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An Application of Ephemeroptera, Plecoptera and Tricoptera (EPT) Index Method in Assessing Water Quality: A Case Study of River Kibisi, Mt. Elgon area, Kenya

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Abstract
Mt. Elgon region is one of the most cherished water towers in Kenya. However, rivers arising from this water catchment have been heavily impacted by pollution due the degradation of the catchment as a result of human encroachment. Poor water quality has in turn negatively impacted on human health due to an increase of waterborne diseases that have proved to be fatal. These rivers are the main sources of drinking water, other domestic uses and animal watering. Despite the health problems caused by use of contaminated river water in the region, fast methods for water quality assessment are lacking and untested. Therefore, this study aimed at testing the Ephemeroptera, Plecoptera and Tricoptera (EPT) method in the assessment of water quality status of River Kibisi in Mt. Elgon area. The EPT method is a quick and reliable water quality assessment method that has successfully been applied in many temperate countries including South Africa. Study sites were selected on the basis of pollution levels that included an impacted (mildly polluted) site at the edge of the forest, (moderately polluted) site in the upland agricultural area and heavily polluted site in the lowland urban area. At each site both physical (water temperature, turbidity, transparency and TSS) and chemical (pH, dissolved oxygen, conductivity and TDS) characteristics were measured in situ using standard methods prior to the sampling of the benthic macro-invertebrates. The collection of the benthic macro-invertebrates was done using the Hess sampler of area 0.0284 m^2 and a mesh size of 100µm. Benthic macro-invertebrates and were preserved in 4% formaldehyde and transferred to the laboratory in Kisumu (KEMFRI) where they were sorted, enumerated and identified out for the orders Ephemeroptera, Plecoptera and Tricoptera. Count data was used for the computation of the EPT Index. Results obtained showed that the three sampling sites differed significantly in water quality status based of the physical and chemical analysis with Temperature with a mean 15.3±0.46, 17.9±0.67, 19.7±055; Turbidity had a mean 78.0±27.1, 112.0±40.9, 182.0±39.2; TSS had a mean of 13.1±1.86, 26.0±6.82, 44.8±8.62; Transparency had a mean 0.6±0.10, 0.6±0.11, 0.23±0.05. Conductivity similarly differed significantly with mean 134.9±7.03, 157.0±10.76 and 166.0±12.69; pH measuring an average of 7.7±0.07, 7.7±0.10 and 7.2±1.16; other parameters showed a similar trends. DO had a mean 7.5±0.59, 6.9±0.54, 5.0±0.62; TDS had a mean 257.8±21.7, 291.8± 348.0±22.7. at the forested, agricultural and urban sites respectively. Analysis of the EPT index correlated closely with the physical and chemical parameters (r^2 = 0.3503; $p < 0.05$ for pH; and r^2 = -0.5398; $p < 0.05$ for conductivity). It was concluded that the EPT index method can be a useful tool in the assessment of water quality for tropical rivers.

1. Introduction

1.1 Background

The term water quality is applied universally to refer to the water status that meets the universal standards set for legitimate and vital water use at any scale i.e. local, regional and international levels (WHO, 2000). The evolution of the term water quality has been due to the expansion of water requirements and ability to measure and interpret water characteristics. The definition of water quality depends on the factors that determine it, and other variables that affect the nature of water resource. The introduction of harmful substances in river water (pollution) results in deterioration water quality standards (degradation), and this interferes with legitimate and vital water use at any scale i.e. local, regional and international levels (Meybeck *et al.*, 1989). However, water quality standards have been established for regulatory purposes and are determined based on the criteria involved depending on domestic, agricultural uses and aquatic life systems (WHO, 2004).

River water quality status is generally affected by many physical, chemical and biological parameters introduced by natural forces and human (anthropogenic) activities. Water quality criteria, standards and related legislation are often used as the main administrative means to manage water quality status in order to achieve user requirements. Water quality standards for surface water vary significantly due to different environmental conditions, ecosystems and intended human uses. Different uses of water raises different concerns and therefore different standards must be considered. The most common national requirements for drinking water of suitable quality for many countries are based on the standards of the World Health Organization guidelines for drinking water (WHO, 1993).

Water quality is an important factor influencing the distribution and abundance of stream fauna and flora.

Species richness is the number of different species represented in an ecological community and species composition is the relative abundance of different species in a region. High water quality streams have the greatest species composition, richness and diversity. Many of the aquatic insects are intolerant to pollutants and they are hardly found in polluted waters. The greater the pollution, the lower the species richness expected because only a few species are able to tolerate such conditions. Highly polluted rivers have less oxygen content, and the absence of this gas inhibits the survival of aquatic biota. Land use has always had an effect on water quality and aquatic biota (Lenat and Crawford, 1994).

Traditionally water quality had always been determined by measuring the quantity of chemicals dissolved in it. There is a lot of subjectivity to data interpretation when traditional methods are applied in quality water assessment. Sometimes results obtained when these methods are applied in the assessment of water quality are unreliable, not precise and fallacious (SWRP, 1996). In addition, the traditional methods of water quality assessment are not cost efficient and are time wasting. Another setback about these traditional methods is that they are never used in measuring the ecological integrity of an ecosystem. These methods have minimal use in the world of modern scientific river water quality assessment because they have been overtaken by events (Teferell and Perfetti, 1996).

Biotic metrics (biological methods) which have long been embraced in the developed world in evaluating and monitoring water quality status are lagging in application in poor countries. Biotic metrics are nowadays used because aquatic organisms are very sensitive to presence of pollutants in the water (Teferell and Perfetti, 1996); and secondly, these organisms spend their whole or entire lives in water (Lenat, 1988). Other advantages are that biological metrics are easily applicable and the results obtained are reliable and precise (SWRP, 1996). Further, benthic assemblages i.e. chironomidae, odonata, crustaceans, worms, molluscs, coleoptera, porifera, fish, and sponges are good biological indicators because they are sensitive to disturbances, stress (both natural and human induced), have limited mobility, are highly exposed and integrate impacts over time. Their populations and life cycles are directly affected by human (anthropogenic) activities leading to impaired or un-balanced community.

The response of the aquatic insects to pollution gives an early warning to possible harm of the water resources. Because the benthic macro-invertebrates spend nearly the entire life in water or in aquatic systems, they show and indicate the effects of physical habitat alteration, point and non-point contaminants and cumulative pollutants over their life cycles. Fundamentally, benthic assemblages are sensitive to water quality status alteration; hence, they are justifiably the most frequently used biological parameters in monitoring water quality (Morse *et al.,* 2007).

Biotic indices are largely developed to measure the stresses and health of ecosystems. The advantage of the bio-monitoring of aquatic depends on the ability of biological communities to reflect not only the water quality status but also the overall ecological state of the entire ecosystem. Most of the biotic indices which are applied in the assessment of water quality of streams also measure the sensitivity of the macro-organisms and their responses to pollution (Lennat, 1988). Benthic macro-invertebrates are known to be useful in monitoring water quality status because they exhibit a relatively wide range of exposes to chemical and the physical water quality stress. In addition, these organisms have long life cycles which enable researchers examine impacts of stresses/contaminants on them. Different benthic macro-invertebrates have different habitat preferences and various levels of pollution tolerance (Plafkin *et al.,* 1989).

The EPT index is used to determine between site differences in water quality or watershed studies with a large number of sites. This method is applicable because benthic macro-invertebrates are sensitive to stress both which are natural and human induced. Their populations are directly affected by human (anthropogenic) activities leading to an impaired or an imbalanced community. Because these organisms spend their entire lives in water, they show the effects of physical habitat alterations that take place in the aquatic systems including point and non-point contaminants and cumulative pollutants over time (Lenat, 1988). It can be used for emergency sampling where it is desirable to rapidly assess the effects of spills and unusual discharges. It can also be used in areas that are naturally known to have a low EPT species richness (either inherent or human induced) or in areas where pollution tolerant groups are of interest. The EPT index can be used to monitor water quality status and prioritize resource management (Lenat, 1988).

It is also used because it is reliable, precise and it is applied in the establishing reference conditions; setting protection and restoration of goals; identifying disturbances; choosing control measures; evaluating the effectiveness of Biological Monitoring Program (BMP) improvement measures and monitoring watershed condition change in the all stages of the river. Undisturbed aquatic environments may support high populations of benthic macro-invertebrates which are important food sources for the aquatic organisms which are associated with unpolluted environmental conditions (Griffiths, 1998).

2. Objectives of the Study

2.1 Main Objective

To assess the water quality status of River Kibisi, Mt. Elgon area, using the EPT richness index method

2.2 Specific Objectives

- To evaluate the effectiveness of the EPT richness index in the assessment of the water quality status of River Kibisi in Mt. Elgon area
- To determine the effects of changes in river water quality on the river's benthic macro-invertebrates
- To compare the effectiveness of the EPT richness index and physico-chemical parameters for water quality assessment of River Kibisi

3. Literature review

3.1 Factors that affect distribution of benthic fauna

A multiplicity of factors regulate the occurrence and the distribution of stream dwelling benthic macro-invertebrates, most important being the current (velocity); temperature; altitude; season; total suspended solids; the substratum; and vegetation. Other factors which affect the occurrence of these benthic fauna include substrates; vegetation; pH; dissolved oxygen; availability of food; turbidity; transparency; total dissolved solutes; conductivity; competition; liability to droughts and floods (Reid, 1961; Hynes, 1970; Odum, 1973).

During base flows, benthic macro-invertebrates are assumed to select patches most suited to their hydraulic requirements. These patches may change as discharge declines and as near bed hydraulic regimes alter. Though due to light floods caused by heavy rains cause displacement of

the benthic macro-invertebrate assemblages downstream (hydrological disturbance), many of the biotic indicators display distinct velocity preferences and are influenced by turbulence regimes (Wetmore *et al.,* 1990; Jowett *et al.,* 1991; Horne *et al.,* 1992; Collier, 1993). Low flows /discharges are usually seasonal and a normal part of river's hydrograph while droughts result from less than normal precipitation for an extended period of time although the beginning of the drought period is hard to define (Humphries and Baldwin, 2003). Substrate is one of the most important factors in the micro-distribution of the macro-invertebrates in lotic systems (Tolkamp and Both, 1979). The relationship between the two is however, very complex. The sediment particle size is a principle determinant of the distribution of stream benthic fauna (Watson, 1978).

Various methods are used to determine the type of substrates that exist in the rivers or streams.

Gore (1978) had developed a surface profiler with a six-to-six matrix of steel rods on a 0.1 m^2 frame. The frame is levelled and the rods pushed gently down until an obstacle is reached, producing a map of substrate profile. Other approximate methods are (techniques) based on substrate size classification which include visual methods (Statzner, 1987).

Substrates that are found in streams are either inorganic or organic in nature. Bed materials of most streams consist primarily of inorganic particles which range from clays, silts to boulders and stream bedrock. Organic substrates (less than 1 mm.) serve as food materials rather than habitats for the benthic macro-invertebrates. Larger organic materials from some parts of the streams and submerged logs function as substrates rather than food for the benthic macro-invertebrates (Hynes, 1970). Large substrates trap fine detritus food materials while being transported in the water column. Substrate composition size decreases downstream with large stones and boulders found in mountain areas, and sandy bottoms in lowland rivers. Even "muddy" rivers have mainly sand and fine gravel in their substratum, and silts are found in backwards or during periods of greatly reduced flow (Hynes, 1970).

Each macro-invertebrate taxon occupies a certain niche according to its feeding group: for instance, some are shredders, while others are collectors-gatherers, scrapers, filterers or predators. Shredders prefer to feed on larger particles of organic matter such as leaves and twigs, and in the process they churn the materials into smaller organic matter which can then be fed upon by collectors and gatherers. Collectors feed on small organic particles that are found at the bottom of the river. Scrappers feed on diatoms and algae that are attached to the underwater surfaces. Filterers feed by straining small organic matter particles out of the water. Filterers have fanlike appendages on the insect's body or built externally by the insect to resemble little under water nets (http://www.Epa.govowowwtr/monitoring).

Predators feed on other macro-invertebrates. Stream impairment may be indicated when one or more feeding groups are missing from a river. In healthy streams all the feeding groups should be present. Generally, stoneflies are predators; mayflies are scrapers and collectors while caddis flies are collectors, scrappers or shredders (Hynes, 1970).

The ratio and the number of these macro-invertebrates change with the stream food resources and human impacts and hence, they can be used as a tool for assessing the ecological status of the biotic and water quality status. Mayflies and caddisflies prefer low current environments but the stoneflies prefer riffle parts of the stream and they live in crevices of the boulders, stones, rocks, cobbles and logs on whom they adhere. The selection of the substratum of a particular type is both common in both lotic and lentic water systems, and may be related to feeding requirements, but sometimes no reason for the choice of a micro-habitat is apparent (Macan, 1974; Tolkamp and Both, 1979).

Most of the causes of poor water quality arise from land based and human (anthropogenic) activities making the evaluation of the ecological status of rivers to represent trends in man's impacts on river systems. The deterioration of water quality represents the presence of stressors and its improvement represents progress towards attaining ecological integrity due to better management and conservation efforts. It is important that water quality should be maintained to the recommended levels of World Health Organization (WHO, 2006).

Almost every anthropogenic activity affects the biophysical environment in some way very often destroying the existing equilibrium or accelerating natural rates of change (Nadakavukaren, 1986). This has had profound effects on the ecology of the benthic macro-invertebrates, especially their diversity, spatial-temporal distribution, sizes and composition (Griffiths, 1998; Shivoga, 1999). There are several biological metrics which have long been embraced in other countries the world over especially in the developed countries. These biotic indicators are used in the assessment and water quality and ecological integrity of the environment. A biotic index is simply the scale for showing the quality of the water resource of the environment by measure or against the type of organisms present in it.

3.2 Methods of evaluating water quality of river systems

Lotic ecosystems are among the most important biological ecosystems on earth (Dudgeon *et al.,* 1996). However, these are the most threatened resources today in the world because of the irresponsible anthropogenic activities and un-relented increase in human populations. It is therefore a big priority to conserve rivers and water streams and to manage those that are already threatened with degradation to ensure their preservation and ecological integrity respectively.

There are many approaches of carrying out estimates of richness of individuals, similarity and diversity of a biotic community (Fausch *et al.,* 1990). The multi-metric approach which takes into account several metrics such as the structural, functional and compositional metrics of biota assemblages is useful in evaluation of water quality. Also of use is the Index of Biotic Integrity (IBI) (Karr *et al*., 1996). The River Invertebrate Prediction and the Classification System (RIVPACS) can also be used to assess water quality (Wright *et al*., 1993).

Another example is the multivariate approach is a measure of mathematical relationship among samples (e.g. the similarity in structure of two communities) for two or more variables (e.g. qualitative presence-absence of species or the quantitative abundance or biomass of species) are selected. Conceptually, this technique is good because it is dependent on sample size, ecologically sound, easy to understand, interpret and apply by aquatic water managers (Johnson, 2001). Though the multivariate approach has higher precision than the micrometric approach, it is more difficult method to understand, interpret and apply by aquatic resource managers and hence, it is less preferred.

3.3 Physico-chemical approaches

Water quality status is affected by many physico-chemical and biological parameters which are introduced naturally or by human (anthropogenic) activities into the river systems. However, benthic indices are most appropriate as they remove much of the subjectivity associated with data interpretation. They also account for habitat differences. These indices provide simple means of communicating complex information to managers, tracking trends over time and correlating benthic responses with stress (Ranasinghe, 2003).

This approach is based on the qualitative measurement of parameters derived from the abiotic components of the lotic environment. The parameters measured range from oxygen, temperature, pH, electrical conductivity, salinity, transparency, Biological Oxygen Demand (BOD) and mineral nutrients ranging from nitrates, phosphates and sulphates (Wetzel and Likens, 1991). The physico-chemical assessments are based on the comparison of the measurements made with the water quality criteria or with the standards derived from such criteria. These are founded on set national standards on water, sewage and other effluent discharges normally set by the Ministry in charge of the environment (Norris and Norris, 1995).

The physico-chemical techniques have the merit of being precise, discriminatory, and quantitative, and thus they are important for determining the type of chemicals pollutants present in a river and their concentrations (Tebbut, 1992). However, the technique of physico-chemical approach to assess water quality in all the water bodies the world over is rather expensive. This is because water samples would be required to achieve a health assessment to acceptable confidence standards (Woodiwiss, 1978).

Furthermore, the knowledge of chemical monitoring and the type of pollutants likely to be present in river water can be used as a pre-requisite for effective assessment (APHA, 1995). Increasing complexity of agro-chemical discharge as well as domestic discharge can prove to be very difficult to completely assess the quality of water in these rivers. When chemical discharge are irregular in nature, it becomes hard to be monitored or detected (Hart *et al.,* 2007). Physico-chemical measurements alone cannot be used to effectively assess water quality of streams because their status keep changing too often and their ecological influence are too complex to be understood (Tebbut, 1992).

3.4 Use of biotic indices in monitoring water quality

Water quality monitoring is the sampling of the conditions of water including sediments, physico-chemical parameters, fish tissues and the macro-invertebrates in order to determine the pollution level of lotic and lenthic water systems. We monitor to characterize water and identify the changes in trends in water quality over time; identify specific existing or emerging water quality problems; gather information to design specific pollution prevention or remediation programs; determine whether programs, goals e.g. compliance of population implementation have been met; and to respond to emergencies for instance flash floods and spills. Thus, water monitoring is a fundamental tool in water quality resource management.

The principle of biological monitoring as a tool is that the incidence and intensity of environmental stressors is based on the degree to which the chosen endpoint organism association deviates from the expected natural diversity (Hynes, 1972). This approach helps to detect ecological changes which are indicative of the water quality though it does not specify the causes of the change making the physico-chemical approach a more viable technique. This method is often applied because it is cheaper in term of costs and since river sample are easy to collect and analyze for inferences of health status (Nixon *et al.,* 1996).

3.5 The rationale of biological monitoring programs

The purpose of developing biological monitoring programs is to enable researchers to be able to assess water quality of lotic and lentic systems. This is a useful approach because it makes use of aquatic biota to evaluate complex river water qualities. Overall biotic communities are generally affected by the multi-presence of chemicals and physical factors that influences the conditions in aquatic biota reflecting the total conditions of the river ecosystems. This approach which is called bioassay uses biota as endpoint to represent the general environmental conditions and assess environmental qualities. The aquatic biotic assemblages include the macro-invertebrates, the phytoplanktons, the zooplanktons, phyto-benthic macro-invertebrates and the fish communities (Depauw and Vanhooren, 1983).

The ecological indicators are used on the basis of biological diversity to portray species and community structures and thus water quality, hydrology and the overall health of a stream. Indicators are used to monitor the levels of toxins and the chemical content i.e. the physical and chemical parameters and the overall nature of the water resource (Nixon *et al.,* 1996). Biological monitoring is a protocol that is designed of monitoring surface and groundwater water quality. The presence or the absence of biota groups are used as biological indicators and the whole living community reflect the overall environmental conditions (Karr, 1981).

3.6 Macro invertebrates prediction and classification system

This system consists of statistical models which are used to predict the expected presence of aquatic macro-invertebrates fauna at sites with no environmental stressors (Simpson and Norris, 2000). These assessment techniques are based on a stepwise progression of multivariate and univariate analysis. A comparison of the samples predicted to occur at test sites and those actually collected provides a target invertebrate community to measure the effectiveness of remediation actions at impaired sites (Wright *et al.,* 1993). These models have the advantage of having a high turnout of results, hence, their use in rapid bio-assessment programs because they are easy to understand and apply by natural resource managers (Hawkins and Norris, 1997).

3.7 Ecological integrity

Ecological integrity refers to a concept that seeks to incorporate the biotic and abiotic components of an ecosystem with regard to how they relate in their functions, goods and service output and their regeneration rates (Maddock, 1999). Within the context of a water ecosystem, ecological integrity is the maintenance of all internal and external processes and attributes that interact with the environment in such a way that the biotic community corresponds in the natural state of specific aquatic habitats (ONORM, 1995).

High river water quality is reflected by good ecological integrity in the river watershed and poor water quality is as a result low ecological integrity in the watershed. Disturbance in the river watershed e.g. farming on the river banks causes poor ecological integrity. The absence or the presence of the biota groups are used as biological indicators and the whole entire living community reflect the overall environmental conditions (Karr, 1981).

For many decades the trend had been to concentrate on the physico-chemical quality aspects in the assessment of water quality of rivers. As much as there has been a rapid development of geomorphological and physical methods of river assessment, riverine morphology, hydrology and connectivity still continue to deteriorate. It is thus pertinent to develop biologically based methods, and to look at all these methods from a biological perspective (Zalewski, 2002).

Increase in the reduction of the water quality in Mt. Elgon Rivers has had serious ecological implications especially in the ability to support human life, livestock and wildlife. There is all the likelihood that rivers in the region are going will face more pollution in the future because the demand for the water resource is on the rise due to un-relented human population increase. Thus, water will continue to diminish in quality as well as in quantity due to the unabated destruction of the forests, the degradation of Mt. Elgon water tower and conversion of the forest cover to land use.

The integrity of the quality and the quantity of the rivers in Mt. Elgon will potentially continue to face pressure due to the increase in commercial activities in the mushrooming urban centers in the region. This may also be due to the poor agricultural practices that have led to enormous discharge of the agrochemical wastes both in the upland and lowland areas of the rivers in the region. For unknown reasons, no assessment of water quality status of Mt. Elgon rivers region has ever been carried and hence, there is no source of reference. Therefore, the pollution status and ecological integrity of rivers in the region is unknown. There is no baseline data to be used to monitor pollution levels in rivers in relation to environmental degradation in the region.

Thus, it is imperative that the ecological status of the rivers in Mt. Elgon be known. This will give an insight of the quality and quantity integrity levels of river basic characteristics that are critical to maintenance and resource conservation and management of the river lifeline of Mt. Elgon. If they continue to remain unattended and unaddressed, the threats to water quality in Mt. Elgon Rivers will continue to have long term negative impacts on the survival of human beings, livestock and wildlife in the region.

3.8 Biological indicator organisms used to determine ecological integrity

Biological Indicator Organisms (BIO) include the macro-invertebrates, micro-organisms, algae and fish (Rosenberg and Resh, 1993). Biotic Indicator Based Assessment (BIBA) can also be used to generate information about the abundance of species taxa and their diversity. Also to be assessed are the physico-chemical conditions of the rivers including conductivity, pH, turbidity, oxygen concentration and salinity levels (Fausch *et al*., 1984).

The biological assessment of biota present in an aquatic system is the only best way to measure the ecological status of a biological community based on environmental functional stresses. Community composition keep altering because of the stresses within the system itself and the impact of pollution on the individual organisms, and this may act as an early warning of degradation in a biological community. The benthic macro-invertebrates are the assemblages most widely used in the bio-assessment of lotic environments because they are a diverse mixture of species exhibiting a range of pollutant levels and are abundant in most of the streams (Barbour *et al*., 1999).

Benthic macro-invertebrates spend most of their lifecycles between sediments and water spheres of lotic environments and this way they are capable of indicating cumulative changes of the external environment. They are important linkages in food chains and food webs as they can be fed upon by other organisms and they also feed on other organisms. They are easy and affordable to collect, and this makes them be most preferred assemblages for biological monitoring.

The EPT richness index method can be used to directly assess the cumulative effects of all activities in the watershed of a lotic water system. These results allow for the establishment of baseline or reference conditions for watersheds to characterize their overall condition, identify potential nonpoint and point source pollutants, target resource efforts in impaired watersheds, and evaluate the effectiveness of pollution control measures. The EPT index uses three orders of the aquatic insects that are easily collected, sorted and identified; it is commonly used as an indicator of water quality.

It is used because it is reliable and it is applied in the establishing reference conditions; setting protection and restoration of goals; identifying disturbances; choosing control measures; evaluating the effectiveness of Biological Monitoring Programs (BMP) improvement measures and monitoring watershed condition change in the early stages of the project (Lennat, 1988).

4. Methodology

4.1 Location of study area

River Kibisi originates from Mt. Elgon (Figure 1) which is situated at altitude of approximately 2,200 meters above sea level. The study area is found at longitude 0^0 45’N and latitude 34^0 45’E. It then flows downstream through a natural forest dominated mainly by indigenous trees/vegetation cover. The river leaves the forest edge and flows through a rich upland agricultural area of extensive and intensive human farming activities and settlements. In the lower reaches it passes through a floodplain before it eventually coalesces with River Sosio, and together they form a tributary that pours its waters into River Nzoia. The larger River Nzoia which has its origin in the Cherang’ani hills and Mt. Elgon water tower flows in the southern direction ending up in Lake Victoria. The erratic weather changes due to climate change and the removal of the riparian vegetation from the river watershed have greatly affected the discharge of River Kibisi causing its volume to dwindle tremendously in recent years. The floodplain in the lowland is dominated by anthropogenic activities that include human settlements, farming, urbanization and grazing. Mt. Elgon is the eighth highest mountain, and it has the largest base than any other mountain in the world (Boys and Allan, 1988).

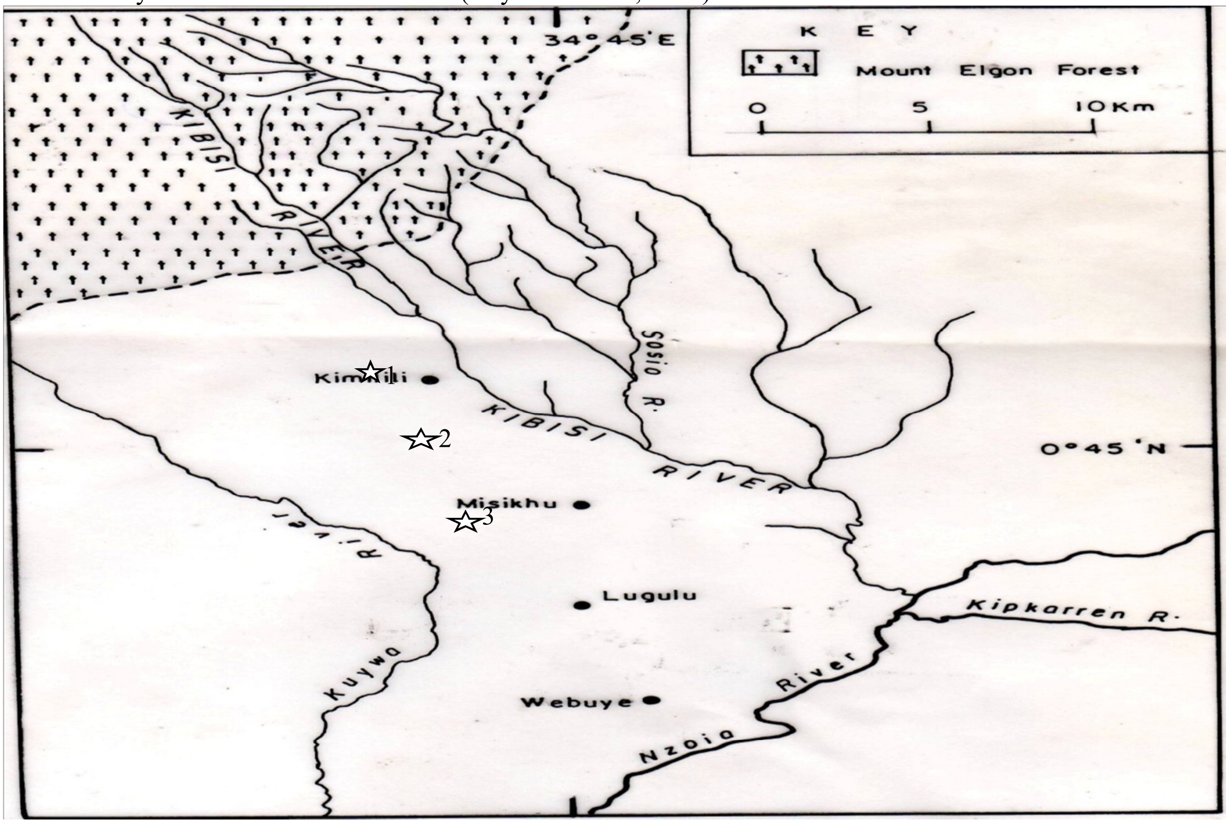

Figure 3.1: Map of Mount Elgon area showing sampling sites 1, 2, and 3 along River Kibisi representing forested, agricultural and urban sites respectively.

The floodplain is dominated by human settlements and farming activities. In the lowland reaches, the color of the river turns brown because of the extensive deposition of soil sediments from open farmlands especially during the rainfall seasons. In the lowland reaches more than the upland reaches, intensive anthropogenic activities are dominant because of the increase in human population. Obviously anthropogenic activities are to blame for the decline of the river water quality degradation. Mt. Elgon is the eighth highest mountain with the largest base area than any other free standing volcanic mountain in the world (Boys and Allan, 1988).

4.2 Selection of study sites

The Kibisi River was selected for this research study because it is one of the perennial rivers out of the expanse Mt Elgon area, and for the fact that it is one of the most polluted, and a source of water supply to most of the homes, institutions and urban centers. Sampling sites were selected randomly based on a number of factors: accessibility, physical proximity, habitat diversity and riparian land uses. The sites selection was also based on the fact that River Kibisi is the source of piped water to urban centers, homes, institutions, and animal watering. The sampling sites were representative by both the mildly polluted and highly polluted sites in the upper and lowland areas. The selected sampling sites included: Forested area (site I), Upland agricultural area (site II) and Lowland agricultural area (site III) plates 3, 4 and 5 respectively.

4.3 Sampling

Sampling was done for a period of four months starting from 15th March 2011 to 30th June 2011. The collection of samples was carried out in a systematic order at three sites which were selected based on ease in accessibility and anthropogenic activities along the river. The first data sampling site I was located near the margins of the forest, the site II was located in an upland agricultural area and the site III at the lowland agricultural area. Each sampling site was marked using a Geographical Positioning System (GPS) to ensure that samples were collected from the same place at each sampling time. The sampling was chosen such that they had to include the river sheds with mild, moderately disturbed and seriously disturbed/impaired catchment areas.

At each sampling site, the data was collected from both the pools and the riffles which were 1 metre off the river banks. Considerations were given to different biotopes namely stones, vegetation, gravel, sand and mud both in and out of the current. Disturbance Removal Sampling Technique (DRST) was used, and this involved defining specific sampling, areas and then disturbing the substrate within the defined area to dislodge the benthic macro-invertebrates which were then washed down into a Hess sampler net. The samples were processed in the field to remove organic debris. This was meant to reduce the volume of the sample, and to clean the composite sample that was taken to the laboratory for identification and analyzes. The collected macro-invertebrates and organic debris components and samples were then stored in containers or sample bottles with 70% ethanol ready for laboratory analysis and classification whereas the inorganic debris components were discarded away in the field. The containers were carefully labeled to maintain identity giving details such as river name, site, date, code and location.

4.4 Physico-chemical characteristics

Significant variations in the physico-chemical characteristics were noted from the forested, agricultural and urban areas throughout the sampling period.

4.5.1 Physical characteristics

The physical parameters such as temperature, turbidity, conductivity, water depth, width of the river channel, transparency, the velocity of water flow and Total Suspended Solids (TSS) were measured in situ using standard methods at sampling stations.

Temperature – Ordinary air temperatures were measured with the help of a mercury glass thermometer with a precision of ± 0.1^0C. A mercury glass thermometer was dipped into the water and left for about three minutes after which it was withdrawn and readings were taken and recorded.

Transparency was estimated as the mean of the depths at which the secchi disk disappeared when lowered into water and reappeared after being raised (Wetzel, 1983).

Depth of the water was measured using a meter rule while the width of the river channel was measured using a tape measure. Measurement of Total Suspended Solids (TSS) was measured by the use of TSS probe meter (model PCT: 40). Pick the number of holder at random, label each holder to a particular station e.g. S1 = 0.5, S2 = 2, S3 = 9. Before filtering the sample, heat the holder and the filter paper in the oven for approximately 10 minutes to drive off all the moisture. Weighing was done with the help of an electrical balance. Filtration process is done with the help of a filter pump. The samples are then transferred to the oven and dried for about 2 hours at 100^0C. Then compute the difference and tabulate the results in milligrams per litre (mg/l.).

Water velocity was measured by observing the time required for a floating object to transverse a known distance downstream. This method was appropriate for coarse estimates of discharge particularly during floods, and required a little time or equipment. A floater was introduced at a short distance upstream along the river so it could travel the speed of the water before passing the first mark. A stopwatch was used to measure the time of travel between the marked sections. Turbidity – a Cecil spectrophotometer CE 323 units of turbidity being Nepherometric Turbidity Units (NTUs) (Owen, 1975);

To measure suspended sediments it was important to obtain samples which accurately reflected the stream's sediment load. Samples were taken during high and low flow periods to develop long-term averages. Samples were taken in such a way that concentration represented an average for a section depending on the particle size. Normally variability was found to be higher towards the centre than towards the edges. Preferably suspended sediment samples were used to measure suspended solids.

The general classification of surface sediments was often done by eye when assessing the distribution of substrate types in a stream reach. Sediments could be classified visually into boulders, cobbles, gravel, sand, silt or clay. Sometimes it was hard to distinguish silt and clay, and hence, they may just be given one name as "mud" as proposed by (Brakensiek *et al*., 1979).

4.5.2 Chemical characteristics

The pH was measured by the use a corning 105 pH probe meter. The appropriate probe was dipped into collected water in a sample container in turns and the reading taken and recorded after equilibration. Conductivity was measured by use of the probe conductivity meter. Conductivity can also be determined by use of chemtrix type 700 conductivity meter with a temperature compensator.

Dissolved Oxygen (DO) was measured by use of a calibrated portable DO meter. The DO meter probe was dipped into the river water and the meter left to equilibrate before the reading was made and recorded. Dissolved oxygen was measured by use of PT1 401 dissolved oxygen meter. The azide modification of the iodometric (Winkler method) method of oxygen determination as described by APHA (1975) could also be used.

Measurement of Total Dissolved Solutes (TDS) was measured by the use of TDS probe meter (model PCT: 40). The measurement of the Total Dissolved Solutes procedure is exactly the same as that of the measurement of the Total Suspended Solids. To measure the amount of water (filtration), the solid is put in the oven. The filtrate and the container and are left in the oven for approximately 10 – 12 hours. They are then removed and reweighed using the analytical balance. The results are calculated in terms of milligrams per litre (mg/l.).

The concentration of Total Suspended Solids (TSS) was estimated gravimetrically on Whatman GFC filters. The river water (a volume of 150 ml) was filtered on site for onwards nutrients analysis in the laboratory. The filter papers used then were carefully folded and wrapped in an aluminum foil for onward drying in the oven at 95^0C for at least three hours. The suspended solids weight was thereafter calculated using the formula below (Wetzel and Likens, 1991).

$TSS = (W_r \text{ mg/l.}) - (W_{c-} \times 10^6)\, V^{-1}$

Wr = Weight of pre-combusted filter in grams.

Wc = Weight of filter + residue in grams.

V = Volume of water sample.

4.6 Biological assessment of water quality

One sample was collected from a pool and one was collected from a riffle at each of the three selected sampling sites at a distance of 1m from the shoreline. In total six samples were collected from the upstream to downstream sites on each of the sampling dates. Therefore, for the whole sampling period forty eight samples were collected. Samples were collected using a modified Hess sampler with an area of 0.0284 m^2 and a mesh size of 100 µm. The sampler was placed in the stream and large rocks cleaned by hand, and the remaining substrate thoroughly agitated for about three minutes to a depth of about 10cm where possible. The dislodged animals passed through a conical net of mesh size 100µm.

The organisms were thereafter washed into the sample bottles and preserved in 70% ethanol solution. In the laboratory, the samples were analyzed with the aid of a dissecting microscope whereby the animals were sorted out to various orders, identified to the lowest possible taxonomic unit using the appropriate keys where possible and there relative abundance determined.

In the laboratory, the benthic fauna were carefully unpacked from the labeled plastic bottles before being sorted out using different sieve of > 1 mm., 0.5 mm., and < 0.5 mm. Each of the replicated samples was washed down the 3 set of sieves to remove ethanol and to separate the benthic macro-invertebrates. The insects were correctly identified and enumerated up to the genus level by the help of a dissecting microscope set at X50 magnification and identification keys provided by Merrit and Cummins (1996). The specimen were then fixed with the help of 4% ethanol and stored in well labeled vials with indication of dates, sites and sieve sizes.

4.7 Application of the EPT index method

The EPT richness index method is the total number of species in the following order of benthic macro-invertebrates: Ephemeroptera, Plecoptera and Trichoptera. For example, if ten (10) genera of Ephemeroptera (mayflies), eight (8) Plecoptera (stoneflies), and five (5) Trichoptera (caddisflies) are found at a site, the total number EPT index would be twenty three (23). The total EPT index will then be compared to values on an EPT rating chart to determine the water quality of the rivers under study. High quality water supports a greater number of EPT insect taxa. Ratings are tailored to account for differences in species pollution tolerance between regions (NCDEHNR, 1997).

Table 3: An example of EPT richness index ranges and their corresponding water quality ratings (NCDEHNR, 1997).

	Ratings				
Index	Excellent	Good	Good – Fair	Fair	Poor
EPT	> 27	21 – 27	14 – 20	7 – 30	0 - 6

4.7.1 EPT index score development

The EPT index increases with improving water quality i.e., there should be a greater number of EPT insects species in cleaner water. Ratings are tailored to account for differences in species pollution tolerance between regions. (NCDEHNR, 1997). Table 1 above shows an example of EPT richness index criteria developed for Mt. Elgon region in Bungoma County, Kenya.

The EPT richness index can also be used to directly assess the cumulative effects of all activities in the watershed of a lotic water system. The results allow for the establishment of baseline or reference conditions for watersheds to characterize their overall condition, identify potential nonpoint and point source pollutants, target resource efforts in impaired watersheds, and evaluate the effectiveness of pollution control measures. It is used because it is reliable and it is applied in the establishing reference conditions; setting protection and restoration of goals; identifying disturbances; choosing control measures; evaluating the effectiveness of Biotic Monitoring Programs (BMP) improvement measures and monitoring watershed condition change in the early stages of the project (Barbour *et al.,* 1996).

4.7.2 Determination of taxa richness

The diversity of the collected samples was determined by the number of distinct taxa and this involved taxa identification to the genus level. According to Barbour *et al.,* (1996) this entailed laboratory identification with the aid of a dissecting microscope at X50 magnifications.

- Total number of taxa; an indication of the variety of macro-invertebrate assemblage.
- The number of EPT taxa of the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies).
- The number of Ephemeroptera taxa.
- The number of Plecoptera taxa.
- The number of Trichoptera taxa.

4.8 Determination of macro-invertebrate species composition

The composition measures were used in the determination of the relative abundance of benthic macro-invertebrate assemblages. They were used to serve as an indicator of their role in the collaborative energy and food cyclic processes in the river. The collected samples compositional metrics were obtained through laboratory identification using a dissecting microscope at X50 magnification of:

- The % of EPT taxa i.e. the percentage of the mayflies, stoneflies, and caddis flies larvae.
- The % of Ephemeroptera taxa.
- The % of Plecoptera taxa.
- The % of Trichoptera taxa.

4.9 Data analysis

Different statistical methods were used in the analysis of the data from the three sampling sites along River Kibisi. The abundances of the collected benthic macro-invertebrates were compared using Kruskall Wallis H which is a two sample non-parametric test. This sampling technique was also used to compare variations of physico-chemical characteristics between sampling sites. Pearson Rank Correlation (r^2) analysis was used to assess the relationship between benthic macro-invertebrate abundance and physico-chemical factors. Differences were considered significantly at $p < 0.05$. All data were analyzed using the Statistical Program for Social Sciences (SPSS).

5. Results

5.1 Morphological Characteristics

5.1.1 River Widths

River widths of the river Kibisi site I were 4.1 ± 0.33m; site II 5.0 ± 0.51m; and site III 4.1 ± 0.72; during the entire sampling period at the forested (site I), agricultural and urban sites respectively. Mean river widths at the three sampling sites, however, did not vary significantly (Kruskall-Wallis H test, K = 1.715, $p > 0.05$). Two sites (site I and III) had equal mean widths for the entire sampling period of 4.1 ± 0.33m. and 4.1 ± 0.72m. respectively while site II recorded the highest mean width of 5 ± 0.51m. The rocky bottom riverbed at site II made water to spread out and hence, increased its width (Plate 4). River width at different sampling sites during sampling periods differed significantly. The river widths at site I had minimal variations that ranged from 2.26 – 7.15m. (Table 4.2).

5.1.2 Water Depths

Water mean depths varied from a low of 0.9 ± 0.04 m., 0.7 ± 0.05 m. and 1.5 ± 1.15 m. at sites I, II, and III respectively. Mean water depth however, did not differ significantly at sampling sites Kruskall Wallis H test, K = 1.24; $p < 0.05$) (Table 2). However, expected results were that the depths of the river should have increased in the downstream direction as is always with other lotic bodies in other parts of the world.

Table 4.2: The table shows physico-chemical characteristics measured at the three sampling sites along River Kibisi Mt. Elgon area

	Means ± SE			
Parameter	**Site I**	**Site II (Forested)**	**Site III (Agriculture)**	**Level of (Urban) Significance**
Temperature (^{0}C)	15.3 ± 0.46	17.9 ± 0.67	19.7 ± 0.55	***
pH	7.7 ± 0.07	7.7 ± 0.10	7.2 ± 1.16	n.s.
DO (mgl^{-1})	7.5 ± 0.59	6.9 ± 0.54	5.0 ± 0.62	***
Conductivity (µScm^{-1})	134.9 ± 7.03	157.0 ± 10.76	166.0 ± 12.69	**
TSS (mgl^{-1})	13.1 ± 1.86	26.0 ± 6.82	44.8 ± 8.62	n.s.
Turbidity (NTUs)	78.0 ± 27.1	112.0 ± 40.9	182 ± 39.2	**
Width (m)	4.1 ± 0.33	5.0 ± 0.51	4.1 ± 0.72	n.s.
Transparency (m)	0.6 ± 0.10	0.6 ± 0.11	0.23 ± 0.05	*
Velocity (m/s)	1.2 ± 0.10	0.4 ± 0.12	1.5 ± 1.15	**
Depth (m)	0.9 ± 0.04	0.7 ± 0.05	1.5 ± 1.15	**
TDS (mg/l)	257.8 ± 21.7	291.8 ± 25.2	348.0 ± 22.9	n.s.

Key: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; n.s. = not significant

5.1.3 Water Velocity

Water velocity at the three sampling sites on River Kibisi did not differ significantly (Kruskall Wallis H test, K = 4.820, P > 0.05). Site II had the lowest water velocity averaging 0.4 ± 0.12m/s compared sites I and III that mean velocities of 1.2 ± 0.10m/s and 1.5 ± 1.15m/s (Table 4.1). All sampling sites were characterized by almost constant velocities during sampling period (Table 4.1). Site II had the lowest water velocity averaging 0.4 ± 0.12m/s compared with sites I and III had mean velocities of 1.2 ± 0.10m/s and 1.5 ± 1.15m/s respectively (Table 4.2).

5.2 Physical Characteristics

Physical variables determined at study sites are presented as in Table 4.2. Among the variables that were measured included temperature, turbidity, Total Suspended Solids (TSS) and transparency. These parameters varied significantly at sampling sites according to prevailing conditions in the river watershed and in the water column during the study period as evidenced from the study findings. Other reasons for variations in results during the period were anthropogenic activities and natural forces.

5.2.1 Water Temperature

Mean water temperatures, however, differed significantly between sites (Kruskall Wallis H test, K = 0.001; p < 0.05), averaging 15.3 ± 0.46^{0}C, 17.9 ± 0.67^{0}C and (19.7 ± 0.55^{0}C). The average temperatures varied greatly throughout the study period with lowest temperatures being recorded in the month of June since the sampling period coincided with the long rainy season between the months of March and July (Fig. 4.1).

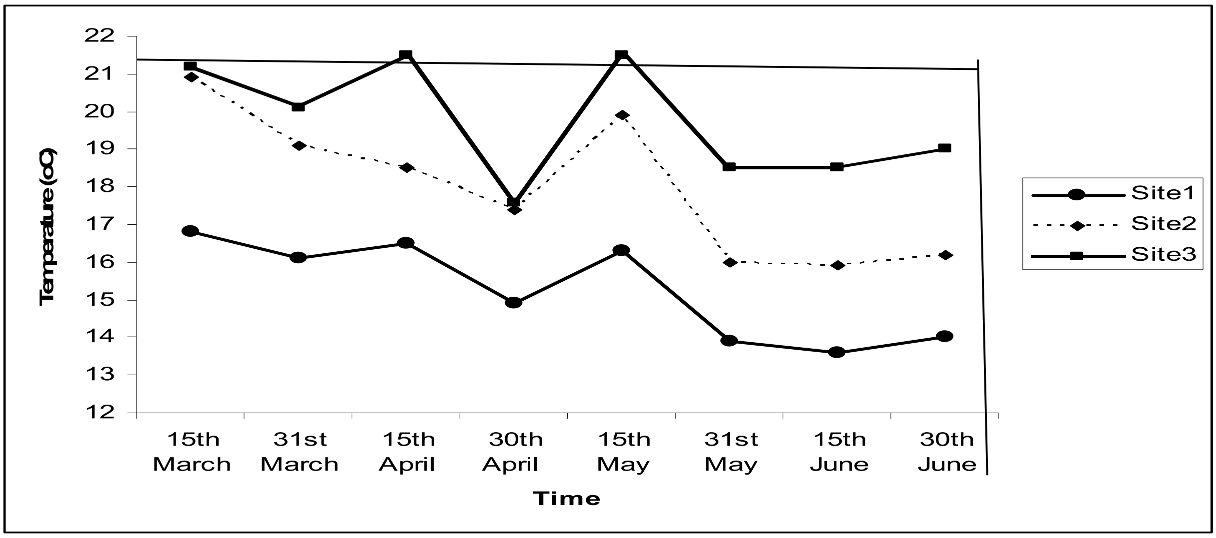

Figure 4.1: Water Temperature variations at sampling sites I, II and III along River Kibisi, Mt. Elgon area

4.2.2 Water Turbidity

Turbidity varied between sampling sessions, though not significantly, ranging from as low as 112.0 ± 40.9 at site II, to a high 182.0 ± 39.2 at site III (Fig. 4.2). All the three sampling sites , however, generally did not show high levels of turbidity during the study period. Serious levels of water degradation were evident in lowland reaches of the river which had high concentrations of sediments turning the river water brown in colour (Plate 3.5).

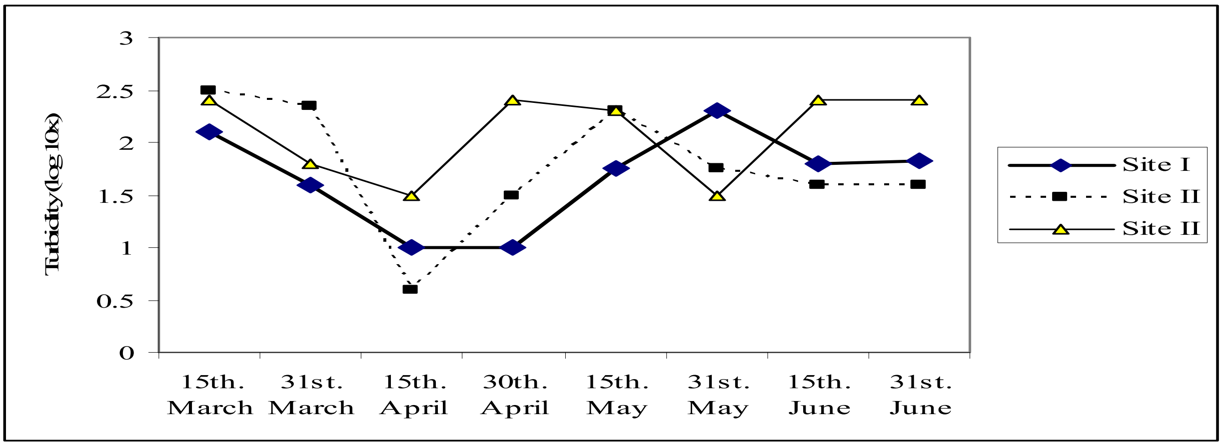

Figure 4: Variations in Turbidity at sampling sites I, II and III along River Kibisi, Mt. Elgon area

Heavy pollution was observed in the lowland reaches of River Kibisi was evidenced by the photograph graph (Plate 4.1). The brown color of the water is as a result of sediment and silt deposition of organic and inorganic materials from the open agricultural farmlands and the river watershed that end up in the river. The situation has recentlty been aggravated by increased anthropogenic activities and the natural forces along the watercourse of River Kibisi especially during the rainy periods.

4.2.3 Water Transparency

Water transparency was significantly lower (Kruskall-Wallis H test, $K = 7.291$, $P > 0.05$) at site III with mean transparency 0.23 ± 0.05m (Fig. 4.7). Water transparencies at site I and II had mean of 0.6 ± 0.11m, respectively. Like water turbidity, water transparencies were generally high at all the three sampling sites along River Kibisi on 15th April 2011 and declined throughout the rest of the sampling period. The lowest transparency of 0.03m was recorded at site III while the highest transparency was 1.2 m was recorded at site II (Fig. 4.1).

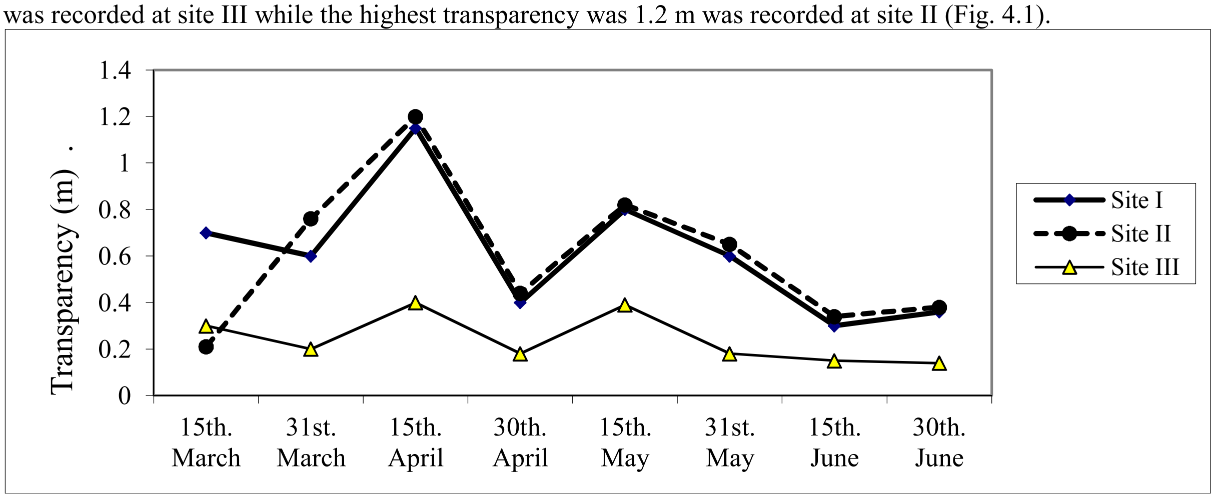

Figure 4.3: Variations in Water Transparency at three sampling sites I, II anRiver Kibisi, Mt. Elgon area

4. Total Suspended Solutes (TSS)

Total Suspended Solids (TSS) similarly increased though not significantly from site I to site III averaging 13 ± 1.86mgl^{-1}, 26 ± 6.82mgl^{-1} and (44 ± 8.62mgl^{-1}) respectively. However, site III showed the greatest variation in TSS during the study period, rising as from low in late March 5.6 to 68mg/l (Fig. 4.6) due to high inflow of sediments from the watershed or the catchment (Plate 3.5).

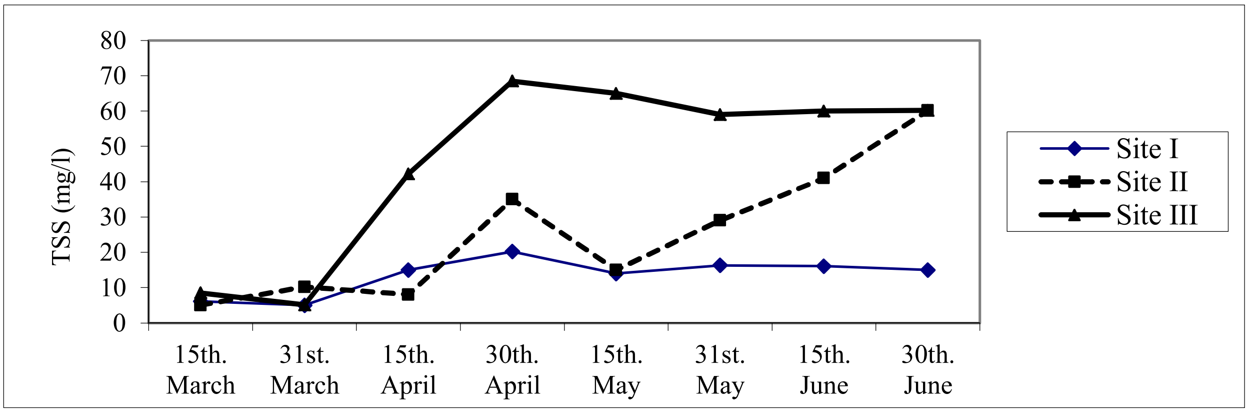

Figure 4.4: Variations in Water TSS at three sampling sites I, II and III between the months of along River Kibisi, Mt. Elgon area

4.3 Chemical Characteristics

4.3.1 pH

Water pH varied from a low of 6.6 at site I to a high of 8.03 between sites during the study period. At the forested site, pH ranged from 7.3 to 7.9 and from 7.1 to 8.03 at the agricultural site. At the urban site, pH varied from 6.6 to 7.8 (Fig. 4.5). The mean water pH, however, varied significantly among sampling sites (Kruskall-Wallis H test, K = 6.98, $P < 0.05$ at particular sampling dates 7.2 ± 0.07, 7.6 ± 0.10 and 7.6 ± 1.16, at forested, agricultural and urban sites respectively. pH also varied greatly through time with low pH values recorded at the urban site reaching a low of 6.6 as compared to the agriculture and forested sites, where pH of 7.10 and 7.3 respectively, were recorded. Though the river water pH remained relatively stable at sites I and II, the indication is that the river became more increasing acidic in the downward direction.

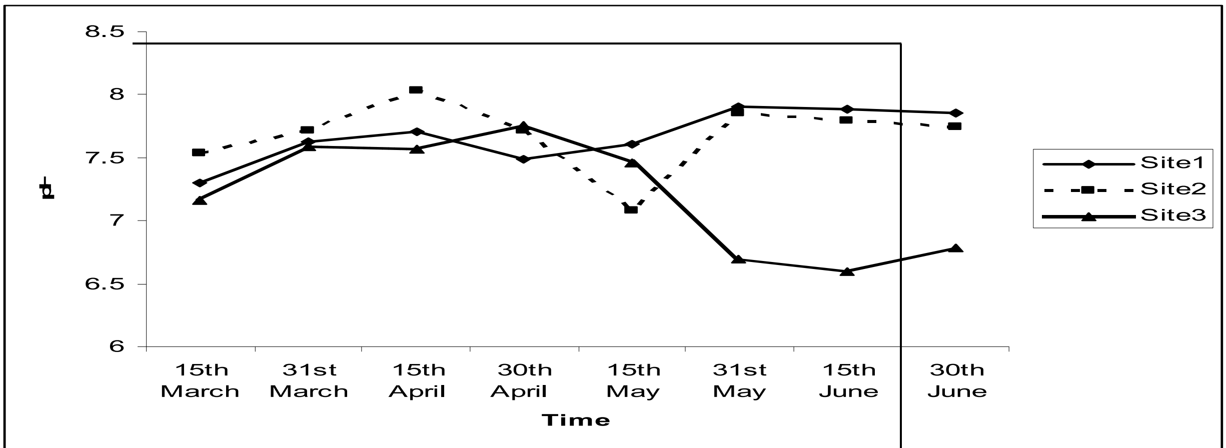

Figure 4.5: Variation in Water pH at three sampling sites I, II and III along River Kibisi, Mt. Elgon area

4.3.2 Dissolved Oxygen (DO)

Dissolved oxygen decreased significantly from site I to site III (Kruskall-Wallis H test, K = 8.05, $P < 0.05$) averaging 5.0 ± 0.62 mgl^{-1} while those of sites I and II were 7.5 ± 0.59 mgl^{-1} and 6.9 ± 0.62 mgl^{-1}, respectively. The lowest concentration of oxygen was recorded at site III (2.26mgl^{-1}), and the highest at site I (8.94 mgl^{-1}) (Fig. 4.6). Dissolved oxygen (DO) concentration at site III through the study period was highest at site I, moderate at site II and lowest at site III which was consistent with the water quality status at each site (Fig. 4.6)

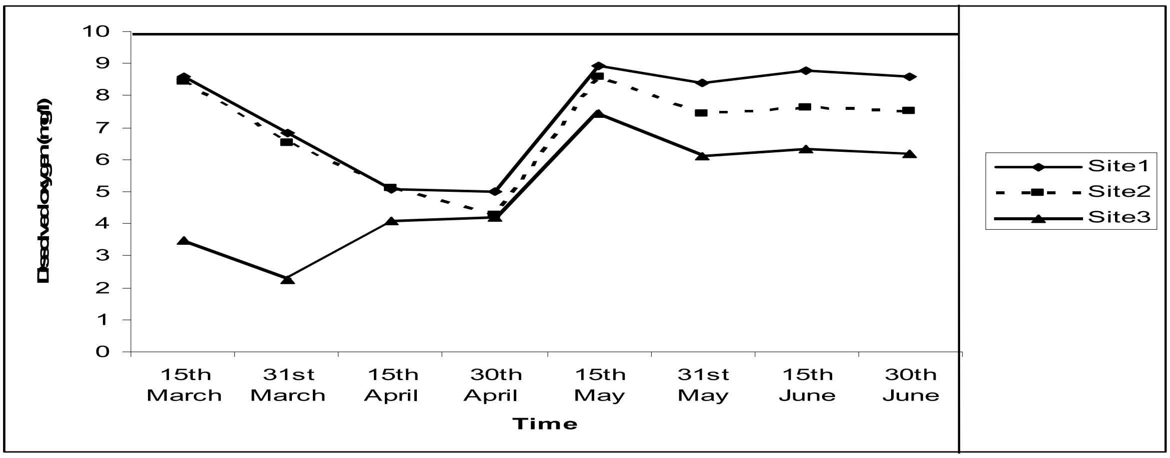

Figure 4.6 Variation in Dissolved Oxygen (DO) at three sampling sites I, II and III along River Kibisi, Mt. Elgon area

4.3.3 Conductivity

Conductivity increased though not significantly from the forested site to the lowland sampling site averaging $134.9 \pm 7.03\mu Scm^{-1}$, $157.0 \pm 10.6\mu S/cm$, $166.0 \pm 12.69\mu\ Scm^{-1}$, respectively, at the three sampling sites I, II, and III of River Kibisi (Kruskall Wallis H test, $K = 4.54$, $P > 0.05$) (Fig. 4.1). During the study period, conductivity of the river water rose significantly at all the three sampling sites after the onset of the rain period in the month of April (Fig. 4.5) due to increased inflows from the catchment. Surprisingly, conductivities decreased significantly as the season progressed reaching a low $135\text{-}245\mu Scm^{-1}$. $127\text{-}203\ \mu Scm^{-1}$ and $110 \pm 60\ \mu Scm^{-1}$ at sites I, II and III respectively by the month of May 2011.

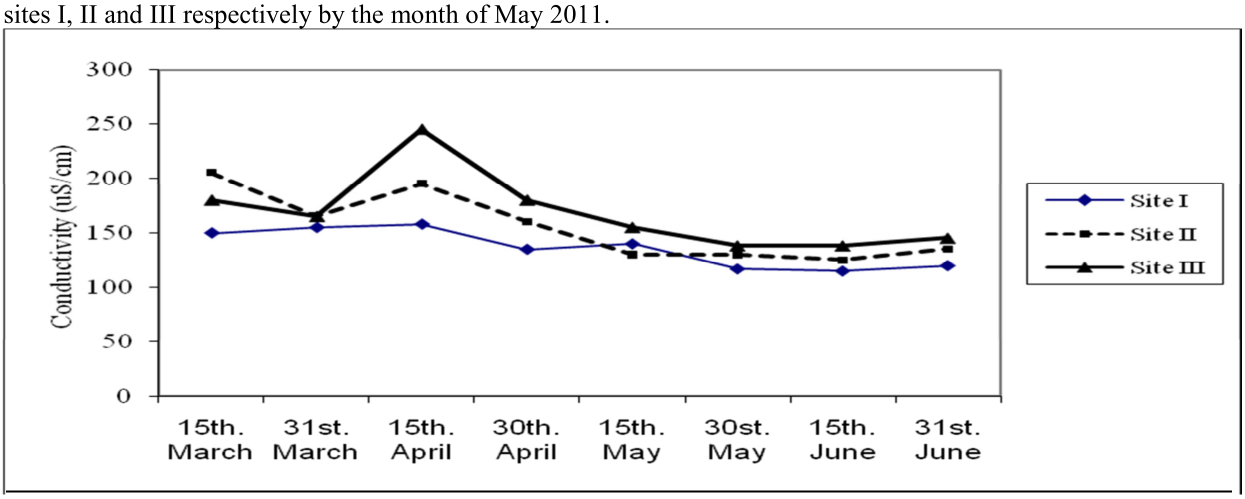

Figure 4.7: Variations in Water Conductivity at sampling sites I, II and III along River Kibisi, Mt. Elgon area

4.3.4 Total Dissolved Solutes

The concentration of Total Dissolved Solutes (TDS) varied significantly (Kruskall-Wallis H test, $K = 7.215$, $P < 0.05$), among the three sampling sites along River Kibisi (Fig. 4.8). Site III had the highest TDS concentration averaging 348 ± 22.9mg/l, while sites I and II recorded lower mean TDS concentrations of $257.8 \pm 21.7mgl^{-1}$ and $291.8 \pm 25.2\ mgl^{-1}$ respectively. Minimal differences in TDS concentration between the three sampling points occurred in March, after which subsequent months were characterised by greater differences. This observation is considered to have been influenced by changes in weather patterns especially that of rain.

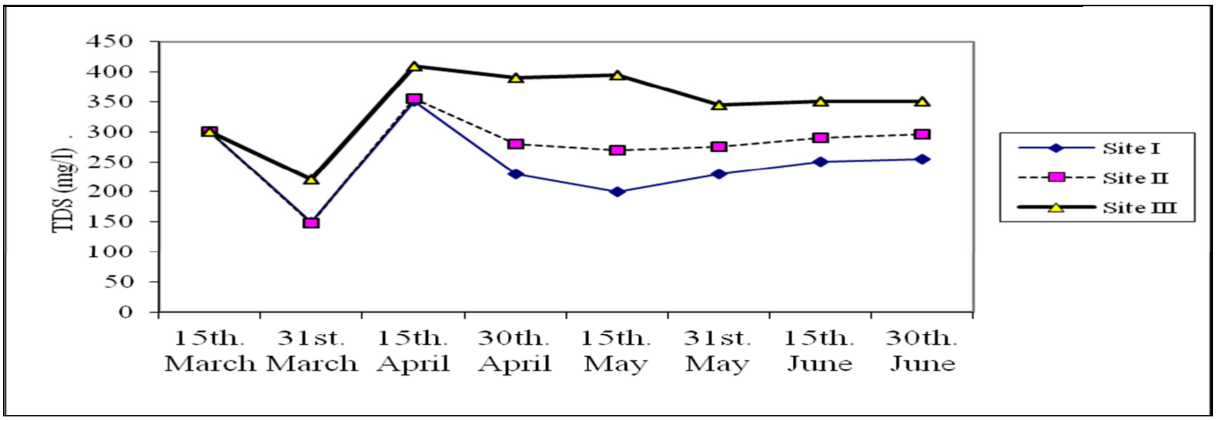

Figure 4.8: Relative changes in TDS at sampling sites I, II and III along River Kibisi, Mt. Elgon area

4.4 Benthic community structure

Out of the collected 48 samples collected during the study, 759 benthic macro-invertebrate individuals were enumerated, analyzed and identified to the level of genera (Table 4.3). The sampled macro-invertebrate individuals at the three sampling sites comprised a total of 17 genera of which 9 belonged to the order Ephemeroptera, 1 to the Order Plecoptera and 7 to the Order Trichoptera (Table 3). Of the three Orders of interest, the Ephemeroptera Order had the highest species richness comprising 53% of the total samples that were collected, while the Order Trichoptera had slightly low species richness with 42% and the Plecoptera had the lowest species richness with only 5%. The Orders Ephemeroptera and the Trichoptera were observed at all the three sampling sites along River Kibisi though River isn't comprised of only three Orders. The other Orders were not of interest as of now.

Table 3 below also shows the Relative Abundance (R/A) of the various taxa of benthic macro-invertebrate individuals as a result of the study. However, not all the macro-invertebrates are shown in the table. The genus *Rhithrogena*, for instance had the highest relative abundance value of 29.59% while the genus *Kogotus*, had the lowest relative abundance of 5.2% of the individual specimens. *Limnephilus, Branchycentrus, Trianodes, Nectopyche* and *Chimarra* were among the taxa that had the lowest relative abundances (0.14%). The families Heptageniidae, Baetidae and Caenidae were found at all the sampling sites.

Table 4.3: Relative abundance of Ephemeroptera, Plecoptera and Trichoptera Orders of benthic macro-invertebrate genera richness in River Kibisi, Mt. Elgon area

MACRO-INVERTEBRATES			
ORDER	FAMILY	GENUS	RELATIVE ABUNDANCE (R/A)
Ephemeroptera	Heptageniidae	*Epeorus*	14.37%
		Rhithrogena	29.59%
		Stenonema	4.1%
		Heptagenia	1.2%
	Baetidae	*Baetis*	9.8%
		Cloeon	10.12%
	Isonychiidae	*Isonychia*	18.6%
	Ephemerellidae	*Ephemerella*	4.5%
	Caenidae	*Caenis*	0.24%
Plecoptera	Perlolidae	*Kogotus*	5.2%
Trichoptera	Hydropsychidae	*Hydropsyche*	2.5%
	Limnephilidae	*Hesperophylax*	0.14%
		Limnephilus	0.14%
	Branchycentridae	*Branchycentrus*	1.5%
	Leptoceridae	*Trianodes*	0.14%
		Nectopyche	0.14%
	Philopomidae	*Chimarra*	0.14%

4.4.1 Occurrence and Relative Abundances of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa

The relative abundances of the sampled Orders varied greatly along River Kibisi with the commonly occurring genera being genus *Rhithrogena* (29.59%), genus *Baetis* (21.74%) and genus *Epeorus* (14.37%). Contrary to this, a few species were also recorded with low relative abundances. These include genus *Caenis* (0.24%) and *Hesperophylax* (0.14%) and genus *Nectopsyche* (0.14%) (Table 4.2).

During the rainy period benthic macro-invertebrates were swept by mini floods from the upland reaches to the lowland reaches. Thus, increasing their numbers increased downstream (Table 4). In the dry spell season only moderate numbers were recorded compared to the wet season. Human (anthropogenic) disturbances that destabilized micro-habitats in the lowland reaches might have caused the migration to the upland reaches of the river. This is as a result of the fact that these organisms completely avoid seriously impaired (polluted) river waters and only the pollution tolerant are found in river beds in the lowland reaches.

Table 4 below shows the presence (+) and absence (-) of benthic macro-invertebrates at the three sampling sites along the watercourse of River Kibisi. The insects belonging to the Orders Ephemeroptera and Trichoptera were found at all the three sampling sites while the Order Plecoptera was found at both sites I and II. The genera *Rhithrogena, Stenonema* and *Isonychia* were found at all the sampling stations. The genera *Heptagenia, Baetis, Cloeon, Kogotus, Hydropsyche, Hesperophylax* and *Limnephilus* were recorded at two sampling sites.

Table 4.4: The presence (+) and absence (-) of EPT benthic macro-invertebrates at sampling sites I, II and III along River Kibisi Mt. Elgon area

Order	Family	Genus	Site I	Site II	Site III
Ephemeroptera	Heptageniidae	*Epeorus*	+	-	-
		Rhithrogena	+	+	+
		Stenonema	+	+	+
		Heptagenia	-	+	+
	Baetidae	*Baetis*	+	+	-
		Cloeon	+	+	-
	Isonychiidae	*Isonychia*	+	+	+
	Ephemerellidae	*Ephemerella*	+	+	-
	Caenidae	*Caenis*	+	-	-
Plecoptera	Perlolidae	*Kogotus*	+	+	-
Tricoptera	Hydropsychidae	*Hydropsyche*	+	+	-
	Limnephilidae	*Hesperophylax*	+	+	-
		Limnephilus	+	+	-
	Branchycentridae	*Branchycentrus*	+	-	-
	Leptoceridae	*Trianodes*	+	-	-
		Nectopyche	+	+	-
	Philopomidae	*Chimarra*	-	-	+
Totals			15	12	5

The benthic macro-invertebrates community at sites I, II and III was equally rich comprising a total of the three orders (Fig. 4.9). However, only two benthic macro-invertebrates Orders were found to be more abundant and accounted for over 90% of the sampled individuals. They were Orders Ephemeroptera with a relative abundance of (60%) and Order Trichoptera with a relative abundance of (40%) respectively. Both these Orders were dominant at all the three sampling sites while the Order Plecoptera occurred at sampling sites I and II but completely disappeared at sampling site III.

The benthic macro-invertebrates fauna had the richest abundance at sites I and II with 15 and 12 genera respectively (Table 4). On the contrary this biotic community at site III had the lowest generic richness comprising only 5 genera (Fig. 4.10). The most common genus was *Isonychia* which appeared at all the three sampling sites whose relative abundance was 54.81%. Similarly, *Rhithrogena* genus was noted to occur commonly at all the three sampling sites. The genus that recorded the lowest occurrence at all the three sampling stations was genus *Hydropsyche*.

Site I (Forested)

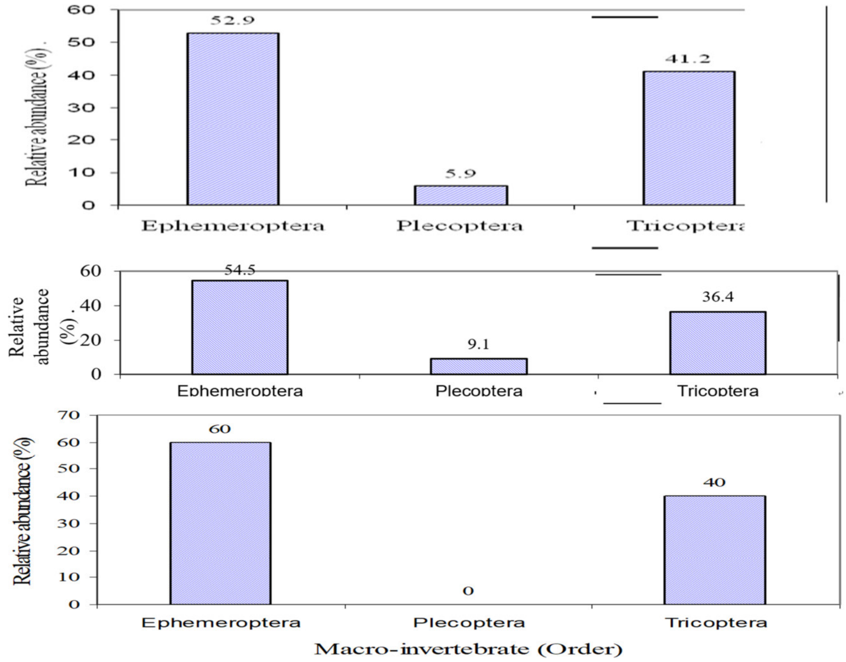

Figure 4.9: Relative abundance of benthic macro-invertebrate Orders at sampling sites I, II and III along River Kibisi Mt. Elgon area

Site I (Forested)

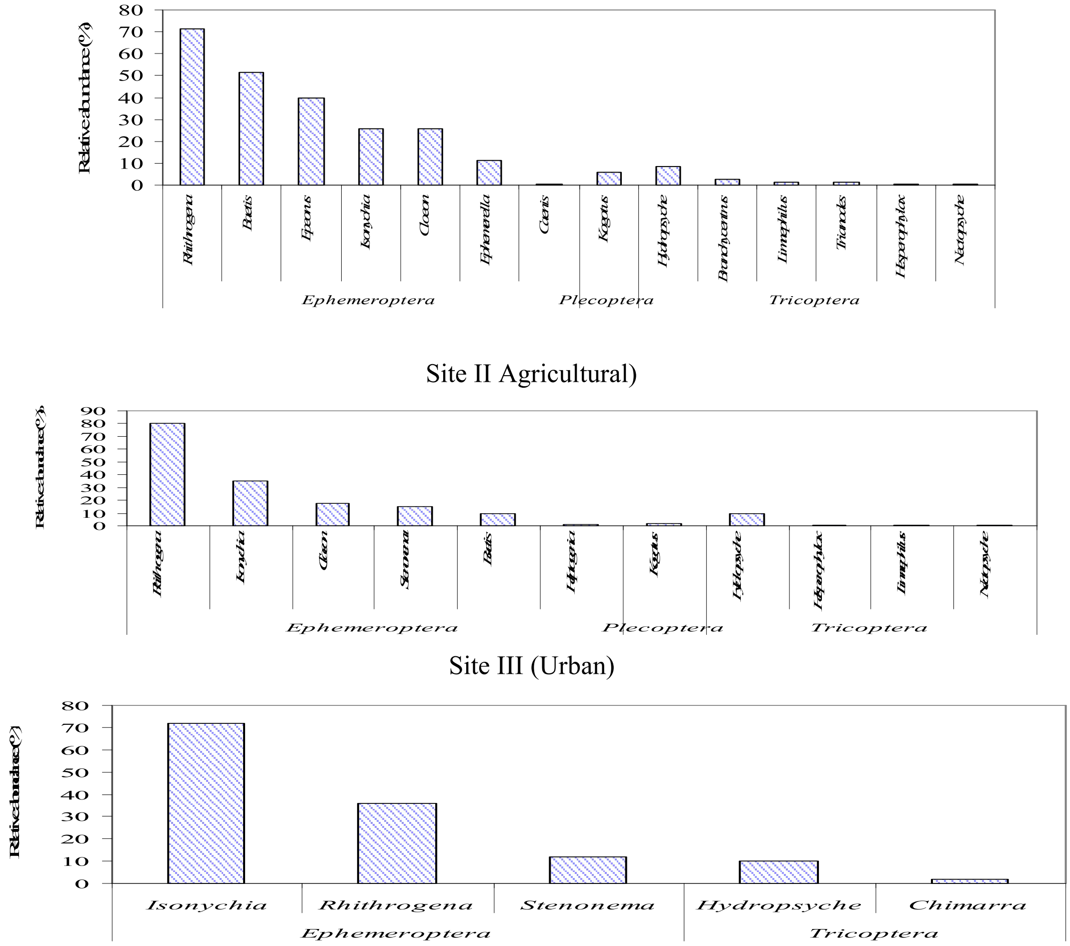

Figure 4.10: Comparison of the relative abundance of the benthic macro-invertebrates genera among sampling sites I, II and III along R. Kibisi in Mt. Elgon area

4.4.2 Variations in EPT species richness index

Comparisons of the EPT richness index values of the three sites showed hogh significant differences (Kruskall-Wallis H test, K = 20.16, $P < 0.05$), with site III recording the lowest index of 10 ± 0.71 (Fig. 4.11). However, site I had the highest mean index of 34 ± 1.33 and it was followed by site II with a mean index of 25.0 ± 1.22. Just like other physical and chemical characteristics, EPT indices at the three sampling sites were noted to change with time. Results obtained indicated that fewer species were found in the lowland agricultural station which was characterized by serious impairment of river water quality due to increase in water quality stresses as result of burgeoning anthropogenic activities.

Comparisons within the EPT genera richness showed tremendous variations (Table 4.4). This is why site I was assigned water quality status of being Excellent water quality; site II of being Good water quality and site III of being Fair water quality. The EPT richness index assigns water status values as follows: ≤ 6 = Pooor water quality; 7 – 13 Fair water quality; 21 - 27 Good water quality and ≥ 27 as excellent water quality (NCDEHNR, 1997). Therefore, according to the results obtained from the study research: site I was mildly polluted; site II was moderately polluted and site III had very serious impairment.

Table 4.5: The Ephemeroptera, Plecoptera and Trichoptera species richness index (NCDEHNR, 1997) at sampling sites I, II, and III along River Kibisi, Mt. Elgon area

	SAMPLING SITES		
	Site I (Forested)	**Site II (Agricultural)**	**Site III (Urban)**
Sampling Date		**EPT species richness index**	
15th March	40	21	10
30th March	29	20	35
15th April	20	20	22
30th April	30	60	17
15th May	12	32	48
30th May	10	35	53
15th June	8	36	59
30th June	6	37	59
Mean± SE	**34±1.33**	**25±1.22**	**10±0.71**
Water Quality	**Excellent**	**Good**	**Fair**

4.4.3 Correlation analysis of EPT richness indices

The results of correlation (Spearman's Rank Correlation test ($P > 0.05$, Rho = 0.6143) between EPT index and physical characteritics showed significant negative correlation for temperature and water velocity. transparency, and non significant negative relationship with trubidity Correlation results between EPT indices and chemical charcteristics, however, showed significant positive relationship with dissolved oxygen concentrations, and non significant positive relationship with water pH. Contrary to this, a significant negative relatioship was noted between EPT indices and conductivity values, while a non significant negative relationship was recorded between EPT indices and total dissolved solids concentration. Further, comparisons between water temperature and dissolved oxygen concentration did not show any significant correlation $r^2 = -0.7753$; d.f. = 2; $p < 0.01$. (Table 4.6).

Table 4.6: The correlation between Ephemeroptera, Plecoptera and Trichoptera richness index and physico-chemical parameters among sampling sites along R. Kibisi, Mt. Elgon area

PARAMETER	SPEARMAN'S (Rho)	P-VALUE	REMARKS
Temperature	-0.7753	0.0001	Significant
Turbidity	-0.3298	0.1156	Not significant
Transparency	0.4081	0.0476	Significant
Velocity	-0.5843	0.0027	Significant
pH	0.3503	0.0933	Not significant
Dissolved oxygen	0.6587	0.0005	Significant
Conductivity	-0.5398	0.0065	Significant
Total Dissolved Solutes	-0.295	0.1618	Not significant

6. Conclusions and recommendations

6.1 Conclusions

The research study proved that there is a significant relationship between water quality status of River Kibisi and the benthic macro-invertebrate community as well as the physico-chemical characteristics. The EPT richness index proved useful in the assessment of the water quality status of River Kibisi in Mt. Elgon region. It was effectively, easily and adequately applied for the first time in the region, and the results obtained were precise, reliable and cost efficient. In the future, the bio-assessment of water quality status of rivers in the region should be taken care of by the various parameters that affect river water quality other than limiting such a study to the EPT biotic indicator organisms as a better scientific approach. From the results, the water quality of River Kibisi varied from excellent to fair in the downstream direction due to increase in pollution levels as evidenced by high water turbidity, poor transparency, low species richness, composition and diversity of the benthic macro-invertebrate fauna. This was as a result of natural forces and an increase in anthropogenic activities.

The results obtained were precise and reliable and thus they can be applied as a point of reference in future bio-assessments in the region. The results can also be used to make decisions on water quality and ecological integrity of rivers in the region. The results showed variations in overall values of physico-chemical parameters and benthic macro-invertebrates communities throughout the whole sampling period due to differences in river water pollution levels and changes in weather patterns**.** There was a significant relationship between the physico-chemical characteristics of River Kibisi with the benthic macro-invertebrate community and that of the water quality. There was a decline of the benthic macro-invertebrates richness, composition, diversity and as well as water quality in the downstream direction due to increase in pollution levels. The EPT % rates or values were highest at station I and lowest at station III. Sampling site I had an excellent water quality while site II had good water quality, and site III had fair water quality. The findings of the water quality assessment of River Kibisi by use of the EPT richness index were in consistence with other similar study findings in other parts of the world. Pollution has always impacted negatively on water quality status of rivers and streams as well as on benthic macro-invertebrates richness, composition and diversity.

6.2 Recommendations

- Poor farming practices along River Kibisi watershed associated with an increase in pollution levels should be done away with. New farming technology e.g. organic farming should be practised with an aim of protecting the water quality in rivers.
- Residents in the region to plant indigenous trees especially in river watersheds to create more riparian vegetation to improve water quality statuses and ecological integrity of streams. The forest cover should be protected, conserved and sustained to improve the ecological integrity of rivers in the region.
- The County and the National governments in collaboration with other stakeholders should put in place new laws and regulations to have the region operate under new management for the protection and sustainability of the water quality resource in the region.
- An adequate monitoring strategy should be implemented on ecological integrity of river watersheds in future. Mitigation and adaptation programs should be embraced to improve water quality resources of river ecosystems in the region.
- The study research has indicated that methods of ecological status assessment based on the selected macro-invertebrates would be a good approach for effective monitoring and screening of aquatic ecosystem health in selected river ecosystems.
- Continuous bio-assessment process based on EPT biotic indicators of rivers in the region to be conducted as often as possible in order to develop a long term profile of water quality status and ecological integrity of rivers. A protective criterion should be established to reduce the toxic effects and negative impacts that compromise the water quality of River Kibisi.
- The study research will provide key information for all government agencies, organizations and individuals responsible for provision of quality water in the region. The findings will be relevant to service providers, water quality regulators, area residents, stakeholders and the whole country at large. That it is now essential for anyone else to set up a water quality assessment and monitoring programme in rivers in Mt. Elgon region because the precedence has been achieved by this study.

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