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Effects of nutrients on the water quality and the algal community of river Nyakomisaro-Riana, Kisii, Kenya

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Abstract

Water quality changes affect the ecological functioning of riverine ecosystems as well as their ability to support organisms and sustain environmental values. The study eighteen months study was conducted from May 2013 to October 2014 to determine the changes in water quality and algal community. Water samples for nutrient and algae composition were collected in triplicates monthly at five sampling sites along the Nyakomisaro-Riana River and laboratory analyses were conducted by following the standard methods described by the American Public Health Association (APHA). Data was oorganized, described and analysed with One-Way Analysis of Variances (ANOVA) and bivariate regression, using the Microsoft Excel 2010 and Minitab software's and the significance of ddifferences considered at the *p*-value of ≤ 0.05. Tukeys pairwise multiple comparisons were used for *post hoc* analysis. The level of Total Phosphorous (TP) exhibited a general increasing upstream - downstream trend with an overall mean of 250.99±25.31 μgL^{-1} and a range of 2.59 - 1281.40 μgL^{-1}. The Soluble Reactive Phosphorous (SRP) concentrations ranged between 1.66 - 632.00 µgL-1 with a spatial mean of 57.24±8.59 μgL^{-1} within a range of . , while Total Nitrogen (TN) concentration had an overall mean of 996.49±128.60 μgL^{-1} and ranged between 4.76 - 4332.33 μgL^{-1}. The lowest mean TN concentration (664.87±90.49 μgL^{-1}) was recorded at site NK1 while the highest mean (1349.27±146.48 µgL-1) was recorded at site R1. Nitrate -Nitrogen [NO3-N] concentration ranged between 0.18 - 742.90 µgL-1 with an overall mean of μgL^{-1} 142.28±16.40 μgL^{-1}. Regression analysis showed a positive correlation between Nitrate nitrogen and distance downstream (b = 15.05, a = 112.12, R 2 = 0.40). Out of 135 algal species recorded, 113 had a low percentage occurrence of less than 30%. The algal community comprised of seven genera of diatoms, six genera of chlorophyceae and cyanophyceae and three genera of euglenophyceae. The percentage algal abundance indicated the existence of a climax community, the blue green algae (*Microcystis aeruginosa*) with a dominance of 34%. This suggested that nutrient loading into Nyakomisaro-Riana River is high. The study recommends that regular monitoring of water quality parameters and algal community changes should be conducted to control the nutrient discharges into the river.

Keywords: Nyakomisaro-Riana river, phosphates, nitrates and algae

1. Introduction

Water quality refers to physico-chemical and to some extent biological aspects of the water environment [1] while water quantity refers to the mass of water overlying or discharged into a waterbody. The quality and quantity aspects are crucial dimensions that affect the stream health and the ecosystem integrity of riverine ecosystems because they influence the richness and diversity of different species. ANZECC AND ARMCANZ [2], reported that the anthropogenically mediated water quality and quantity changes may affect the structure and functioning of riverine ecosystems, therefore it is necessary to ensure proper linkages between the quantity and quality of water in an ecosystem [3, 4]. These two attributes not only support the occurrence and coexistence of healthy biological communities, but also make important contributions towards the availabillity of water for various uses [5]. Streamflow also affects water quality [6]. For instance during low discharge water temperatures are usually high and is increased water transparency due to the settling of suspended solids in the stream bed. However, the dissolved oxygen (DO) levels decrease due to warmer temperatures and increased metabolic processes. On the contrary, during high discharges, runoff from the adjacent catchment transports particulate and dissolved organic matter (CPOM and FPOM)

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into the river, which are utilized by the riverine communities to support food webs. Due to the recent population growth around the river catchments, anthropogenic influences such as improper disposal of human and animal wastes are negatively affecting water quality [7]. Unsustainable land-use practices, unplanned urban settlements without proper sewerage disposal and solid waste handling facilities and and storm water control constitute some of the major sources of nutrient pollution [7, 13]. Some of the discharged nutrients cause eutrophication resulting to excessive algal growth and proliferation, which is associated with water quality problems such as deterioration of water quality, toxic algal blooms, reduced dissolved oxygen concentration which is detrimental to the occurence, survival and growth of aquatic organisms such as fish [8, 9]. For instance in the year 2008, the occurence of algal blooms interrupted the provision of clean drinking water in Kansas city, USA [10]. To solve this problem of euthrophication in surface waters and its associated impacts, it is necessary to prevent excess nutrient loading into riverine ecosystems. Excessive algal growth attributed to excess nutrient loading is among the main causes of water quality deterioration in rivers and their interconnected ecosystems[11 - 12]. Rapid population growth has reduced ecosystems capacity to sequester nutrients [13]. In Lake Victoria catchment, this has been manifestly consipicous in the Winam Gulf- Kisumu where dense blooms of phytoplankton biomass blanketing the surface waters has been empirically observed. This decrease in water transparency causes a shift from demersal to pelagic food webs[11]. The major cause of this phenomenon can be traced back to high levels of nutrient loading which has been observed and reported in the influent rivers. In nature, nitrates and phosphates are the main limiting nutrients for aquatic plant productivity and they occur at a ratio (P: N) of 1: 16. Excess application of inorganic nitrogenous and phosphatic to improve soil productivity can sometimes cause nutrient enrichment of surface and sub-surface waters through leaching of nutrients [14-15]. Currently, the concentration of leached nutrients in surface waters is of global environmental concern due to excessive growth of algal blooms and proliferation of macrophytes in eutrophic waters[16, 17]. Therefore, this study sought to determine the changes in water quality and algal community in the Nyakomisaro-Riana River withi the period of May 2013 and October 2018.

2. Materials and Methods

2.1 Study Area and Sampling Sites

The study was conducted in River Nyakomisaro-Riana which flows through Kisii Town whose location is 1850 meters above sea level. The town is located 300 km South West of Nairobi and stretches between longitude 34°45′0″E to 34°47′0″E and latitude 0°40′0″S to 0°42′0″S in Kenya (Fig. 1). It is located in Kisii highlands with a mean annual rainfall of 2000 mm. Kisii town has recorded averagely maximum and minimum temperatures ranging between 30 ºC and 10 ºC. The town is densely populated with an average of ~1100 people per km^2. A large number of residents draw water from surrounding rivers and sunk wells for various uses while approximately 20% of the town population is connected to piped water and sewer line, a situation that poses a serious threat to the water quality and ecological integrity of surface and ground water sources.

Fig 1: Study area Map and Sampling Sites.

(NK1: upstream sampling station adjacent to source, NK2, NK3 and R1 midstream sampling stations along the transect and R2: is the downstream sampling station. Modified from the Kisii Region lands office map (NK - River Nyakomisaro, R - River Riana)

River Nyakomisaro tributary stretches through a point distance of 5 kilometers before joining with the Nyanchwa River thus forming a confluence at the upper Riana River catchment. Five sampling sites (NK1, NK2, NK3, R1 and R2), were marked through satellite mapping using a Magellan GPS-315 meridian.

2.2 Sampling and Data Collection

The sampling of ex situ parameters used the standard methods published by the American Public Health Association [18]. Water samples were collected from each sampling site in quadruplicates using 300 ml transparent plastic bottles which had been rinsed with distilled water and transported to the Kenya Marine and Fisheries Research Institute Laboratories (KEMFRI) in a cooler box at 4°C within a period of 24 hours. One bottle was fixed with the acidic Lugol's solution for identification and enumeration of algae and the determination of algal biodiversity indices. A subsample of 100 mls of water was filtered and preserved for culturing the microbial load colonies and the other two bottles set aside for nutrient analysis in the laboratory.

2.2.1 Identification and Enumeration of Algae

Fof algal identification and enumeration, a one millilitre of water was placed and allowed to settle in a sedimentation chamber for a period of three hours. Algal cells were observed at a magnification of 400 times under the inverted microscope (Model Zeiss Axioinvert 35), identified to species level and cells of the same species counted. For the Blue green algal cells, ten fields of view were enumerated. The area for enumeration of larger algal cells was 12.42 mm^2. Low power magnification of ×100 was used in observing the larger and rare algal taxonomic groups. Identification of algae was done using field guides, laboratory guides [19, 20] and published identification methods such as those of Huber-Pestalozzi [20] From these, the Nygaard's trophic state indices [21] were computed by using the formulae below:

Chlorophycean index = (Chlorophyceae)/Desimidaceae .... (1)

Euglenophycean index = Euglenophyceae/(Myxophyceae + Chlorophyceae) .(2)

Myxophycean index = (Myxophyceae)/Desimidaceae .... (3)

Compound Coefficient = (Myxophyceae + Chlorophyceae +Bacillariophyceae + Euglenophyceae)/Desmidaceae ....(4)

2.3 Data Analysis

Data was organized, described using Microsoft Excel 2010 software and loaded into Minitab where further analyses were performed using with One-Way Analysis of Variances (ANOVA) and bivariate regression[22]. Significant differences in among the sampling sites were considered at a predetermined p-value of ≤ 0.05. Turkeys pairwise multiple comparisons was used as post hoc to determine which sampling sites significantly differed and clarify the actual source of significant differences Descriptive statistics were used to show upstream to downstream trends of different parameters.

3. Results

3.1 Spatial Variations of Nutrient Concentrations in Nyakomisaro-Riana River

All the selected nutrients under study exhibited high variability around their spatial means. The highest variability in mean concentration (SE = 128.60) was recorded for total nitrogen concentration while mean soluble reactive phosphorus level exhibited the least data variation (SE = 8.59). The mean and standard errors of nitrogen and phosphorus levels are shown (Table 1).

Table 1: Spatial mean concentrations of nitrogen and phosphorus in River Nyakomisaro - Riana River

Parameter	Size (n)	Range	Mean	STDEV	SE	95% CL
Total Phosphorous (μgL^{-1})	270	2.58 - 1281.40	250.99	186.01	25.31	50.77
Soluble Reactive Phosphates (μgL^{-1})	270	1.65 - 632.00	57.24	63.13	8.59	17.23
Total Nitrogen (μgL^{-1})	270	4.76 - 4332.33	996.49	994.99	128.60	257.93
Nitrates (NO_3-N) (μgL^{-1})	270	0.18 - 742.90	142.28	120.54	16.40	32.90

3.2 Total Phosphorous (TP)

The mean Total Phosphorus level generally increased among the sampling sites from upstream to downstream (Figure 3), with an overall mean of 250.99±25.31 μgL^{-1} and a range of between 2.58 - 1281.40 μgL^{-1} (Table 1). The lowest mean TP concentrations (117.43±19.86 μgL^{-1}) was recorded in site NK1 while site R1 recorded the highest mean TP concentration (480.19±63.24 μgL^{-1}) (Fig. 2).

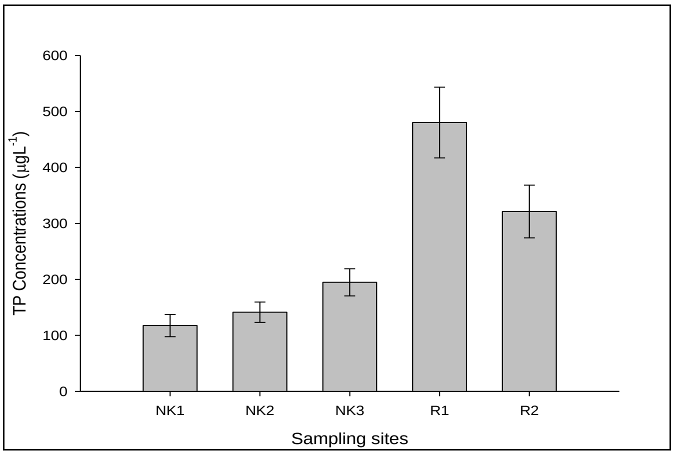

Fig 2: Variation in total phosphorous concentrations among the sampling sites in River Nyakomisaro - Riana

Furthermore, the mean TP level was significantly different among the sampling stations ($F_{4,\ 269}$ = 15.02; *p* = 0.000). Tukey's multiple mean comparisons showed that there was a significant decrease in the mean TP concentrations between site R1 and R2. Further, the TP mean concentrations of NK1, NK2 and NK3 were not significantly different, but were significantly lower than the means of sites R1 and R2. There was a strong positive correlation in Total Phosphorous concentration between sampling sites and distance (D) from the source downstream. The correlation coefficients b = 74.65 and r = 0.79, forms a baseline for future assessment of Total Phosphorus levels in the River Nyakomisaro-Riana as shown in Figure 3.

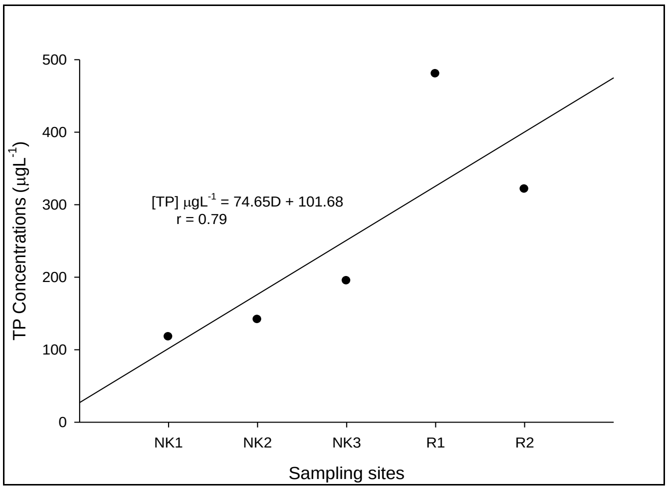

Fig 3: Relationship between Total phosphorus levels and the upstream - downstream distance of River Nyakomisaro-Riana

3.3 Soluble Reactive Phosphorus (SRP)

The mean SRP concentrations decreased from the source to the mature part of the river (Figure 5) with an overall mean of 57.24±8.59µgL^{-1} and a range of 1.66-632.00 µgL^{-1} (Table 1). The mean SRP levels showed a slightly different upstream - downstream trend compared to TP levels. The lowest mean SRP level (20.12±2.26 µgL^{-1}) was recorded at site NK1 while the highest mean (83.02±17.88 µgL^{-1}) was recorded at site R2 (Figure 4).

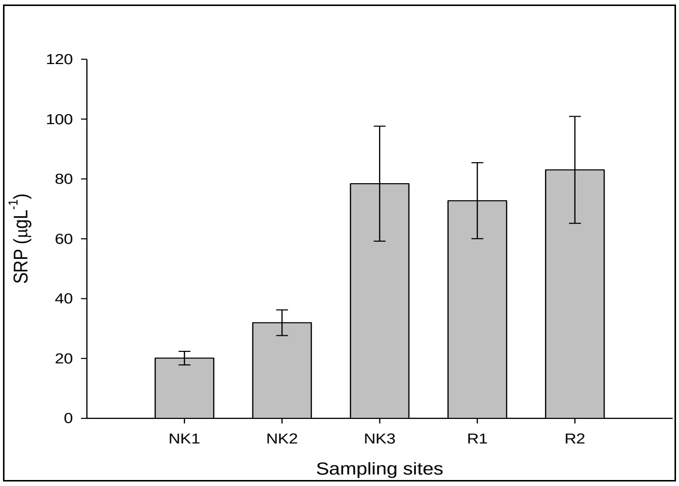

Fig 4: Spatial Variation of Soluble Reactive Phosphates in Nyakomisaro - Riana

There was significant mean differences in SRP concentrations among sampling sites in River Nyakomisaro-Riana ($F_{4,\ 269}$ = 4.82; *p* = 0.001). Tukey's multiple mean comparisons showed that the mean SRP level of NK1 was significantly lower than the mean levels of sites NK3, R2 and R1, which were not significantly different from the mean SRP levels of site NK2. There was a strong positive correlation between SRP level and upstream-downstream distance. The correlation coefficients (b = 16.66 and r = 0.91) forms a baseline for assessing future changes in SRP levels along the River Nyakomisaro - Riana tributary (Fig. 5).

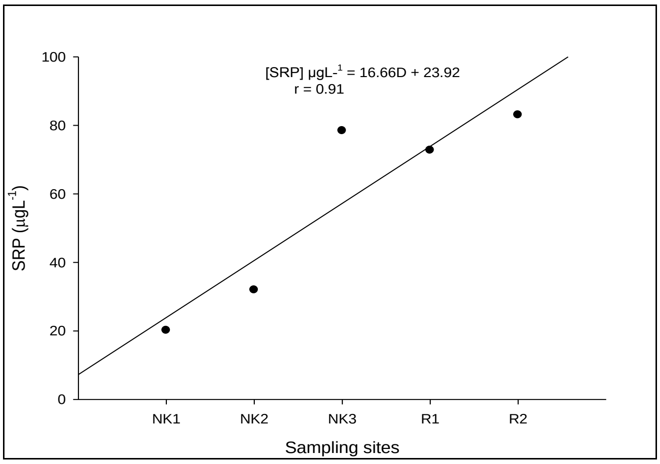

Fig 5: Relationship between SRP levels and the upstream - downstream distance

3.4 Total Nitrogen (TN)

The mean TN levels generally increased among the sampling sites in an upstream - downstream trend (Fig. 7) with an overall mean TN concentration of 996.49±128.60 µgL^{-1} and ranged between 4.76-4332.33 µgL^{-1} (Table 1). The lowest mean TN concentrations (664.87±90.49 µgL-1) was recorded in site NK1, while the highest mean (1349.27±146.48 µgL-1) was recorded in site R1 (Figure 6).

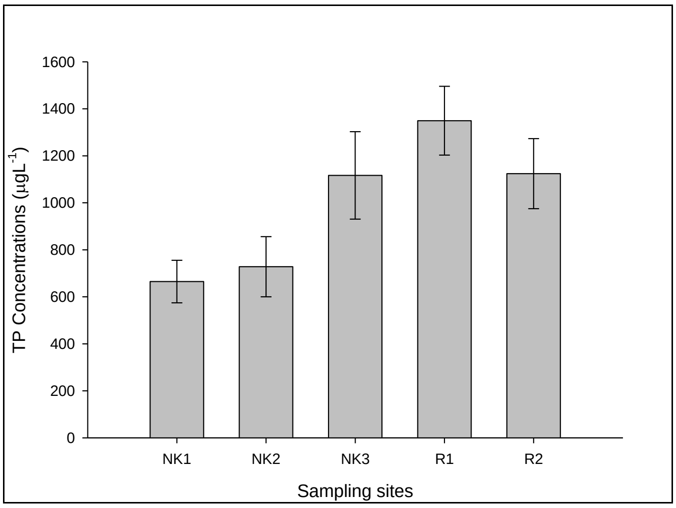

Fig 6: Spatial variation of total nitrogen concentration in Nyakomisaro - Riana River

There was significant mean differences in TN concentrations among sampling sites ($F_{4,\ 269}$ = 4.09; *p* = 0.003). Tukey's multiple comparison of the means showed that the mean TN level of site R1 was significantly higher than the means of NK1 and NK2 but exhibited no significant differences with the mean concentrations of sites NK3 and R2. There was a strong positive correlation between mean Total Nitrogen level and upstream - downstream distance. The correlation coefficients (b = 153.95 and r = 0.84) provides a baseline for tracking the changes in TN levels in River Nyakomisaro-Riana (Fig. 7). The slope of the regression model (b = 153.95) shows that the level of TN doubles that of TP.

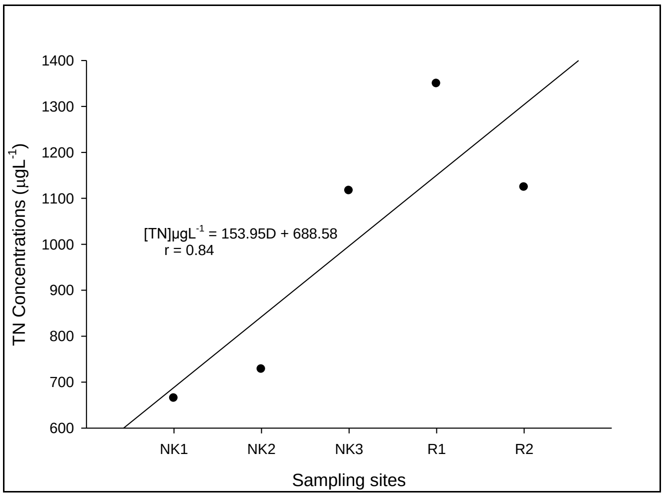

Fig 7: Relationship between TN and Upstream-Downstrean of Nyakomisaro-Riana River

3.5 Nitrates

The mean Nitrate (NO_3-N) level decreased from upstream to downstream (Fig. 9) with the overall mean (142.28±16.40 μgL^{-1}) and range of between 0.18-742.90 μgL^{-1} (Table 1). The lowest mean NO_3-N concentration (90.28±13.77 μgL^{-1}) was recorded in site NK1 but there was the highest mean NO_3-N concentration (192.02±27.64 μgL^{-1}) recorded in site R1 (Figure 8).

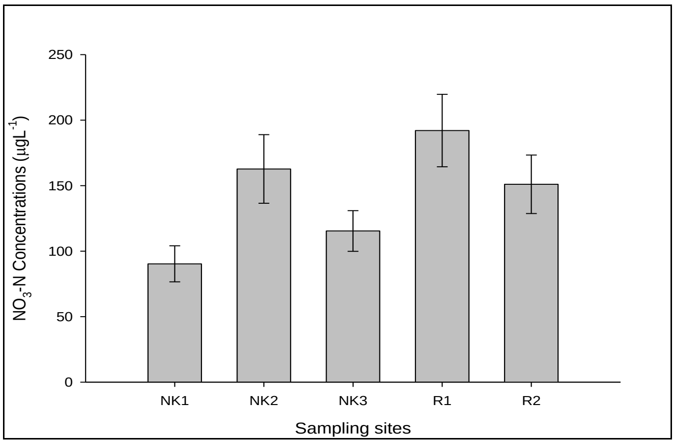

Fig 8: Spatial variation of total nitrate concentrations in Nyakomisaro - Riana River

There was significant mean spatial differences in the mean NO3-N concentrations along River Nyakomisaro-Riana ($F_{4, 269}$ = 3.36, p = 0.01). Tukey's multiple mean comparisons showed that the mean nitrate concentration of site NK1 was significantly lower than that of site R1 but showed no significant differences from the mean nitrate levels of sites NK2, NK3 and R2. There was a significant positive correlation between NO_3-N levels and distance from the source downstream. The correlation coeficients (b = 15.05, r = 0.60), provides a baseline for assessing future changes in NO_3-N levels along River Nyakomisaro-Riana tributary (Figure 9).

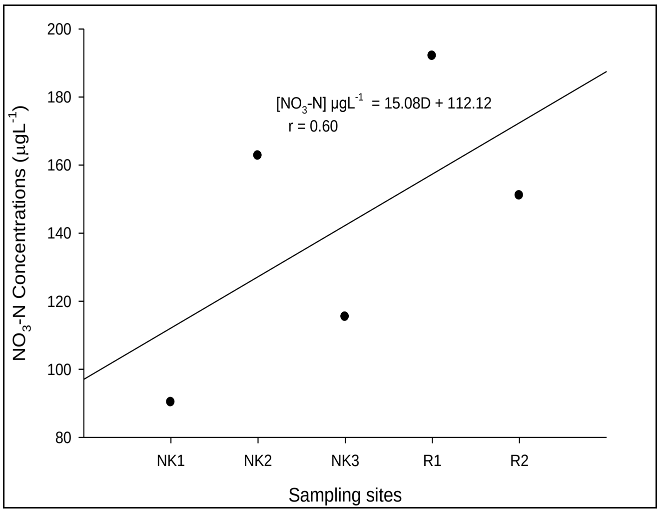

Fig 9: Relationship between nitrate concentrations against upstream-downstream of Nyakomisaro-Riana River

3.6 Relative occurrence of algae in River Nyakomisaro - Riana

A total of 135 algal species were recorded in River Nyakomisaro-Riana, out of which 113 algal species exhibited less than 30% percentage of occurrence. This study considered the algal species with percentage of occurrence of 30% or more to be significantly distributed. In the order of occurrence, diatoms were the most dominant with 7 genera, followed by green algae (Chlorophyceae) and Blue green algae (Cyanophyceae), each comprising of 6 genera. The least occurring were the euglenophyceae comprising of 3 genera. *Romeria elegans was* the most dominant algal species in class chlorophyceae with 67.5% relative abundance (Table 2).

Table 2: Relative occurrence of algae in River Nyakomisaro – Riana

Species	Class	Occurrence	Relative Occurrence
Romeria elegans	Chlorophyceae	27	67.5
Chroococcus turgidus	Cyanophyceae	23	57.5
Coelastrum microporum	Chlorophyceae	23	57.5
Euglena acus	Euglenophyceae	22	55
Chroococcus dispersus	Cyanophyceae	22	55
Cymbella cistula	Diatom	19	47.5
Aphanocapsa rivuralis	Cyanophyceae	17	42.5
Tetraedron arthromisforme	Chlorophyceae	17	42.5
Planktolyngbya limnetica	Cyanophyceae	17	42.5
Botrycoccus braunii	Cyanophyceae	16	40
Aulacoseira ambigua	Diatom	14	35
Cyclotella kutzinghiana	Diatom	14	35
Navicula granatum	Diatom	14	35
Nitzschia sub-acicularis	Diatom	14	35
Nitzschia palea	Diatom	13	32.5
Kirchneriella lunaris	Chlorophyceae	13	32.5
Anabaena flos-aquae	Cyanophyceae	12	30
Synedra cunningtonii	Diatom	12	30
Euglena viridis	Euglenophyceae	12	30
Scenedesmus obliquus	Chlorophyceae	12	30
Trachelomonas armata	Euglenophyceae	12	30
Scenedesmus acuminatus	Chlorophyceae	12	30
Others			< 29

Other algal species with percentage occurrences of more than 50% were; *Chroococcus turgidus* (57.5%), *Coelastrum microporum* (57.5%), *Euglena acus* (55%) and *Chroococcus dispersus* (55%). In this study more cyanophytes had percentage of occurrence of more than 50% compared to other algal classes which implies that the river is eutrophic.

3.7 Relative abundance of Algae in River Nyakomisaro - Riana

The results of relative abundance indicates the existence of a climax community of class Cyanophyceae (*Microcystis aeruginosa*) with a dominance of 34% (Table 3). This was followed another blue green algaal spexies - *Anabaena flos-aquae* with a relative abundance of 9%. In general, the first four species of blue green algae dominated the Nyakomisaro-Riana River and more than 142 species had relative abundance of less than 1%.

Table 3: Relative abundance of Algae in River Nyakomisaro – Riana

Species	Class	Frequency	Relative Abundance
Microcystis aeruginosa	Cyanophyceae	31139	33.89
Anabaena flos-aquae	Cyanophyceae	8114	8.83
Aphanocapsa rivuralis	Cyanophyceae	5436	5.92
Anabaena cirnalis	Cyanophyceae	4143	4.51
Coelomoron vestitus	Chlorophyceae	3379	3.68
Coelomoron mierostoldes	Chlorophyceae	3239	3.53
Coelomoron reguraris	Chlorophyceae	3065	3.34
Microcystis flos-aqua	Cyanophyceae	3015	3.28
Chroococcus dispersus	Cyanophyceae	2716	2.96
Chroococus turgidus	Cyanophyceae	2077	2.26
Merismopedia tennuissimma	Cyanophyceae	1854	2.02
Anabaenopsis tanganyikae	Cyanophyceae	1392	1.51
Coelastum microporum	Chlorophyceae	1120	1.22
Romeria elegans	Chlorophyceae	993	1.08
Aulacoseira nyansenssis	Diatom	992	1.08
Others			< 1.00

Despite the widespread distribution of diatoms, all species exhibited low relative abundance of less than 1% except only one species, *Aulacoseira nyansensis* which had a relative abundance of slightly greater than 1% (1.08%), whereas other classes such as Cyanophyceae had 9 species and Chlorophyceae had 4 species with relative abundance of greater than 1%.

The ecological characteristics and the Nyagaard's indices of River Nyakomisaro-Riana tributary are shown in Table 4.

Table 4: Variation of Nygaard's trophic state index in among sampling sites in River Nyakomisaro – Riana

Nyagaard's Index	Trophic Status Indices	NK1	NK2	NK3	R1	R2	Conclusions
Myxophycean	Oligotrophic (0.0 - 0.4) Eutrophic (0.1 - 3.0)	3.83	5.80	2.54	11.86	11.37	Eutrophic
Chlorophycean	Oligotrophic (0.0 - 0.7) Eutrophic (0.2 - 9.0)	1.05	1.17	2.14	1.74	2.24	Eutrophic
Euglenophycean	Oligotrophic (0.0 - 0.7) Eutrophic (0.0 -1.0)	0.07	0.01	0.04	0.03	0.03	Oligotrophic
Compound	Oligotrophic (< 0.01) Eutrophic (0.01- 2.5)	5.22	7.08	4.89	13.94	14.06	Eutrophic

From table, the compound, Myxophycean, and chlorophycean indices lied above the recommended eutrophic index in all sampling sites while the euglenophycean index took the oligostrophic status since its index classification.

4. Discussions

Nutrients required for growth and production by plants and other aquatic organisms generally occur in the earth's crust in phosphorus to nitrogen ratio of 1:16 [23]. However, the observed total phosphorus to total nitrogen ratios for the Nyakomisaro-Riana River (1: 4.0), was ~ four times higher than the Redfield ratio of 1:16. Further, the nitrates concentration was above the 10 mgL^{-1} level recommended by NEMA. This shows that the Nyakomisaro-Riana River was getting direct nutrients inputs from different sources containing high levels of phosphates and nitrates. The sources of nutrient input include untreated sewage, agricultural waste, leachate from dumpsites and farms within the catchments of the Nyakomisaro-Riana River which corroborates with the findings of Clark, Haverkamp, & Chapman (1985) [24].

The observable sites for discharge of untreated sewage into the river include the Mobamba Coffee processing plant in Mwembe, Daraja Moja, and the Kenya Prisons. Other point sources of nutrients input include the Nyambera dumpsite, which discharge the nutrient leachates into the river. Mwamburi[25], reported that high levels of pollutants in surface waters are derived from an effluent mixture of industrial and municipal wastes. Additional nutrients input into the river might have result from non-point sources, which include informal (unplanned) settlements located in the riparian area without a proper sewage connection, soapy detergents from car wash, kitchen refuse and domestic wastes from the hospitality industry and agricultural farms. Changes in nutrient levels were observed due to changes in runoff which transports Course & Fine Particulate Organic Matter and other materials into the river. For instance, during high rainfall periods, lowest SRP levels were recorded because the runoff mainly carried TP loads from the catchment. High levels of nutrient input might have been due to intermittent discharges of effluents from municipal wastes, carwash areas and waste dumpsites and untreated sewage.

The dominance of certain algal species in an aquatic ecosystem can serve as an indicator of its trophic status[25]. For instance, the dominance of the cyanophyte, *Microcystis aeruginosa* in the Nyakomisaro-Riana shows that the river is eutrophic whereas the presence of a high abundance of diatoms is often used to show that water quality has not been compromised by various anthropogenic activities in the catchment [26, 27]. In this study, the dominance of the class Cyanophyceae species, such as *Microcystis sp* (33.9%), *Anabaena sp* (13.3%) and *Aphanocapsa sp* (5.9%), was a good indicator that the level of pollution in Nyakomisaro-Riana River was high. Most algal species within the class Cyanophyceae assemblage are known to proliferate in eutrophic waters and produce harmful algal toxins[28].

Polluted water from Nyakomisaro-Riana can pose detrimental effects to people if used for bathing or drinking since may contain toxin producing blue-green algae, which have been studied and documented[29, 30] . These include chronic liver injury, skin itching, diarrhorea, vomiting in human beings and death of aquatic organisms, such as the fish and waterfowl. A further study is needed to identify the type of algal toxins contained in the blue green algal species recorded this river and relate them to their effects to human beings and aquatic organisms.

The dominance and high abundance of the blue-green algae species in the Nyakomisaro-Riana River was promoted by high nutrient loading from the surrounding catchment. Members of class Cyanophyceae have been reported to occur oftenly in polluted waters where the total phosphorus to nitrogen ratio has been altered by various human activities. Some species of *Anabaena,* such as *Anabaena circinalis*, are capable of nitrogen fixation because of thickened nodules (cells) which provide sites for nitrogen fixation. The presence of these species in the the Nyakomisaro-Riana River could be an indicator that nitrogen was the limiting nutrient in the river. It could also depict a scenario of phosphate supply exceeding the nitrogen supply required to satisfy the algal nutrition requirements.

Some algal species such as *Romeria ankensis* and *Cyclotella kutzingiana which were* recorded at sites NK1 and R1 are an indicator of low pH in a water body[31]. This therefore implies that acidic effluents might have been discharged through runoff into the river from the Nyambera dumpsite and Daraja Mbili market which might have contributed to the acidity of the waters at the two sampling sites.

In the Nyakomisaro river, direct disposal of the agricultural waste and garbage through runoff and untreated sewage outflows from the catchment are the main sources of high levels of phosphate and nitrate loading into the river. In addition, overcultivation of land close to the riverbank of site NK2 and replacement of natural vegetation with cultivated crops such as nappier grass and kales was manifestly conspicuous in the riparian zone of this section the river. Probably, some of the nutrients from fertilizers applied to improve soil fertility could have been leached and transported into the river through surface runoff to causing excessive algal growth. Maesstrini *et al.* [32] and Mokaya, et al. [33] reported that soluble reactive nitrate (NO_3^-) concentrations vary significantly type of anthropogenic activities in the river catchment. Studies by Shivoga, *et al.* (2005) [34], Twesigye *et al.*(2011) [35] and Ogendi *et al.* (2015) [36] also found that agricultural activities and human settlement along the river catchment negatively impacted its water quality.

5. Conclusions and Recommendations

Nutrient enrichment in inland waters pose serious health problems to the users and aquatic biodiversity. Eutrophication results in excessive production of algal blooms which deteriorate water sources making water unsuitable for drinking and other domestic uses. The total phosphorous to nitrogen ratio in the Nyakomisaro-Riana Rivers deviated from the Redfield ratio of 1:16. This shows that the river is receives the effluent containing in nutrients from surrounding catchments. A number of activities anthropogenic activities such as organic waste dumpsites and carwash and farming along the river bank do contribute to poor water quality of this river. The abundance and dominance of the blue-green algal species in the river during certain periods of the year, indicate that the river are eutrophic. Therefore, there is need to monitor the discharge of pollutants from point and non-point sources. Further, conservation measures should be undertaken to restore the river from eutrophication. These findings provide a baseline for future related studies to be conducted in assessing the interactions between nutrient levels and algal abundance, diversity and distribution in this river and other related ecosystems.

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