, 0.38, 0.38 and 0.38 respectively. The level of dominance for most species was less than 0.5, indicating that the different species co-existed well. The study finds that there were more macro-invertebrate species at Mbita East of the course wayshoreline during the wet season as compared to the dry season, thus, suggesting that seasonal changes in water quality influenced positive growth in species diversity at the shoreline of Mbita. Along Homabay shoreline at sewage discharge point, the most common species were *Corixidssp, Lethorousamericanus, Spaniodomasp, Sphaeriumsp*and *Tubifextubifex* with diversity index of 1 each. *Physasayi* had the least diversity index of 0.65. *Corixidssp, Sphaeriumsp*and*spaniodoma* species were found during both seasons indicating that such species were tolerant to seasonal changes in water quality at the shoreline of Homabay. However, in OluchKimira river mouth shoreline, the species with the highest diversity were *Hydropsyche, Paleomonetespaladosus, Ranastra and CaenisMoesta* each with a diversity index of 1 and least in diversity were *Agrionsplendens*and*Polycentropus*sp each with a diversity index of 0.38. Some species e.g. *Baetis*sp, had low diversity during the dry season but disappeared totally during the wet season. Other species such as *Tubifextubifex* emerged during the wet season but were not found during the dry season.

3.2.Water Physico-Chemical Parameters along Lake Victoria Shoreline

To assess the Lake Victoria water quality;depth, transparency level, temperature, turbidity, total dissolved solids, conductivity, dissolved oxygen, ORP and PH were considered for analysis. The results are presented in Table 1.

Parameters	Mbita East		OluchKimira		Homa Bay		One way ANOVA Output
	Mean	SD	Mean	SD	Mean	SD	
Depth(m	1.76	.13	1.46	.24	1.59	.20	F(2,15) = 3.60, p= .053
Secchi(m)	1.12	.15	.25	.09	.44	.06	F(2,15) = 112.49, p= .000
Temp(◦C)	25.81	.45	24.78	.49	26.48	.50	F(2,15) = 19.11, p= .000
Turbid(FTU)	23.90	16.12	317.47	53.19	56.48	11.16	F(2,15) = 145.02, p= .000
TDS(mgL^{-1})	68.04	12.77	84.20	12.63	79.24	13.70	F(2,15) = 2.42, p= .123
Cond(μScm^{-1})	121.19	11.29	147.86	9.81	143.58	10.47	F(2,15) = 11.08, p= .001
DO(mgL^{-1})	6.76	.85	5.49	.80	5.09	.22	F(2,15) = 9.76, p= .002
ORP(mV)	-180.75	30.01	-170.49	29.05	-187.78	24.67	F(2,15) = .58, p= .573
PH	8.04	.45	7.92	.31	8.47	.47	F(2,15) = 2.99, p= .081

Table 1: Average Status of Water Physico-Chemical Parametersalong Lake Victoria Shoreline

From the Table 1, the results indicates that significant differences existed in the levels of secchi(water transparency), temperature, turbidity, conductivity, and dissolved oxygen along the shorelines of Mbita East of the course way, OluchKimira river mouth and Homabay sewage discharge point,with relative higher average levels of turbidity and conductivity at OluchKimira, higher average temperature at Homabay, and greater levels of transparency and dissolved oxygen at Mbita East of the course way shoreline.However**,** the results indicates that dissolved oxygen(DO) concentration along Mbita East shoreline was within the recommended concentration range of between (6.5- 8.0mgL-1) based on World Health Organization guidelines but lower at Oluch River Mouth and lowest along the shoreline at Homa Bay sewage discharge point. This was an indication of pollution and poor water quality at Homabay and OluchKimira shorelines

3.2.1.Status of Nutrients Load Parameters

The nutrients load evaluated included nitrates, nitrites, SRP, silica, ammonia, total nitrates and total nitrites. The results of analysis are presented in Table 2.

Parameters	**Mbita East**			**OluchKimira**			**Homa Bay**		**One way ANOVA Output**
	Mean	**SD**		**Mean**	**SD**		**Mean**	**SD**	
Nitrates(μgL^{-1})	4.83	1.17		39.83	12.83		13.67	3.14	$F(2,15)= 33.92, p= .000$
Nitrites(μgL^{-1})	2.67	.52		14.50	2.81		9.67	2.94	$F(2,15)= 37.85, p= .000$
SRP(μgL^{-1})	15.17	6.56		24.83	3.49		24.33	9.69	$F(2,15)= 3.58, p= .054$
$SiO_2(mgL^{-1})$	3.17	1.60		16.00	6.87		6.67	2.88	$F(2,15)= 3.65, p= .000$
$NH_4(\mu gL^{-1})$	3.67	1.21		21.67	5.47		13.17	5.19	$F(2,15)= 25.03, p= .000$
TN(μgL^{-1})	91.83	22.48		363.67	152.73		310.33	151.37	$F(2,15)= 7.99, p= .004$
TP(μgL^{-1})	107.67	56.96		266.67	29.62		194.67	56.54	$F(2,15)= 15.59, p= .000$

Table 2: Average Status of Nutrient Concentration

The results in Table 2 indicate that all the nutrients, except SRP varied significantly in concentration along the Lake Victoria shore study sites. The nutrient load parameter levels were highest in OluchKimira river mouth, followed by Homabay sewage discharge point and lowest along Mbita East of the course wayshoreline. Therefore, suggesting that pollution level was greatest along OluchKimira river mouth, followed by Homabay sewage discharge point and least along Mbita East shoreline.

4. Conclusion

The study concludes that seasonal changes in physico-chemical parameters and levels ofnutrients load concentration along the Lake Victoria shorelines of Mbita East of the course way, OluchKimira river mouth and Homabay sewage discharge point influenced spatio-temporal diversity of benthic macro invertebrate species. High nutrient concentration, turbidity and conductivity along OluchKimira river mouth had an impact on the diversity of pollution tolerant species of benthic macro invertebrateswhile greater levels of water transparency and dissolved oxygen concentrationalongMbita East had an impact on the diversity of pollution sensitive species of benthic macro invertebrates. At Homa bay, the low dissolved Oxygen concentration and high temperature influenced the species diversity.

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