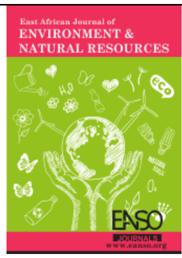

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Original Article

Water Quality, Phytoplankton Composition, and Microcystins Concentrations in Water Pans in Narok Semi-Arid Landscape, Kenya

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Narok, Water Pans, Phytoplankton Composition, Microcystin, Physico-Chemical Parameters.

ABSTRACT

Water pans in the semi-arid Narok socio-ecological landscape provide essential ecosystem services to local communities, livestock, and wildlife, but are increasingly threatened by land use changes, demographic expansion, and climate variability. There is thus an urgent need to safeguard the ecological integrity of these water bodies. This study was conducted to establish factors that determine phytoplankton and algal structure in relation to their toxins, impact on water quality, and ecosystem health from January to July 2023. Triplicate samples for phytoplankton enumeration and algal toxins were collected from twenty purposively selected water pans identified in Google Earth. Dissolved oxygen, temperature, conductivity, and pH were measured in-situ using hand-held meters while chemical concentrations were analyzed using standard procedures as guided by APHA, (2017). Enumeration and identification of phytoplankton were done at 400x magnification. Chlorophyll a concentration was determined by filtration followed by cold extraction in ethanol. Microcystin algal toxins were analyzed using the Elisa Kit Model No. 357 C. The main algal taxa identified were: Cyanophyceae, Bacillariophyceae, Chlorophyceae, Euglenophyceae, Zygnematophyceae and Dinophyceae. The most dominant algal species were Microcystis aeruginosa (25.44 %), Merismopedia spp (23.49 %), and Anabaena flos-aquae (16.06 %). Five Microcystin toxins were identified namely MC-LR, MC-YR, MC-LA, MC-RR, and MC-dmLR. Concentrations of MC-LR and MC-YR exceeded WHO acceptable standards and were significantly correlated. There was a significant difference in chlorophyll a, temperature, dissolved oxygen, conductivity, and pH among different water pans (ANOVA; $p<0.05$). The total phosphate concentration to total nitrogen concentration ratios (TP:TN) for all the water pans differed from the expected TP:TN ratio of 1:16. The presence of micro toxins in the water pans presents a concern over the suitability of the water for domestic, livestock, and wildlife use. This situation is likely to worsen with increasing episodes of drought, resulting in the concentration of the toxins in water.

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INTRODUCTION

Phytoplankton are photosynthetic organisms adapted to living in the well-lit euphotic zone where there is sufficient light penetration. Phytoplankton are primary producers in a water body (Chukwu and Afolabi, 2018) and enhance global primary production and are the base of the food web in the aquatic environment (Hallegraeff et al., 2021), which supports other trophic levels and fisheries production of a water body. The study of phytoplankton species diversity, abundance, and seasonal variation in a water body is important in understanding aquatic ecosystems and determining water quality and productivity of freshwater bodies which among other things, determine fisheries potential of the water body and suitability of the water for domestic and recreational use (Ray et al., 2021).

Phytoplankton are highly sensitive to changing water conditions caused by natural and anthropogenic activities as well as climate change (Owino et al., 2020). They can therefore be used as indicators of water pollution when monitoring water quality, as well as indicators of general environmental change in the aquatic ecosystem over time. The presence of excess inorganic nutrients, such as nitrogen, phosphorus, and silica, in a water body may lead to the blooming of harmful algae like cyanobacteria. Cyanobacteria blooms have some toxin-producing species, which pose a potential health hazard to humans and other living organisms, and the risk is high when eutrophication occurs in freshwater systems. Reynolds et al. (1987); suggest that phytoplankton biomass and composition can be used as an indicator of water quality since phytoplankton communities give more information on changes in water quality than nutrient or chlorophyll-*a* concentrations (Ptacnik et al., 2009). The blooming of algae reduces water quality when they coagulate on the water's surface and decompose (Khan, 2022). In Lake Victoria, a great diversity of cyanobacterial species has been documented, with the dominant species being *Microcystis spp.* (Olokotum *et al*., 2020). Species of this genus produce microcystins that have significant hepatotoxicity in humans and animals (Rastogi et al., 2014; Nyaundi et al., 2015; Sitoki et al., 2012; Oberholster et al., 2004) and have been identified as a significant threat to human health. Beyond microcystin, other toxins prevalent in freshwater include neurotoxins (anatoxins and saxitoxins) and cytotoxins (Cylindrospermopsin). These toxins are resistant to pH changes and dissolve easily in water, ethanol, methanol, and acetone (Obuya et al., 2024). The solubility of

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microcystins can facilitate their distribution throughout the water column, which increases the risk of contamination in drinking water sources (Ren et al., 2023). Cumulatively, these characteristics affect microcystins and are detected, analyzed, and treated in water sources, which ultimately affects the risk of human exposure. Therefore, the presence of cyanobacterial toxins within water pans represents a critical (and potentially lethal) threat to local communities, which rely on the water pans for domestic use and agriculture, as well as a source of water for livestock and wildlife. Further, there have been few biomonitoring programs of harmful cyanobacteria as well as the presence of algal toxins in both raw and portable domestic water.

Narok County's arid and semi-arid Mara River Basin in Kenya is a fast-changing landscape due to climate variability, human activities, and land-use changes. There is an urgent need to safeguard the integrity of the county’s water bodies. There is a paucity of published work on the influence of current and past land-use changes, as well as emerging climate variabilities, on the biotic structure and dynamics of ecosystems providing water resources in this fast-changing socio-ecological system. There is therefore a need to generate empirical limnological data that may inform policies for the sustainable management and utilization of water pans and similar aquatic ecosystems. The objective of this study was to provide empirical data on water quality and phytoplankton composition and assess the presence, composition, and concentrations of cyanobacterial toxins (microcystins) in water pans located in drier areas where pastoralism and wildlife are the predominant land use activity, and water pans located in the more humid areas, crop agriculture predominates. Water pans in the arid and semi-arid (ASAL) Narok landscape provide vital ecosystem services such as provision of domestic water, water for irrigation, and water to resident and migratory wildlife and are thus an important life support system in the terrestrial ecosystem. The water pans could also be important in low-tech aquaculture to diversify food security.

MATERIALS AND METHODS

Study Area

The study was conducted in the Narok, a semi-arid landscape in the Great Rift Valley in Kenya bordering Tanzania to the south at latitudes 0° 50′ and 1° 50′ South and longitude 35° 28′ and 36° 25′ East. Narok socio-ecological landscape covers an area of about 17,944km^{2}and at an altitude of about 1827m above sea level (Narok County Government, 2013) with a population of 1,157,873 (KNBS, 2019). The landscape is characterized by diverse geographical features, including savanna plains, humid hills, and parts of the Great Rift Valley. The landscape is known for its rich biodiversity and natural resources. It is home to several wildlife conservancies, including the world-famous Maasai Mara National Reserve, which forms a significant part of the Serengeti-Mara ecosystem. Pastoralism and wildlife are the main socio-economic activities in the drier savanna areas while crop agriculture predominates in the more humid Mau highlands.

The Narok landscape is predominantly characterized by pastoralism and agriculture. The Maasai people, who are known for their traditional way of life, including cattle herding, form a significant part of the population. Livestock rearing, particularly cattle, goats, and sheep, is a major economic activity in the region. Agriculture also plays a crucial role in the economy of Narok. The fertile soils support the cultivation of crops such as maize, wheat, barley, potatoes, and vegetables. Irrigation farming is practiced in some areas, particularly along the Mara River and its tributaries and some water pans.

Sampling Sites

Water pans covering the Narok Socio-ecological landscape have been georeferenced by GIS and remote sensing and also established through ground truthing (Al-Khalifa, 2023). Twenty (20) water pans

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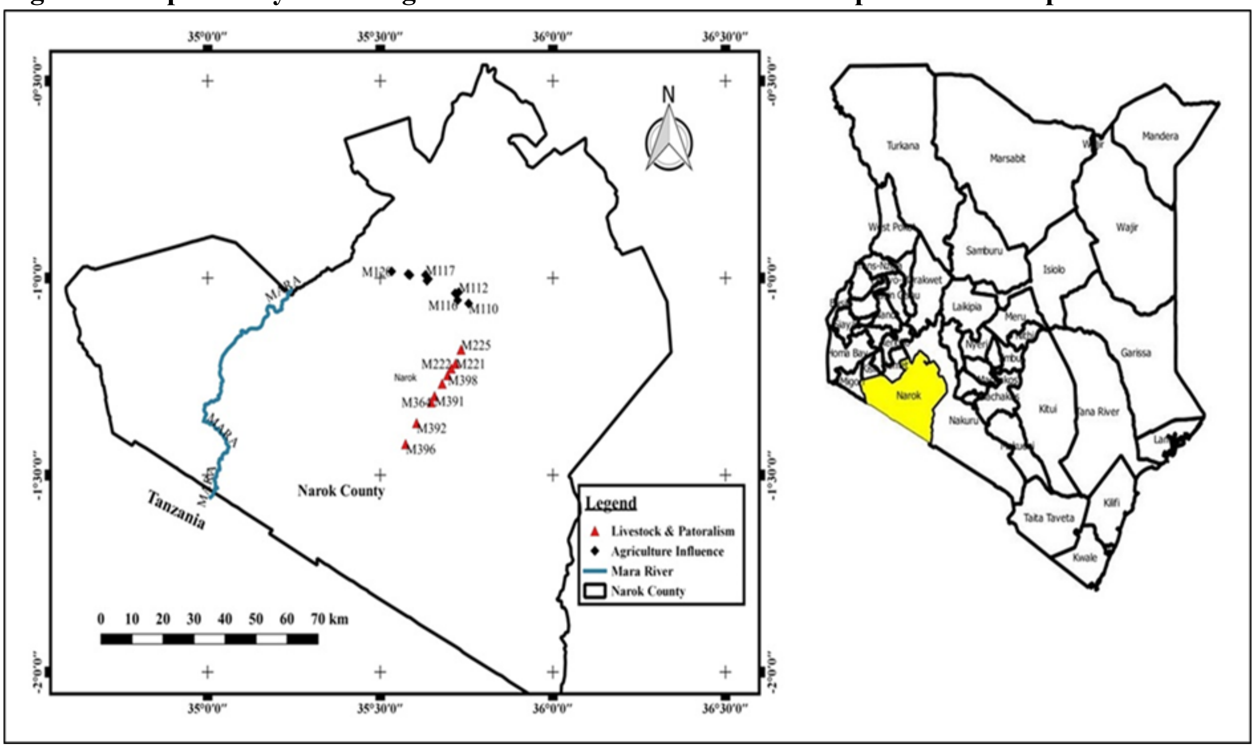
located in the humid areas (along Narok town-Mullot transect), where crop agriculture is dominant, and in drier areas (along Narok town-Sekenani transect), where livestock and wildlife are major land use activities, were identified purposively for sampling during the study. 11 water pans were selected along the Narok town-Mullot areas, where agriculture is mostly practiced, and 9 from Narok town-Sekenani transect, where livestock and wildlife are dominant. Both areas are influenced by different microclimates hence the differences in land use practices. Factors such as size, location, use, ownership, accessibility, and water capacity were considered when identifying water pans to be sampled for the study. The water pans identified in areas where agriculture and pastoralism are mostly practiced were coded as: M112, M116, M100, M110, M114, M117, M115, M118, M119, M120 and M121 while the water pans located in the drier Narok-Sekenani transect were coded as: M225, M221, M222, M348, M391, M364, M392, M396 and M398 in google earth (Figure 1).

Figure 1: Map of Kenya Showing the Location of the Narok Landscape and the Sampled Water Pans



Sample Collection

Seasonal sampling of the water bodies was carried out between January – early March 2023 and between May – July 2023 to cover both the dry and wet seasons, respectively. To reduce the effects of photorespiration and obtain maximum photosynthetic activity, sampling and determination of physico-chemical variables were done between 8 am and 12 noon. At each sampling site, 1-litre plastic bottles were used to collect sub-surface water samples for phytoplankton abundance quantification, microcystin extracellular quantification, and for nutrient analysis.

Physico-chemical Parameters

Hand-held Hanna H198194 meters were used to measure the following physico-chemical parameters *in situ*: pH, Dissolved oxygen (DO), total dissolved solids (TDS), water temperature, turbidity and electrical conductivity. The water column parameters were taken at 200 – 500 cm

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depth for water pans estimated to be less than 1.5M deep and at 500cm to 1M deep for pans estimated to be over 15.M deep. 1-litre pre-cleated polythene sample bottles were used to collect water for nutrient analysis. The bottles were preserved with sulfuric acid and stored in cooler boxes at ~4℃; for further laboratory analysis of dissolved nutrients. The APHA (2017) protocols were used to analyze all water nutrients. Thus, nutrients were analyzed using the following techniques: Total nitrogen (TN) and total phosphorus (potassium persulphate digestion method); Soluble reactive phosphorus (SRP) (the ascorbic acid method); Silicate (hetropolyblue technique), ammonia and ammonium concentrations (phenol hypochlorite methods). The cadmium reduction method was used to analyze nitrates and nitrites.

Phytoplankton Sampling

Samples for quantitative phytoplankton analysis and enumeration were taken using 25ml vial bottles from 2 – 3 points within the pan to make a single composite sample and were fixed with Lugol's solution. For qualitative analysis; of phytoplankton and microcystins samples, a 30mm mesh size phytoplankton net was used to collect water from 2 -3 points at 200 cm to 1M depth ranges, depending on approximate pan depths. Acidic Lugol's solution was used to preserve a 25-ml portion of the sample.

Phytoplankton Analysis

A sub-sample of 2 mL was placed in a Utermöhl sedimentation counting chamber and allowed to settle for at least 3 hours. A Zeiss Axio inverted 35 Microscope was used to undertake phytoplankton species identification and enumeration at 400x magnification. Up to 10 fields of view were counted for the very abundant coccoid cyanobacteria, while a 12.42 mm^2 transect was counted for the abundant and large algae. For the bigger and rarer taxa, identification and enumeration were done by examining the whole bottom area of the chamber under 100X magnification. Estimation of phytoplankton was achieved by counting all individuals, whether the organisms were colonies, filamentous, or single cells. Huber-Pestalozzi (1968); and some publications on East African lakes (Cocquyt et al., 1993) were used to identify the phytoplankton taxa to the lowest taxonomic unit possible.

Algal Sampling

A 250-ml borosilicate glass bottle was used to collect water samples for algal toxins analysis. Water samples were collected at depths less than 30cm along the pond edges where concentrations of algae were observed. Chilled samples were transported to the laboratory and refrigerated at 4℃ and were analyzed within one week of collection.

Algal Toxins Analysis

Standard procedures adopted by Miruka et al. (2021) and Sitoki et al. (2012) to study algal toxins in Lake Victoria were adopted for this study. A 25 ml syringe with a reusable syringe filter holder and disposable 0.22µm filter paper was used to filter a 100 ml sample. All samples were subjected to similar treatment before analysis. The samples were then mixed with an antibody solution and added to a 96-well microtiter plate. The wells were covered with parafilm and shaken before incubation for 90 minutes at room temperature. After incubation, the parafilm was removed, and the contents were vigorously discarded into a sink. The wells were washed three times with buffer solution, after which an enzyme conjugate (microcystin-LR conjugate solution) was added. The wells were then covered, mixed again, and incubated for 30 minutes at room temperature. After incubation, the cover was removed, and the contents were discarded into a sink after gentle shaking. The wells were then washed three times with buffer solution, followed by the addition of substrate solution, which was incubated for 30 min at room temperature. A stop solution was subsequently added and the absorbance was measured at 450 nm using a model (Model NO 35CC) ELISA photometer. Microcystin concentration was found to be inversely related to

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colour intensity, with concentrations calculated based on a standard competitive curve specific to the toxin. The structures of microcystin variants were further analyzed through high-performance liquid chromatography (HPLC-DAD) under specified equipment settings.

Data Analysis

Data transformation was considered before subjecting the data to analysis of variance (ANOVA), and normality of the data was determined using the SPSS software version 26 and R Software version3.5.0. Significant values (level of significance α = 0.05) of the tested parameters were obtained through multiple comparison tests. Significant correlations were determined to better understand associations between water quality variables.

RESULTS

The correlation between physico-chemical parameters indicated that, temperature had a moderate positive correlation with TN, TP, NH_3 and NH_4^+ (r= .318*, r= .400*, r= .385*and r= .345* respectively). Conductivity had a strong positive correlation with alkalinity (r= .839**) and hardness (r= .639**). Dissolved oxygen had a moderate correlation with pH (r= .393*), TN (r=-.479**) , hardness (r= -0.308) and silicate (r= .401*). pH had a strong positive correlation with silicate (r= .512**) and a moderate correlation with TN (r= -.371*), hardness (r= -.466**), NH_4^+ (r= -.397*) and SRP (r= .433**). Total nitrogen had a strong correlation with TP, NH_3, NH_4^+, NO_3^-, NO_2^+ and silicate (r= .666**, r= .613**, r= .691**, r= .648**, r= .729** and r= -.528** respectively). Total phosphorus had a strong positive correlation with NH_3 (r= .648**), NH_4^+ (r= .597**), NO_3^- (r= .693**) and NO_2^+ (r= .669**). Alkalinity had a strong positive correlation with hardness (r= .764**). On the other hand, Ammonia showed a strong positive correlation with NH_4^+ (r=.886**) , NO_3^- (r= .725**) and NO_2^+ (r= .711**) (Table 1).

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Table 1: Correlation between Physico-chemical Parameters

Variables	Temp.	Condu.	DO	pH	TN	TP	Alkalinity	Hardness	NH_3	NH_4^+	NO_3^-	NO_2^+	SRP	Silicate	Chlo-*a*
Temp.	1														
Condu.	-0.05	1													
DO	0.296	-0.042	1												
pH	0.048	-0.113	.393*	1											
TN	.318*	0.034	-.479**	-.371*	1										
TP	.400*	0.277	-0.088	-0.199	.666**	1									
Alkalinity	0.002	.839**	-0.124	-0.226	0.05	0.214	1								
Hardness	0.133	.639**	-0.308	-.466**	0.268	.351*	.764**	1							
NH3	.385*	0.144	-0.063	-0.269	.613**	.648**	0.281	0.304	1						
NH_4^+	.345*	0.171	-0.223	-.397*	.691**	.597**	.360*	.401*	.886**	1					
NO_3^-	0.267	0.249	-0.094	-0.21	.648**	.693**	0.265	0.224	.725**	.724**	1				
NO_2^+	0.259	0.224	-0.268	-0.187	.729**	.669**	0.189	0.22	.711**	.719**	.842**	1			
SRP	-0.116	-0.059	0.181	.433**	0.168	.327*	-0.164	-.325*	0.132	-0.041	0.302	0.188	1		
Silicate	-0.163	0.076	.401*	.512**	-.528**	-.398*	0.035	-0.258	-0.253	-0.279	-0.288	-.369*	0.144	1	
Chlo-*a*	0.141	0.208	-0.194	0.094	0.137	0.182	0.298	0.124	0.183	0.192	0.251	0.246	-0.013	0.024	1

* Correlation is significant at the 0.05 level (2-tailed).

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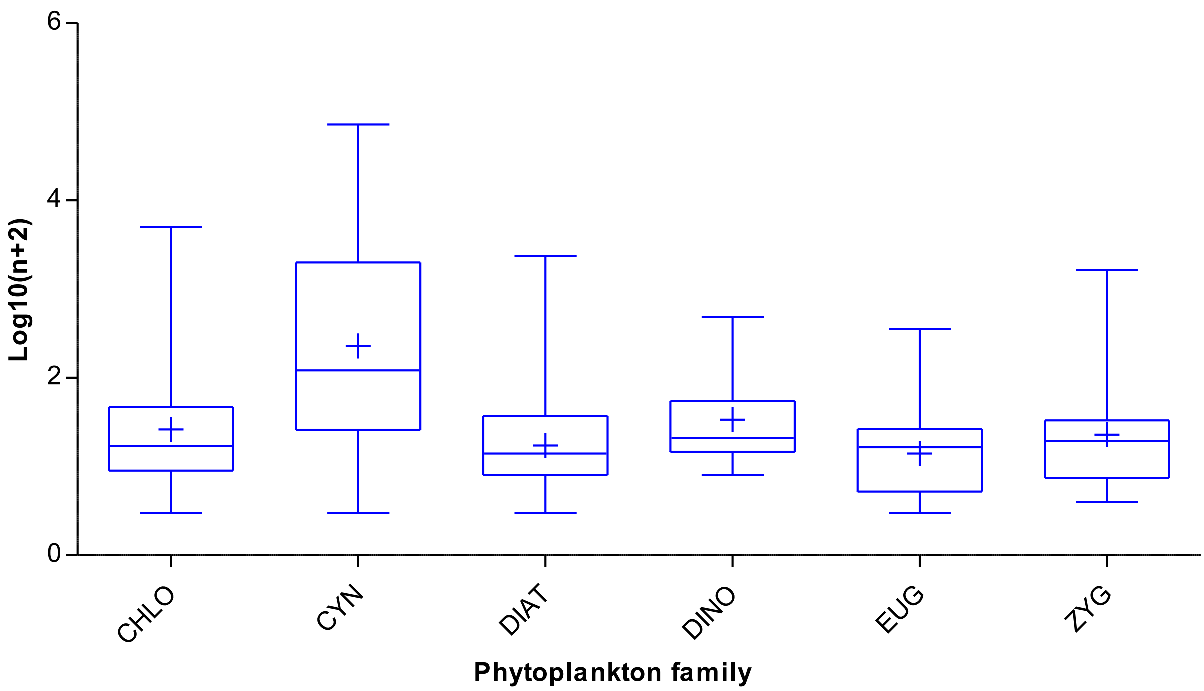
Phytoplankton Families in the Water Pans

During this study, six algal taxonomic groups were identified from the 20 water pans namely zygnematophyceae, cyanophyceae (the blue-green algae), chlorophyceae, euglenophyceae, bacillariophyceae (commonly referred to as diatoms), and dinoflagellates. Of these, the most dominant taxa across all water pans were bacillariophyceae and cyanophyceae, occurring multiple times compared to the other 4 groups, while dinoflagellates and euglenophyceae were the least prevalent (Figure 2).

Figure 2: Distribution of Log-transformed Phytoplankton Abundance Across Seven Families in Water Pans



Algal Toxins within the Water Pans in the Narok Landscape

A total of six different microcystins namely MC-LR, MC-YR, MC-LA, MC-RR, and MC-dmLR, were reported in this study during the wet and the dry seasons. Three of them, commonly produced by blue-green algae, were in relatively high quantities, while 2 were only reported in one or two instances, throughout the sampling period.

MC-LR ($p = 0.1567$), MC-YR ($p=0.1915$), MC-LA ($p=0.3005$) and MC-dmLR ($p=0.1573$) levels did not vary significantly between different sampling locations in water pans. However, MC-RR levels varied significantly different sampling locations in the water pans ($P=0.0358$). MC-LR was the most dominant toxin across all the pans, followed by MC-YR and MC-LA.

Two-way ANOVA of the five main toxins showed that the toxins were significantly different from each other ($F=6.392$, df 4, $P=0.0004$) as well as between sampling locations ($F=3.909$, df 10, $P=0.0009$). Following the Bonferroni posttest, MCLR and MCLA ($t=4.367$, $P<0.001$) and MCLR and dmLR ($t=4.172$, $P<0.001$), MCLR and MCRR ($t=5.013$, $P<0.001$), MCYR and MCLA ($t=3.247$, $P<0.05$), MCYR and dmLR ($t=3.591$, $P<0.01$) and MCYR and MCRR ($t=3.893$, $P<0.01$) varied significantly at the M100 sampling location.

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Relationship between Phytoplankton Species Abundance and the Water Quality Parameters

Spearman's correlation indicated significant relationships between phytoplankton species and physico-chemical parameters (Table 2). Conductivity was positively related to temperature, total nitrogen, and total phosphorus while it was negatively related to DO ($P<0.05$). Abundance was negatively related to all physico-chemical parameters considered except DO and pH. Considering individual Cyanobacteria taxa, *Microcystis* sp and *Anabaena* sp. exhibited a negative relationship with conductivity, temperature, total phosphorus, total nitrogen and depth while showing a positive relationship with DO and pH. *Aulacoseira* sp, *Ampora sp*, and *Nitzchia sp*. exhibited negative correlations with DO and pH while exhibiting a significant positive correlation with temperature, total phosphorus, and total nitrogen. A similar trend was shown by chlorophytes taxa *Scenedesmus* sp., *Coelastrum* sp., and *Botryococcus* sp. showed significant positive associations with DO.

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Table 2: Relationship between Phytoplankton Species Abundance and the Water Quality Parameters in Water Pans

Taxa	D.O mg/l	Conductivity	Temperature	pH	Total Phosphorus	Total Nitrogen
Microcystis sp	+0.656*	-0.336	-0.461	+0.244	-0.731*	-0.673*
Scenedesmus sp	+0.331	-0.044	-0.394	+0.159	-0.757*	-0.626*
Kirchnella sp	0.139	-0.366	-0.270	+0.130	-0.317	-0.441
Synedra sp	-0.463	+0.276	+0.519*	-0.347	+0.662*	+0.510*
Nitzschia sp	-0.579*	+0.137	+0.647*	0.517*	+0.758*	+0.574*
Euglena sp	+0.518*	+0.257	-0.119	+0.183	-0.344	-0.244
Strombomonous sp	+0.217	+0.153	-0.264	-0.063	-0.417	-0.217

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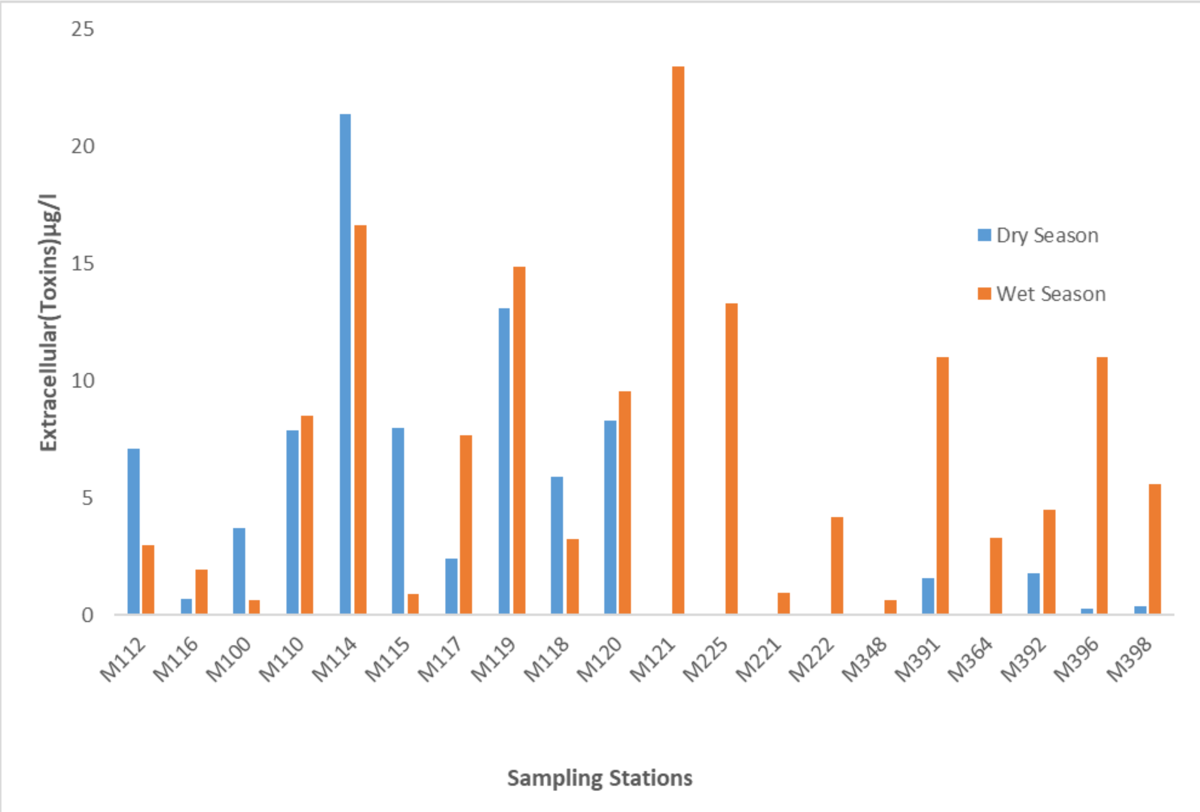
Cyanobacterial toxins (Microcystins) were detected in most of the samples (Figure 3). Twenty of the sampling sites recorded microcystin concentrations above the WHO standards of 1 µgL-1, with only the M348 and M221 sites having values within the WHO guideline levels. Microcystin structural variants, Microcystin-LR, were present in all samples except M221. M121 showed the highest concentration of microcystins, with over 22.4 µgL-1 in the dry season, followed by site M114, which recorded microcystin concentrations of 21.7 µgL-1 during the dry season.

Figure 3: The Concentration of Extracellular MC Toxins in Water Pans during the Dry and Wet Seasons.



DISCUSSION

The characteristics and stability of physio-chemical parameters influence aquatic life largely, and they also enable phytoplankton to develop adaptations that improve sustained productivity and metabolism. Phytoplankton form the base of the pyramid of productivity (Usman, 2016). Physico-chemical parameters such as temperature, pH, salinity, turbidity and nutrients influence phytoplankton species composition and distribution in a water body (Negi and Vishal, 2015). Water temperature is an essential factor that controls aquatic life while dissolved oxygen decides the ecological health of freshwater and protects aquatic life (Sharma *et al*., 2020).

Changes in the physico-chemical properties of water bodies can have both positive and negative impacts on the biota, influencing factors such as the survival and growth rates of organisms. This, in turn, may lead to the disappearance of certain species or affect their reproductive capabilities (Edward and Ugwumba, 2010). Climate change is envisaged to the have greatest impact on water resources in Africa's arid landscapes. This, coupled with increasing human population and land use changes, is likely to greatly impact livelihoods with concomitant negative impacts on food security and health. The variations in physico-chemical parameters recorded during the study could have influenced the dynamics of the water pans, including ecology, species composition, and abundance of the organisms in

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the aquatic ecosystem, which in turn influence aquatic processes of productivity in water pans. As the data shows, the changes of physical and chemical parameters in water pans are extremely variable and unpredictable across sampling stations. This may be attributable to the shallow mean depth and landscape context of the Narok socio-ecological landscape, which is strongly influenced by extremely variable seasonal; runoff from adjacent agricultural farm lands. seasonal; runoff from adjacent agricultural farm lands. seasonal; runoff from adjacent agricultural farm lands.

This together with the nature of the water pans' inflows influences the development of algal blooms and production of algal toxins. All these factors are indicators of cultural eutrophication in the water pans' ecosystem functioning. Further these factors together with climate change may be responsible for the variable nature of spatial and temporal changes in the algal community structure observed.

Species of cyanobacteria especially *Microcystis* and *Anabaena spp,* are known for their nitrogen fixation in aquatic ecosystems from the atmosphere because they have specialized cells known as heterocysts, which enable them to fix nitrogen for their photosynthetic requirements. Microcystis are characterized by the presence of vacuoles in their cells which enable them to maintain buoyancy in the water column and are therefore capable of positioning themselves at depth levels that have optimal photic conditions for their photosynthesis. According to Wetzel (1991), eutrophic waters provide a conducive environment for algal proliferation. Such eutrophic waters are characterized by high nutrient levels, particularly those of nitrogen and phosphorus. Under such conditions blue-green algae dominate. Similar observation was made in Lake Victoria and Nyaguta water pans in Kisii, Kenya, where total nitrogen and total nitrites were high, and a rich community of cyanophyte algae, consisting of *Microcystis spp, Anabaena spp, Merismopedia spp,* and *Planktolyngbya spp* was prominent (Miruka et al.,2021). In our study, *Microcystis spp* and *Anabaena spp* were the dominating phytoplankton in the water pans. These two species are known to produce powerful neurotoxins -microcystin and anacystin, respectively. These toxins can cause serious illnesses and even death to human's, domestic animals, wildlife, and other aquatic organisms. (Falconer et al., 2001). However, in this study, only microcystins were observed. This could be due to the limitation of the sensitivity of tests used to detect toxins. There is thus a gap in the information on other types of toxins which could be present in the Narok water pans, and furthermore, robust studies are required to identify the presence of other species of toxins that may be present in these vital water resources. The observed temporal changes in algal composition in the water pans may suggest similar temporal changes in algal toxin production. Further studies are required to investigate this, as well as determine the presence of other cyanotoxins in these water bodies. Studies (Lung'ayia *et al*., 2001; Wilfred et al., 2005) have shown a shift in phytoplankton species composition from a moderate mix of diatoms, greens, and blue-greens to the predominantly bloom-forming and nitrogen fixing cyanobacteria in Lake Victoria. Similar ecological shifts may be happening these small water bodies.

The presence of *Anabaena* and *Microcystis* cyanotoxin producing algal species in the water pans should be of concern. The most undesirable effects of the blooming of cyanobacteria in water systems are related to human health risks and water quality (Zamyadi et al., 2021). Cyanotoxins are known to be harmful to humans and livestock, and their presence in a water body compromises its quality and presents a major health and environmental concern. Such cyanobacteria are found in eutrophic waters and their presence has been demonstrated in Kenya's main water bodies, including main Lake Victoria (Simiyu et al., 2018: Roegner et al., 2020), its associated water bodies, and Lake Naivasha (Krienitz et al., 2013). The small size of the water pans results in higher toxin concentrations may particularly make the presence of such potentially harmful algae a major public health and environmental concern since the

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water pans are a critical source of domestic water and water for livestock in this water-stressed socio-ecological system. Episodes of harmful algal blooms (HABs) and concomitant increases in toxin-producing algae are likely to increase with increasing climate variability in this region.

Water pans in this landscape are the major source of surface water, and ensuring their quality and suitability for domestic, livestock, and wildlife use should be a top water management priority in this highly water-stressed environment. Demonstration of algal blooming and presence of potentially harmful toxins calls for the urgent institution of water management practices to protect these water bodies. Such management activities should include providing guidelines on suitable siting of water pans (e.g.) away from slope areas influenced by direct run off), avoiding mixed use of water pans (same pans used by humans and wildlife/livestock), constructing channels running from the pans to serve as livestock watering points and planting vegetation around the pans to reduce surface run off flow and protect the pans from eutrophication.

CONCLUSIONS

The study confirmed the high presence of microcystins in the water pans. This may have serious implications on the suitability of the water for domestic, livestock and livestock use and public health use. Incidents of toxicity are likely to increase with increasing incidences of climate variability, thereby further increasing the vulnerability of local communities to emerging climate stresses. This baseline information is instrumental in providing preliminary data for subsequent community-based participatory research and in empowering communities in semi-arid prone areas to protect their local economies and health.

Recommendations

Continuous monitoring of the proliferation of harmful algal bloom (HABs) and production of toxins in the water pans should be carried out.

The presence of phytoplankton and macrophytes in some of the water pans provides a basis for evaluation of primary production that will help understand the trophic status and to assess the fish production potential of these water pans.

Education and awareness creation among local communities on the public health implications of direct consumption of the water is to be initiated.

Undertake management of the water pans by implementing nature-based solutions (NBS) such as planting macrophytes around the pans to protect them from surface run-off mediated eutrophication.

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