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Engaging Riparian Communities in Near Real Time Bio-monitoring of Critical Micro-Catchments: A Case of Lake Bosomtwe, Ghana

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Abstract:
Although many studies have documented the use of macro invertebrates in aquatic biomonitoring, far fewer have explored the involvement of local communities in monitoring at Lake Bosomtwe. As an indirect yet relevant consequence, data availability remains a constant challenge in modeling spatio-temporal variability of water quality at Lake Bosomtwe and many other community water sources. This article therefore seeks to present the methodologies, lessons and best practices from the application of participatory GIS in monitoring water quality in near real-time scales. It assesses the water quality parameters that were used and the observed mean variations in point pollution levels around the lake. Multivariate techniques and nonlinear estimation models were combined to assess biological quality. This method allowed us to classify sites according to increasing levels of contamination, after the probabilities of occurrence of taxa along a gradient of contamination taking into account the reference condition. It was observed that distribution of macro invertebrates did not indicate a consistent variation or trend. However, the study showed a consistent relationship between the distribution of macro invertebrates and water temperature and air temperature. Also while Pouch snail showed high temporal consistency, its spatial distribution across the lake is quite poor. The distribution also indicates a R^2 value of 0.1798.The results suggest that the method used is sensitive to organic pollution, easy to interpret by ranking species according to their tolerance, and could be a good framework for monitoring near real-time water quality in lakes especially where there is a lack of relevant ecological information.

Keywords: *macro invertebrates, community participation, near real-time monitoring, water quality.*

1. Introduction

The availability of good quality water is a necessary feature for preventing diseases and improving quality of life [16]. Water is important for the development of every nation and access to clean water is important for human development [1, 11, 14]. Provision of safe, clean, accessible and affordable water is considered to be a fundamental human right [27]. Natural processes such as weathering and soil erosion as well as anthropogenic activities mainly affect the quality of freshwater. The anthropogenic activity represents a constant polluting source whereas surface runoff is a seasonal phenomenon, mainly affected by climatic conditions [24].Lakes have long been at the center of human attention, development of human communities and increase in irresponsible use of water resources has deteriorated river and lake water qualities [2, 21]. Increase in population and pollution caused by toxic waste water, surface runoffs from domestic and agricultural sources have increased pollution load and further limited healthy water resources [22] especially for stagnant water resources like Lake Bosomtwe in Ghana. The knowledge of point sources of pollution and pollutant in the region are prerequisite for appropriate use of water [22]. Lakes provide social and economic importance such as tourism, recreation and are culturally and aesthetically important for people all over the world. They also play an equally important role in flood control [3]. Lake and surface reservoirs are nature's most critical freshwater resources and have various uses. They are used for domestic purposes, irrigation purposes and serves as ecosystems for aquatic life. Therefore, monitoring the quality of such resources has a high priority for the determination of current conditions and long term trends for effective management. It is important to frequently monitor water quality used for various purposes. But it is often difficult to monitor surface water quality for various purposes such as drinking, recreation and irrigation at all times. Although many studies have documented the use of macro invertebrates in river and stream biomonitoring [19, 20, 21,30] far fewer have explored the involvement of local communities in water quality monitoring at Lake Bosomtwe. As an indirect yet relevant consequence, data availability remains a constant challenge in modelings patio-temporal variability of water quality at Lake Bosomtwe and many other community water sources.

Adequate data on is critical to understand biogeochemical cycles, hydrological cycles, and ecological cycles and for management purposes, policy formulation and implementation. Satellite remote sensing provides near real-time data with synoptic and repetitive coverage and thus, gives significant data on resources [11]. Remote Sensing, coupled with Geographic Information System (GIS) and Global Positioning System (GPS), provide the capabilities to assess water resource quality in a time and cost-effective way. It has an added advantage of assessing land cover/use in inaccessible areas [10].Several water management projects have focused on the application of these tools in monitoring both quality and quantity of lake water resources. However, not much study has been conducted in the area of engaging local communities and schools in the monitoring of lake resources. This article therefore seeks to present the methodologies, lessons and best practices from the application of participatory GIS in monitoring water quality at Lake Bosomtwe in near real-time scales. It assesses the water quality parameters that were used and the observed mean variations in point pollution levels around the lake.

2. Community Participation in Water Quality Monitoring

Water quality can be described in terms of physical, chemical and biological characteristics. Although biologists have been studying the effects of human activities on aquatic systems and organisms for decades, their findings have only relatively recently been translated into methods suitable for monitoring the quality of water bodies. Artificial (and in some cases natural) changes in the physical and chemical nature of freshwaters can produce diverse biological effects ranging from the severe (such as a total fish kill) to the subtle (for example changes in enzyme levels or sub-cellular components of organisms). Such imbalances could indicate that the ecosystem and its associated organisms are under stress or that the ecosystem has become unbalanced. As a result, there could be possible implications for the intended uses of the water and even possible risks to human health. In this direction, governments and development agencies[1] have established water monitoring initiative to develop national approaches to the monitoring of hydro-ecological health and integrity with a major focus being bioassessment procedures, using macro invertebrates, [23, 30]. Given the resources and effort devoted to development of such initiatives it is important to determine whether predictive modeling could be adapted to the level of local communities in the context of monitoring water quality of lakes in developing countries like Ghana.

Participation is often used in different disciplines and applied to many fields with many variations in meaning and interpretations [7]. In the context of development plans and programmes, participation can be defined as the process through which stakeholders influence and take part in decision making in the planning, implementation, monitoring and evaluation of programmes and projects [4]. Participation can be regarded as a process that empowers people and communities through acquiring skills, knowledge and experience, leading to greater self-reliance and self-management [6].Public participation is often used interchangeably with or alongside a number of other terms such as information sharing, consultation, involvement and empowerment. However, public participation is more commonly rooted in the concept of community development which is concerned with the creation of improved social and economic conditions through emphasis on voluntary cooperation and self-help efforts of the communities [12]. In watershed management, local communities are the primary stakeholders provisioned by their constant interaction with the environment, valuable knowledge and experience that makes them the best managers of the watersheds [17]. In this regard, the World health Organisation (WHO) protocol on Water and Health of 2006 encourages the involvement of all stakeholders i.e. professionals, scientific experts, the public at large, non-governmental organizations (NGOs) and local action groups in dealing with issues concerning water and health. It has been observed that given the chance, communities can participate effectively in matters relating to water resources management. Evidence from Gujarat (India) demonstrates the linkages between local community involvement in water project management and empowerment of stakeholders, especially imparting them with the capacity to negotiate with other stakeholders at higher levels concerning issues that affect their livelihood and lifestyle [4]. Despite the wide involvement of local communities in water services, local communities have rarely been considered as playing a role in monitoring water quality due to lack technical capacity. The UNESCO led project “Sustainable Management of Lake Bosomtwe in the Ashanti Region, Ghana” has established a broad framework for sustainable management and conservation of Lake Bosomtwe and how Friends of the Earth-Ghana introduced led the Capacity Building for lake monitoring and protection by involving 18 local communities. Given the broad focus of this study, the emphasis on the methodological approach adopted for this engagement is less prominent. As such, this study builds on that broader framework but details places emphasis on community engagement specifically in bio-monitoring. Whereas local communities often mobilize support for enhancing access to water resources, communities have not shown an equal capacity in terms of monitoring the quality of water resources. It was therefore considered prudent to test the applicability of predictive modeling using macro invertebrates to the monitoring and assessment of hydro-ecological health and integrity of the Lake Bosomtwe in Ghana.

3. Materials and Methods

3.1. Study area

Lake Bosomtwe is located 35 km southeast of Kumasi, the capital of the Ashanti region in central Ghana. Kumasi is at about 65°N, 150 km from the coast, and has an elevation of 310m [25,26]. Other nearby towns includes Konongo (elevation 233 m), 30 km to the northeast of the lake, and Bekwai (elevation 230m), and 20 km to the southwest. Lake Bosomtwe lies in an isolated closed basin

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[1]Abreu A. D. | Salinas A.H. | Clusener-Godt, M (2016). “Sustainable Management of Lake Bosomtwe in the Ashanti Region, Ghana. The United Nations Educational, Scientific and Cultural Organization, 7, place de Fontenoy, 75352 Paris 07 SP, France.

entirely surrounded by the Pra River basin, which has an area of 22500 km2 and has climate, vegetation, and bedrock similar to the lake basin (Figure. 1). The lake is the habitat for mainly macro invertebrates. The climate is characterized by a dry season between December and February, highest rainfall in June, and a cooler and drier period in August with smaller rainfall in October. Because the area of the watershed is small compared to that of the lake, 80% of the water that enters the lake annually is from rainwater on its surface which makes the water balance of the basin extremely sensitive to small changes in annual rainfall [25,26]. The average monthly temperature ranges from 23.2oC in August to 26.8oC in February, and average monthly humidity range from 84.7% in August to 75.3% in January.

3.2. Data Collection and Analysis

In their work on development of an index for assessing aquatic habitats at a variety of spatial scales and levels of perturbation, a large set of environmental variables (86) were used, including regional and local ones, reflecting the geo-morphological characteristics and human activities occurring in each basin as well as variables describing the riverine habitat. The collection of benthic invertebrates was made at each sample site. This study adopts a similar method [15, 16, 30] but focuses more on macro invertebrates as a measure of pollution levels from point to point. The technique developed in this study is based on a predictive model that allows the classification of the relative degree of disturbance of test sites in lotic systems, on the basis of a comparison of their faunistic composition with reference sites. Thirty –five (35) sites were selected and water samples tested by local communities. Figure 1 is an illustration of the selected sites for sampling.GIS information was used to define the reference sites in each ecotype. Afterwards, multivariate techniques and nonlinear estimation models were combined to assess biological quality. Multivariate analysis techniques applied to the physical and biological data sets allowed the determination of the relative importance of local and regional environmental descriptors responsible for the discrimination of the invertebrate assemblages. This method allows for the classification of sites according to levels of contamination. The results suggest that this method is sensitive to organic pollution, easy to interpret by ranking species according to their tolerance, and could be a good framework for monitoring near real-time water quality in lakes especially in where there is a lack of relevant ecological information.

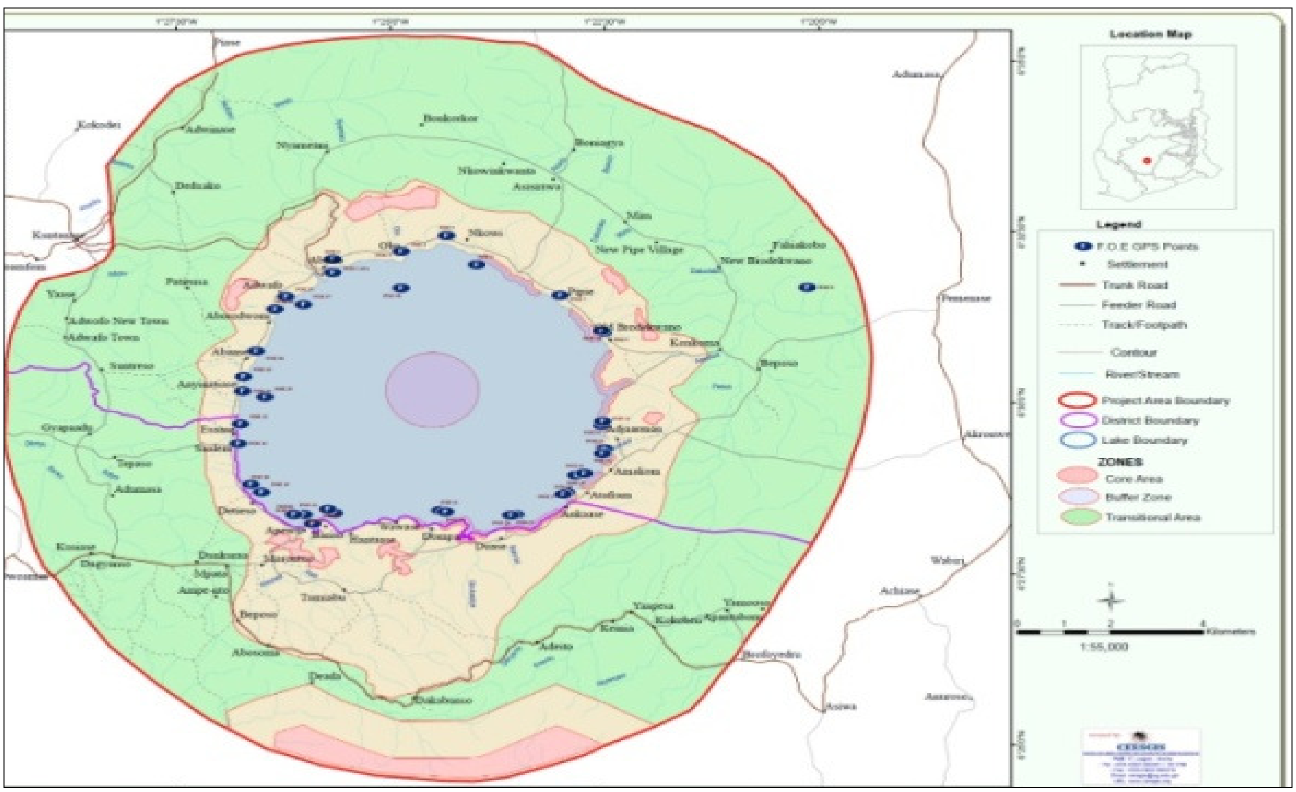

Figure 1: Geographic distribution of sample stations

4. Results and Discussions

The study used calculations of distribution of macro invertebrates as the base criteria for evaluating the water integrity (i.e. Sodium Absorption Ratio), which is the measure of pollution tolerance in closed water bodies. It was recorded that the mean distribution of macro invertebrates was quite diverse spatially and temporally. Table 1 indicates that Midge Larva had the highest presence (14.6) across the selected sample points while Crayfish recorded the lowest presence (0.09) (figure 2).

Key Parameters	Beetle larva	Midge larva	Aquatic worms	Pouch (and other snails)	Dragonfly nymph	Crayfish	Mayfly nymph	Stonefly nymph	Dobsonfly larvae	Caddisfly larva
Mean	.38	14.60	3.74	1.06	2.30	.09	3.10	.69	.80	1.76
Std. Error of Mean	.104	1.302	.521	.211	.278	.041	.455	.176	.252	.291
Minimum	0	0	0	0	0	0	0	0	0	0
Maximum	6	62	19	10	12	3	23	14	15	15

Table 1: Mean distribution of macro invertebrates across all selected points
Source: FoE-Ghana, 2014

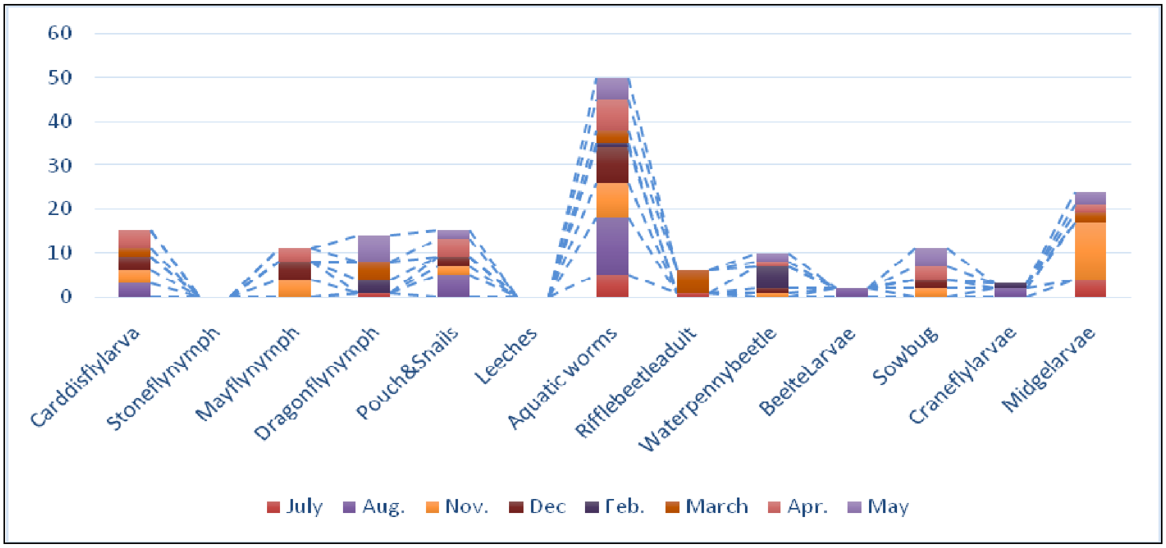

Figure 2: Annual average distribution of macro invertebrates at Lake Bosomtwe

The study observed that, the variation in abundance of invertebrates varies both by space and time or season. Figure 3 is a time series analysis of macro invertebrate abundance over a period of one year. It indicates that stonefly nymph and leeches are the least abundant invertebrates in an entire year. The highest abundant are aquatic worms, midgelarvae, carddisflylavae, dragon fly nymph and pouches and snails, in that order, are the most abundant in an entire year. In a time series analysis, the pattern of distribution of macro invertebrates was observed to vary significantly across a period of 29 months in 3 clusters (Figure 3.)

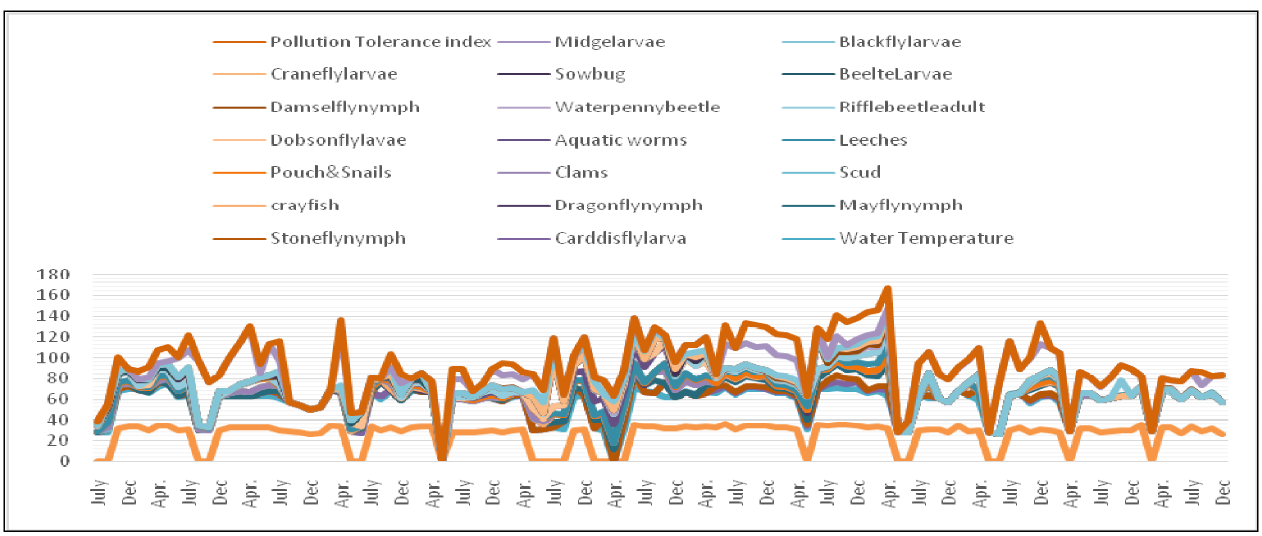

Figure 3: Moving average distribution of macro invertebrates across three sites at Lake Bosomtwe

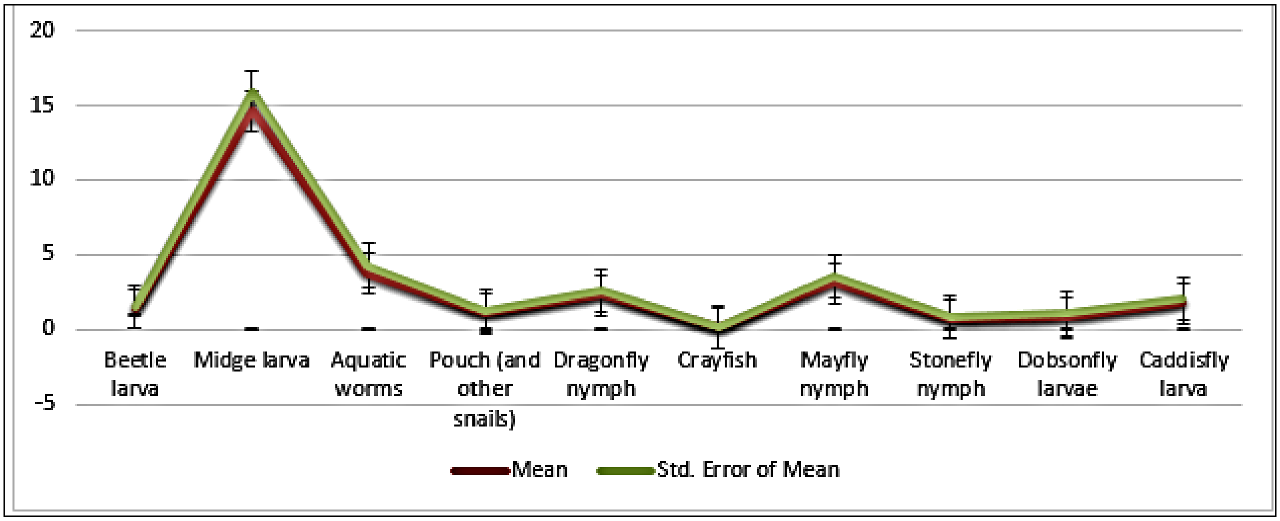

Figure 4: Mean abundance of macro invertebrates by pollution tolerance index

It was observed that distribution of macro invertebrates did not indicate a consistent variation or trend. However, the study showed a consistent relationship between the distribution of macro invertebrates and water temperature and air temperature (figure 4). The distribution of abundance also indicated significant spatial variations. The study observed the spatial distributions along the selected villages. Figure 5 shows a comparison of the spatial variations in abundance of three invertebrates across four selected communities around Lake Bosomtwe. At Duase, Pipie and Obuu communities, midgelarvae recorded the highest abundance. At Abono however, it was dragonfly nymph which recorded the highest abundance. In all the communities, it was observed that despite the variations in abundance of certain invertebrates, the abundance was also influenced by the water temperature at the given time.

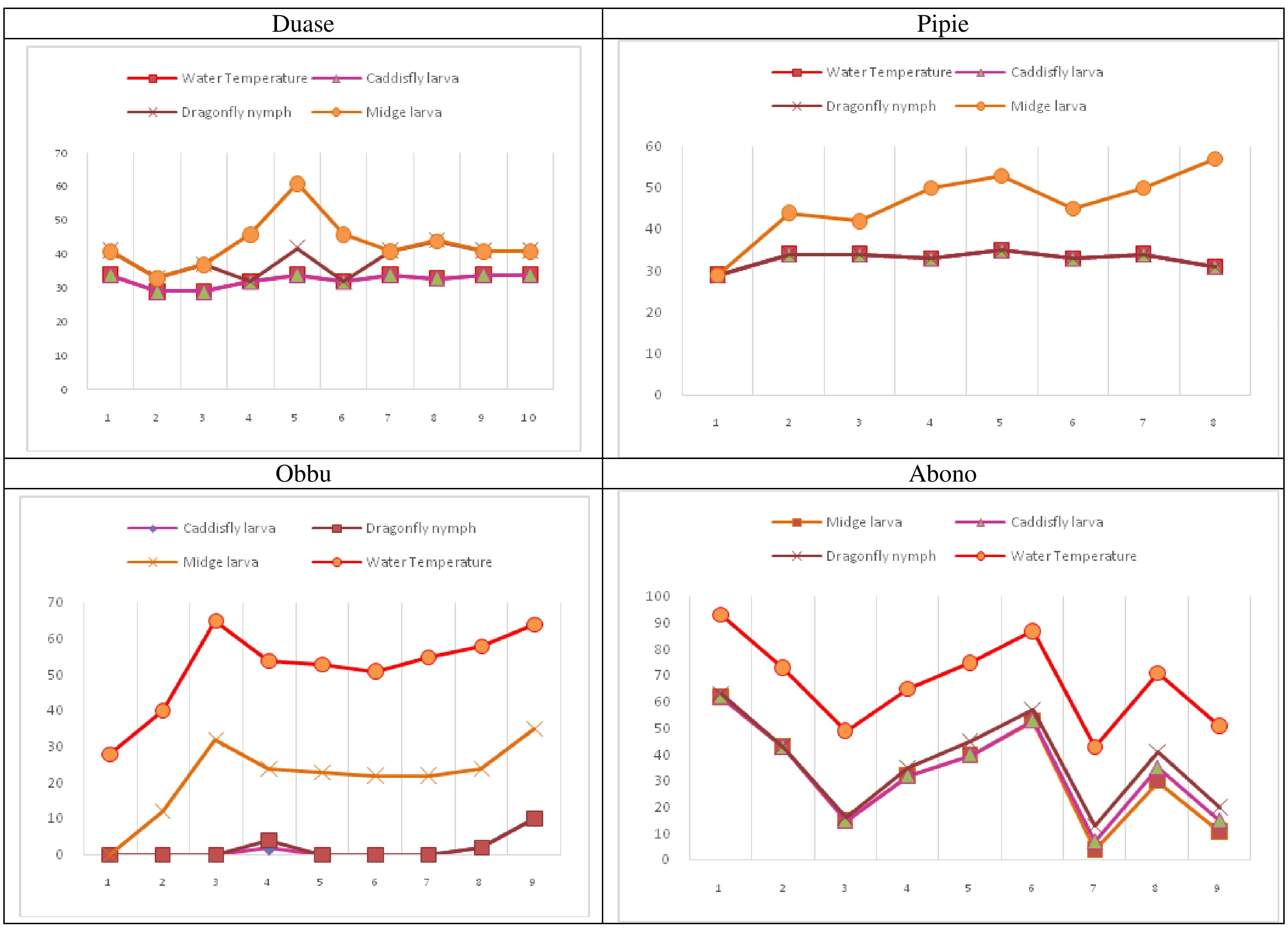

Figure 5: Mean abundance of macro invertebrates by pollution tolerance index

In terms of the distribution across various points, the study show that the Beetle larvae was most dominant in Abaase, aquatic worms and Midge Larva were most dominant in Abono, Anyinatease, and Pipie II (figure 4). Also while Pouch snail showed high temporal consistency, its spatial distribution across the lake is quite poor. These observations indicate that the variation of macro invertebrates is highly inconsistent. The variations is spatio-temporal distributions is a clear indication that terrestrial activities around the lake as well as climatic factors have a significant effect on the ecosystem integrity of the lake. These results are also an indication of the capacity of local communities to effectively capture and record scientific data in support of decision making with regard to water quality and ecological integrity.

Studies indicate that local changes in temperature and rainfall have significant effects in the distribution macro invertebrates. If has been observed that differences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes. These differences shape differential risks from climate change. Impacts of such climate-related events include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being [8]. Also, climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty. The IPCC indicates with medium confidence that currently, the worldwide burden of human ill-health from climate change is relatively small compared with effects of other stressors. However, there has been increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming [8]. Figure6 indicates the average rates of change in distribution (km per decade) for marine taxonomic groups based on observations over 1900–2010.

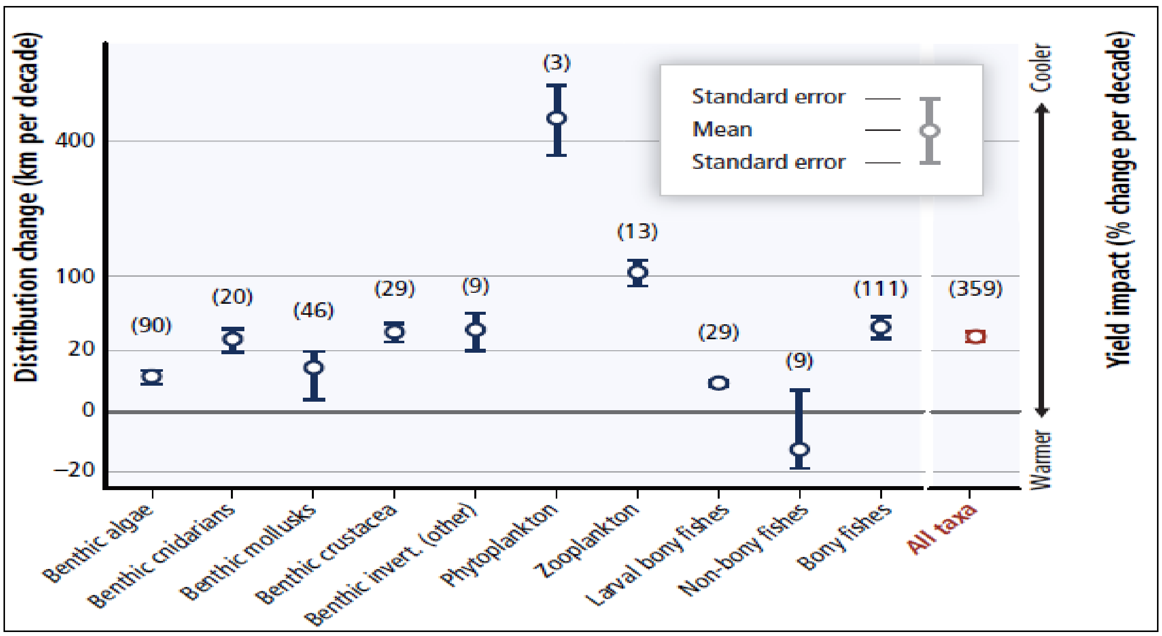

Figure 6: Average rates of change in distribution (km per decade) for marine taxonomic groups based on observations over 1900–2010. Positive distribution changes are consistent with warming (moving into previously cooler waters, generally poleward)
Source: IPCC, 2014

In other studies [18], results on salinity tolerances of selected macro-invertebrates linked mortality to increasing salinity and the nature of the salt used to elevate the salinity. Given the nature of socio-economic activities around Lake Bosomtwe, it is quite likely to associate the variability in macro invertebrates to the spatio-temporal variations in human activities. Sodium adsorption ratio is one of the key factors for measuring the suitability of water for irrigation, as determined by the concentrations of solids dissolved in the water. Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. The study therefore perceives that given the likelihood of high concentrations of SAR in Lake Bosomtwe, the riparian agricultural lands may require soil amendments to prevent long-term damage to the soil. It is quite certain that if irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilth. Despite this indication, the high temporal variations in macro invertebrate abundance concurs with The *South African Water Quality Guidelines for Aquatic Ecosystems* [5] which state that the rate of change in salt concentration, and the duration of change appear to be more important than absolute changes in concentration.

5. Conclusion

Water quality can be described in terms of physical, chemical and biological characteristics. Although biologists have been studying the effects of human activities on aquatic systems and organisms for decades, their findings have only relatively recently been translated into methods suitable for monitoring the quality of water bodies. One such findings that this study concurs is that elevated salt levels in surface waters are a significant problem, of national concern. The responses of biological communities such as macro invertebrates, can be monitored in a variety of ways to indicate effects on the ecosystem. Co-existence and abundance of certain species at particular locations or particular seasons can indicate whether that habitat has been adversely altered. Existing monitoring models however, do not adequately provide information for decision making. Furthermore, the potential of local communities in monitoring water quality is very relevant and needs to be explored. In furthering the community potential in water monitoring the potential of real-time monitoring can be realized, especially for lakes like the Bosomtwe. It is recommended that the real-time water quality monitoring be developed as an information gathering tool to fill the hydro-ecological decision making space.

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7. References

i. Amfo-Otu R, Agyenim J. B, Nimba-Bumah, G.B.: Correlation Analysis Of Groundwater Coloration From Mountainous Areas, Ghana(2014)
ii. Amfo-Otu R, Wiafe E. D., Kocke, B.B.: Assessment of Water Quality in Ahor Lake-Ghana. African Journal of Environmental Science and Technology Volume 5(12) Pp. 1093-1099 (2011)
iii. An Y.J, Kampbell D.H, Sewell G.W.: Water Quality At Five Marines In Lake Taxomas Related To Methyl Tert- Butyl Ether (Mtbe). Environ. Pollut, 118: 331-336 (2002)
iv. Dungumaro, Ew. And Nf. Madulu: Public Participation in Integrated Water Resources Management: The Case of Tanzania. Paper Presented At The 3rd Waternet/ Warfsa Symposium, ‘IntegratingWater Supply And Water Demands For Sustainable Use Of Water Resources’, Dar Es Salaam. 30-31 (2002)
v. Department of Water Affairs and Forestry (DWAF). South African Water Quality Guidelines. Vol1 to 6. Department of Water Affairs and Forestry, Pretoria (1996)
vi. Easterling D. R., Meehl G. A., Parmesan C., Changnon S A., Karl T. R., Mearns L. O. Climate Extremes: Observations, Modeling, and Impacts, American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC(2009)
vii. Heyd, H., Neef. A.: Participation of Local People in Water Management: Evidence from the Mae Sa Watershed, Northern, Thailand. Eptd Discussion Paper. Washington D.C.: International Food Policy Research (2004).
viii. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken,P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32 (2014)
ix. Kushwaha, S.P.S., Dadhwal, V.K.,Van Bloem, S.J.: Remote Sensing Of Tropical Ecosystems. Tropical Ecology, 51(1), Pp. 1 2 (2010)
x. Kushwaha, S.P.S., Mukhopadhyay, S., Hariprasad, V., Suresh Kumar: Sustainable Development Planning In Pathri Rao Sub-Watershed Using Geospatial Techniques. Current Science, 98(11), Pp. 1479-1486 (2010)
xi. Lillesand, T.M., Kiefer, R.W.:Remote Sensing and Image Interpretation (4th Edition). John Wiley And Sons, New (2000)
xii. Nikkhah, H.A.,Redzuan, M.: Participation as a Medium of Empowerment in Community Development. European Journal Of Social Sciences, 11(1), 170–176 (2009)
xiii. Okungu, J.:Water resources management in the Nyando basin: In Proceedings of a workshop on Reversing Environmental and Agricultural Decline in the Nyando river basin. ICRAF, Kisumu, Kenya (2002)
xiv. Oliveira, S. V., Cortes, R. M. V.: Combining Logistic Models With Multivariate Methods For The Rapid Biological Assessment Of Rivers Using Macro invertebrates. Environmental Monitoring and Assessment, 112: 93 113 (2006a)
xv. Oliveira, S. V., Cortes, R. M. V.: Searching Biological Metrics of Macro invertebrates for Biocriteria and Assessment. Submitted To Fisheries Management And Ecology (2006b)
xvi. Oluduro, A.O., Adewoye, B. I.: Efficiency of Moringaoleifera seed Extract On The Micro-Flora Of Surface And Ground Water J. Plant Sci. 6: 453-438 (2007)
xvii. Ong’or, D.O. et.al. Ed. Community conservation Initiatives: Towards livelihood security in the Lake Victoria Basin. Issues, problems and opportunities. A proceeding report (2001)
xviii. Palmer, C.G., Scherman,P.A.: Application of an Artificial Stream System to Investigate the Water Quality Tolerances of Indigenous, South African, Riverine Macro-Invertebrates. WRC Report No. 686/1/00. Water Research Commission, Pretoria (2000)
xix. Rosenberg, D. M. & V. H. Resh: Freshwater Biomonitoring and Benthic Macro invertebrates (1993)

xx. Rosenberg, D. M., T. B. Reynoldson & V. H. Resh: Establishing Reference Conditions in the Fraser River Catchment, British Columbia, Canada, Using the Beast (Benthic Assessment of Sediment) Predictive Model. In: Assessing The Biological Quality Of Fresh Waters: Rivpacs And Other Techniques. J. F. Wright, D. W. Sutcliffe & Schofield, N. J. & P. E. Davies. 1996. Measuring the Health of Our Rivers. Water (Australia), 23: 39-43 (2000)

xxi. Sanchez, E., Manuel F.: Use of the Water Quality Index and Dissolved Oxygen Deficit as Simple Indicators of Watersheds Pollution. Ecological Indicators, 7: 315–328 (2007)

xxii. Simeonov V, StratisJa, Samara C, Zachariadis G, Voutsa D, Anthemidis A, Sofoniou M, Kouimtzis Th: Assessment of the Surface Water Quality in Northern Greece. Water Res, 37: 4119–4124 (2003)

xxiii. Simpson, J. C. & R. H. Norris: Biological Assessment of River Quality: Development of Ausrivas Models and Outputs. In: Assessing The Biological Quality Of Fresh Waters: Rivpacs And Other Techniques. J. F. Wright, D. W. Sutcliffe & M. T. Furse (Eds.): 125-142. Freshwater Biological Association, Ambleside, Cumbria, U.K (2000)

xxiv. Singh KP, Malik A, Mohan D, Sinha S.: Multivariate Statistical Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality of Gomti River (India) - a Case Study. Water Research, 38 (18): 3980-3992 (2004)

xxv. Turner, B. F., Gardner L.R., & Sharp, W. E.: The hydrology of Lake Bosomtwe, a climate-sensitive lake in Ghana, West Africa. Journal of Hydrology 183: 243-261 ((1995)

xxvi. Turner, G F. Lake Malawi Habitats: Online http:// www. hull. ac. Uk /cichlids /malawi_habitats.htm (2004) Accessed November 11, 2010

xxvii. United Nations: Historic re-affirmation that rights to water and sanitation are legally binding, Amnesty International Press Release, 1 October (2010)

xxviii. Wright, J. F., B. Moss, P. D. Armitage & M. T. Furse: A Preliminary Classification Of Running-Water Sites In Great Britain Based On Macro invertebrate Species And The Prediction Of Community Type Using Environmental Data. Freshwat. Biol., 14: 221-256 (1984)

xxix. Wright, J. F., Furse, M. T. & P. D. Armitage: Use of Macro invertebrate Communities to Detect Environmental Stress in Running Waters. In: Water Quality and Stress Indicators in Marine and Freshwater Systems: Linking Levels of Organization. D. W. Sutcliffe (Ed.): 15-34. The Freshwater Biological Association, Ambleside (1994)

xxx. Wright, J. F., D. W. Sutcliffe & M. T. Furse (eds), 2000. Assessing the Biological Quality of Fresh Waters – RIVPACS and OtherTechniques. Freshwater Biological Association, Ambleside, Cumbria, U.K., 373 pp. (2000)