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Research Article

Influence of Artisanal fishing Gears on Physico-Chemical Parameters of Ferguson's Gulf in Lake Turkana, Kenya

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Abstract: The influence of gill net, purse seine and beach seine gears was assessed on the basis of water physico-chemical parameters. The study considered a total of seven water quality parameters viz. Dissolved oxygen (DO), salinity, conductivity, Total Dissolved Solids (TDS), pH, Secchi depth and water temperature. Longitudinal study design was used representing dry and wet seasons. The sampling sites were selected on the basis of their relevance as exclusive gill net, purse seine and beach seine fishing sites and control where no fishing activity was taking place. Physico-chemical parameters were determined in situ. The data generated was analyzed using one-way ANOVA at $p<0.05$ and Student's t-Test at $p<0.05$ to establish spatial and seasonal mean variation of physico-chemical parameters respectively. Correlational analysis was done to establish the relationship among physico-chemical parameters ($p<0.05$). Results indicated that temperature, DO, salinity, conductivity, TDS, pH, and Secchi depth were significantly different in sites where gill net, purse seine and beach seine gears were used including control sites (ANOVA, $p<0.05$). Salinity, conductivity, TDS, pH and Secchi depth varied seasonally (Student's t-Test, $p<0.05$) but not dissolved oxygen and temperature. Correlational analysis showed significant correlation of salinity to Total Dissolved Solids ($p<0.01$, $r=0.830$) and conductivity ($p<0.01$, $r=0.927$). This study revealed that salinity and conductivity values decreased spatially and seasonally towards the mouth of Ferguson's gulf. The use of purse seine gears led to increased dissolved osygen while gill net sites had high Total dissolved solids. The study recommends monitoring of water quality parameters for fish survival and ecosystem health.
Keywords: Artisanal fishing gears, Beach seine, Purse seine, Gill net, Physico-Chemical parameters, Ferguson's gulf, Lake Turkana

INTRODUCTION

The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in wild fishes. Pollution of the aquatic environment by inorganic and organic chemicals has received much attention since it is considered as a major factor posing serious threat to growth and survival of fish [1]. Furthermore, the presence of environmental stresses such as low dissolved oxygen and high temperature reduces the ability of aquatic organisms to maintain its internal environment [2]. The need to manage aquatic ecosystems and fisheries resources has also necessitated research on the influence of fishing gears on water quality with focus on physical-chemical parameters.

Dragged fishing gears along the seafloor could cause reduced light levels due to re-suspension of sediments leading to lowered primary productivity and increased difficulty in finding prey [3]. If re-suspension occurs over a large enough area it can actually cause large scale redistribution of sediments due to exposure of deep anaerobic sediment and upward flux of dissolved nutrients [4-6]. The influence are likely more significant in waters that are normally clear compared with areas that are already highly perturbed by physical forces thus impacting greatly on fish species that are less tolerant to high turbidity levels [7]. Chronic suspension of sediments and resulting turbidity can also affect aquatic organisms through behavioral and lethal influence, depending on exposure. It is therefore imperative to determine whether the changes in physico-chemical parameters dynamics caused by artisanal fishing gears are within the optimal range for survival of fish species. Set nets such as gill nets cause significant increase in suspended particulate matter after fishing activity which could lead to potential cascade impacts on water quality, particularly during retrieval of gear through the action of lead weights on the bottom sediments[8]. Chronic fishing disturbance leads to the removal of high-weight species which have been shown to provide shelter for juvenile fishes, reducing their vulnerability to predation and subsequent changes in the composition of the resident fish fauna [7]. Sediment re-suspended as a result of bottom fishing will have a variety of influence including: releasing nutrients held in the sediment; exposure of anoxic layers; release of contaminants; increasing biological oxygen demand; and smothering of feeding and respiratory organs.

Fish species reaction to suspended particulate matter depends on life history parameters of the species[9]. Mobile organisms can move out of the affected area and quickly return once the disturbance dissipates. Even if species experience high mortality within the affected area, species with short life history stages and high levels of recruitment or high mobility can repopulate the affected area quickly. Furthermore, re-suspension of sediments may lead to shifts in species composition by favoring those species that are better suited to recover or those that can take advantage of the pulsed nutrient supply as nutrients are released from the seafloor to the euphotic zone [10]. In conclusion, the intensity of the disturbance depends on used gear, sediment type and water depth.

Lake Turkana and Ferguson's gulf in particular has recorded an increased fishing activity and intensive use of beach seine, purse seine and gill net gears without any standards and regulations. Furthermore, water quality of Ferguson's can deteriorate through abrasion and scraping by these gears with consequences on fish diversity, abundance and distribution. Kenya Marine and Fisheries Research Institute (KMFRI) [11] instead conducted a limnological survey in Lake Turkana, including Ferguson's gulf but not influence of fishing gears on physico-chemical parameters. It is noteworthy that most of the studies conducted globally and Kenya in particular on influence of fishing gears on water quality have focused on marine environments with emphasis on industrial gears and physical parameters. Moreover, most of these studies have been qualitative with no empirical basis to warrant effective management of fisheries and aquatic ecosystems.

The aim of this study is to determine the influence of artisanal fishing gears on physico-chemical parameters of Ferguson's gulf by providing empirical data on gill net, purse seine and beach seine gears mostly used in artisanal fisheries for management of Lake Turkana ecosystem.

MATERIALS AND METHODS

Site Description

Lake Turkana is the world's largest Desert Lake which is 68,800 sq km (26,600 sq mi) by volume. The lake is 250 km long, 15–30 km wide, has an area of nearly 7,000 km^2. Lake Turkana is found in the Eastern arm of Great Rift valley located in a closed basin stretching from 35^{0}50' to 36^{0}40' E and 02^{0}27' to 4^{0}40' N, in North western Kenya, at an altitude of 360.4 m above sea level. The Turkana has relatively low fish species richness, providing habitat for about 50 species with most of the aquatic fauna dominated by Nilotic riverine fish species. River Omo which drains the southwestern portion of the Ethiopian Massif and flows through the Rift Valley into Lake Turkana is its only perennial tributary, supplying over 90% of the lake's inflow. Ferguson's gulf of Lake Turkana is located about mid-way along the Western shore of Lake Turkana stretching from 03º28.28' N and 035º50.50' E. The vegetation along the lake shore is dominated by the doum palm, *Hyphaene compressa* and grass, *Chrysopogon aucheri*. The introduced invasive plant, *Proposis julifora* is slowly becoming dominant and an increasing threat to navigation and landing at Ferguson's gulf. Following the perennial drought and famine in Turkana County, Ferguson's gulf has recorded increased unregulated fishing activity with most of artisanal fishers using non-selective fishing gears such as beach seines and purse seines.

Study design and Sample collection

Longitudinal research design was used for this study with data collection done from the month of June to November, 2014 representing dry and wet seasons. Ferguson's gulf was purposively divided into four zones consisting of exclusive beach seine, gill net and purse seine fishing sites including control where no fishing activity was taking place. Three sampling sites were purposively selected for each fishing gear and control, totaling to 12 sites as shown in Figure 1. Three replicate samples for each parameter were obtained monthly from each site in situ totaling to 18 replicates per site and 216 for the whole study period. Conductivity, salinity, water temperature and total dissolved solids were measured in mg/l using HACH Sension 5 and HANNA HI 9835 meters while pH was determined using HANNA Ph/ORP H19025C meter. Dissolved oxygen was measured in Mg/l using Adwa AD 630 meter while Secchi depth was measured using a standard black and white disc of diameter 20 cm, with quadrants shaded alternately.

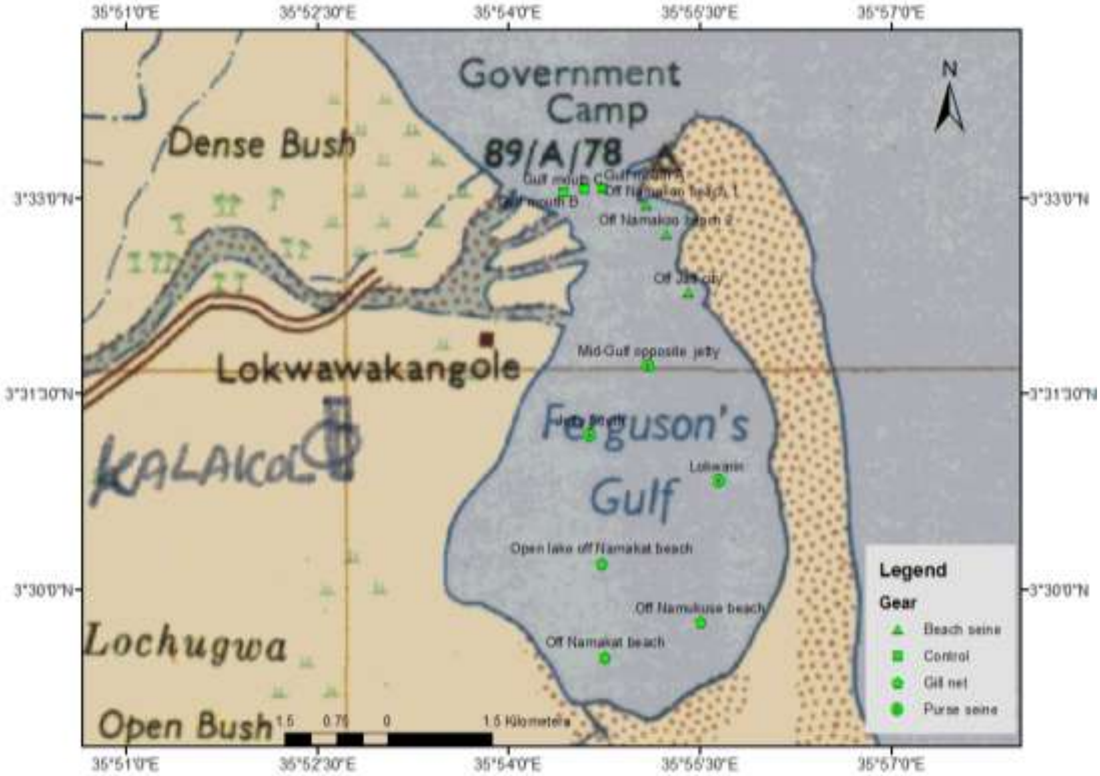

Fig 1: Map of Ferguson's gulf showing sampling sites for Beach seine, purse seine, and gill net gears including control

Statistical Analysis

Descriptive statistics was used to summarize the data presented as means and standard deviations. One-way ANOVA at $p<0.05$ was used to determine differences in physico-chemical parameters in beach seine, purse seine and gill net fishing sites as well as control. For differences in physico-chemical parameters that were found significant at $p<0.05$, post hoc separation of means was done by Duncan's Multiple Range Test to find true differences in means. Correlation analysis at $P<0.05$ was used to describe relationships among physico-chemical parameters. Student's t-Test at $p<0.05$ was used to determine whether physico-chemical parameters differed significantly between wet and dry seasons.

RESULTS

The various water physico-chemical parameter indicators such as dissolved oxygen, salinity, conductivity, secchi depth, total dissolved solids and temperature were analyzed for different fishing sites where different fishing gears were used including control sites and the data was presented in Table 1 and 2. Further, a correlation analysis was done and results presented in Table 3.

Influence of fishing gears on physico-chemical parameters of Ferguson's gulf

According to data on Table 1, Dissolved oxygen (DO) significantly differed in all the fishing and control sites (One-way ANOVA, $F_{(3,212)} = 66.689$, $P = 0.0001$). Duncan's Multiple Range Test (DMRT) further showed significant difference of Dissolved Oxygen in all the fishing and control sites. The highest mean Dissolved Oxygen (DO) of 9.13±0.77mg/l was recorded in purse seine gear sites while the lowest mean DO value of 7.62±0.38 mg/l was recorded in control sites. Mean DO values of 8.51±0.62mg/l and 8.05±0.49 mg/l were recorded in beach seine gear and gill net gears sites.

Table 1: Influence of treatments on physico-chemical parameters of Ferguson's gulf

	Physico-chemical parameters (Mean±SD)						
	pH	Salinity	Conductivity (µS/cm)	Secchi depth (cm)	TDS(mg/l)	DO (mg/l)	Temp. (ºC)
Gill net	9.19±0.62^{B}	2.18±0.29^{A}	4764±532^{A}	21.6±4.2^{A}	1922.1±105.9^{C}	8.05±0.49^{A}	31.2±1.2^{B}
Purse seine	9.27±0.22^{B}	2.13±0.33^{A}	4690.6±646^{A}	25.5±2.1^{BC}	1888.7±109.2^{C}	9.13±0.77^{B}	31.3±1.1^{AB}
Beach seine	8.86±0.45^{A}	1.99±0.32^{B}	43646±615^{B}	24±6^{B}	1840.9±114.5^{B}	8.51±0.62^{C}	30.9±0.7^{B}
Control	9.34±0.63^{B}	1.58±0.24^{C}	3122±228^{C}	26.9±7.6^{C}	1681.5±51.7^{A}	7.62±0.38^{D}	31.1±0.6^{A}

Means with different superscripts in the same column are significantly different at $P<0.05$. (Data analyzed by Duncan's Multiple Range Test)

Salinity values were significantly different in all the fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 45.172, P =0.0001), with Duncan's Multiple Range Test showing significant difference of gill net gear sites from control and beach seine gear sites but not purse seine gear sites. The highest (2.18±0.291) mean salinity was recorded in gill net sites while the lowest value of 1.58±0.24 was recorded in control. Beach seine and purse seine gear sites recorded salinity values of 1.99±0.32 and 2.13±0.33 respectively.

Like wise, conductivity differed significantly in all the fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 116.43, P =0.0001). The lowest conductivity of 3123±228µS/cm was recorded in control while the highest conductivity of 4764±531µS/cm was recorded in gill net gear sites. Conductivity values of 43646±615µS/cm and 4690.6±646µS/cm were recorded in beach seine and purse seine gear sites respectivity. DMRT further established significant difference of gill net gear sites from control and beach seine gear sites but not purse seine gear sites.

The highest pH of 9.34±0.63 was recorded in control sites while the lowest (8.86±0.45) was recorded in beach seine gear sites. Gill net and purse seine gear sites recorded 9.19±0.61 and 9.27±0.22 respectively. Significant difference in pH was established in all fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 9.431, P =0.0001), with Duncan's Multiple Range Test showing that control sites differed significantly from beach seine gear sites but not from purse seine and gill net gear sites.

Furthermore, Total Dissolved Solids differed significantly in all the fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 62.968, P =0.0001). The lowest (1681.5±51.77mg/l) mean TDS was recorded in control while the gill net gear sites recorded the highest (1922.15±105.93mg/l). The mean TDS value of 1888.7±109.2mg/l, was recorded in purse seine gear sites while 1840.9±114.5mg/l mean TDS was recorded in beach seine gear sites. Duncan's Multiple Range Test showed that purse seine gear sites differed significantly from beach seine gear and control sites but not gill net gear sites.

The Secchi depth showed significant difference in all fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 9.6, P =0.0001) with Duncan's Multiple Range Test showing that gill net gear sites differed significantly from purse seine gear, beach seine gear and control sites but beach seine and purse seine gear sites were not significantly different. The highest (26.97±7.57cm) secchi depth mean was recorded in control sites while the lowest was recorded in gill net gear (21.63±4.20cm) sites. Purse seine gear and beach seine gear sites recorded (25.5±2.1cm) and (24±6cm) respectively.

There was significant difference in mean temperature of all fishing and control sites (One-way ANOVA, $F_{(3,212)}$ = 2.672, P =0.012), with Duncan's Multiple Range Test showing that control sites differed significantly from beach seine gear and gill net gear sites but not purse seine gear sites, while beach seine sites did not significantly differ from gill net gear sites. The highest (31.5±1.1ºC) mean was recorded in gill net gear sites while control sites had the lowest mean (31.0±0.7ºC). Purse seine gear and beach seine gear sites had 31.2±0.6ºC and 31.4±1.1ºC mean temperature respectively.

Water physico-chemical parameters variation with Seasons

From the data in Table 2, there was no significant difference of DO with seasons during the study period (Student's t-Test, P<0.05). However, there was significant difference in salinity with the highest mean (2.2±0.31) recorded during the dry period while the lowest mean (1.74±0.29) was recorded during the wet season. Analysis of data with Student's t-Test at P<0.05, showed significant differences in conductivity levels of dry season from the wet season. A higher conductivity mean (4600±940µS/cm) was recorded during the dry period while the lowest conductivity (3900±560µS/cm) was recorded during the wet season. Further, significant seasonal difference in pH mean (Student's t-Test, P<0.05) was established with, a higher pH mean (9.49±0.41) recorded during the wet season while a lowest mean (8.84±0.45) was recorded during the dry period. The study established significant differences in total dissolved solids between dry and wet season (Student's t-Test, P<0.05) with highest TDS mean (1883.9±119.4mg/l) recorded during the wet season and the lowest mean (1782.7±130.6 mg/l) recorded during the dry season. Furthermore, analysis of secchi depth data showed significant differences in secchi depth of the dry season from the wet season with the highest Secchi depth mean (26.4±4.15cm) recorded during the dry season while the lowest mean (22.7±6.4cm) during the wet season (Student's t-Test, P<0.05). However, temperature did not significantly vary during dry and wet season (Student's t-Test, P<0.05).

Table 2: Seasonal variation of physico-chemical Parameters of Ferguson's gulf

Season	Physico-chemical parameters (Mean±SD)						
	pH	Salinity	Conductivity (μS/cm)	Secchi depth (cm)	TDS(mg/l)	DO (mg/l)	Temp. (ºC)
Dry	8.84±0.45^{A}	2.2±0.31^{A}	4600±940^{B}	26.4±4.15^{A}	1782.7±130.6^{A}	8.3±0.9^{A}	31±0.8^{A}
Wet	9.49±0.41^{B}	1.74±0.29^{B}	3900±561^{A}	22.7±6.4^{B}	1883.9±119.4^{B}	8.4±0.7^{A}	31±1.0^{A}

Means with different superscripts in the same column are significantly different at P<0.05. (Data analyzed by Student's t-Test)

Correlation among physico-chemical parameters

According to the data on Table 3, salinity (P<0.01, r=0.354), conductivity (P<0.01, r=0.432) and total dissolved solids (P<0.01, r=0.427) had a weak positive correlation to dissolved oxygen. Furthermore, Pearson product-moment correlation showed a significant strong positive relationship of salinity to conductivity (P<0.01, r=0.927) and total dissolved solids (r=0.830, P<0.01). Results of correlation done on pooled data further indicated that salinity (P<0.01, r=0.927) and total dissolved solids (P<0.01, r=0.830) were positively and strongly correlated to conductivity. Secchi depth had a negative weak correlation to pH (r=-0.248), salinity (r=-0.387), conductivity (r=-0.325), and TDS (r =-0.280) statistically significant at P<0.01. However, no significant relationship between pH and other physico-chemical parameters was established.

Table 3: Correlation matrix of physico-chemical parameters of Ferguson's gulf

	pH	**Salinity**	**Conductivity**	**Secchi**	**TDS**	**DO**
pH	1					
Salinity	.525**	1				
Conductivity	.384**	.927**	1			
Secchi	-.248**	-.387**	-.325**	1		
TDS	.376**	.830**	.844**	-.280**	1	
DO	-.032	.354**	.432**	-.039	.427**	1
Temperature	.074	.144*	.141*	.029	-.027	.065

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

DISCUSSION

Influence of fishing gears on physico-chemical parameters of Ferguson's gulf

The highest dissolved oxygen mean (9.13±0.77mg/l) recorded in purse seine gear sites was due to the fact that purse seine fishers, unlike the beach seine and gill net fishers, agitated the water mechanically using oars and their feet inorder to drive fish into the set nets leading to high dissolved oxygen concurrent with EPA [12] that reported increased dissolved oxygen by mechanical addition. The lowest dissolved oxygen mean recorded in control site (7.62±0.38 mg/l) was due to lack of fishing activity resulting into undisturbed state. Nevertheless, the dissolved oxygen concentration was slightly above the values (2.59-8.46 mg/l) for Lake Turkana established in the previous study by KMFRI [11] and also within the optimal levels (6-9 mg/l), as determined by Bisht *et al.* [13] for fish survival. Therefore dissolved oxygen resulting from purse seine gears does not limit fish growth and survival in Ferguson's gulf as it is within the optimal levels and also within those of the entire Lake Turkana.

This study found out significant differences in salinity and conductivity levels between beach seine gear and control sites, though salinity and conductivity levels at the gill net gear and purse seine gear sites were not significantly different. The highest salinity mean (2.18±0.291) and conductivity mean (4764±531μS/cm) were recorded at gill net gear sites while the lowest salinity mean (1.58±0.24) and conductivity mean (3123±228μS/cm) was recorded at control sites. The influence of artisanal fishing gears on conductivity and salinity of Ferguson's gulf, as the study established, showed a similar trend and a positive relationship, since dissolved ions increases salinity as well as conductivity of water [14]. According to the above findings it is implied that salinity and conductivity levels within Ferguson's gulf followed a gradient with salinity and conductivity values decreasing towards the mouth from the far end of Ferguson's gulf. This was attributed to the mixing with waters of the main lake, which has low salinity compared to the gulf, leading to lower salinity values recorded in the control, beach seine and purse seine gears sites, incomparison to gill net gear sites which were at the far end of Ferguson's gulf. Consistent with current study findings of Odada *et al.*[15] and Harbbot [16] also reported the decreased salinity levels towards North of Lake Turkana due to the influence of dilute Omo river flood waters. The high salinity and conductivity of Ferguson's gulf was also attributed by KMFRI [11] to the seasonal and cyclic filling and drying of the gulf that makes it a hub for marked concentration and deposition of salts to extremely high values, therefore leading to seasonal variation recorded during the study.

This study established that pH varied significantly between beach seine, gill net and purse seine gears sites as well as control sites. The highest pH mean (9.34±0.634) recorded at the control site could be attributed to the influence of freshwater influx from the main lake and dilution by lake water as well as presence of carbonate and bicarbonates. This findings concurred with KMFRI [11], Utah State University [17] and Manikannan *et al.*[18] that reported increased pH with increasing carbonates and bicarbonates in water. The alkaline condition in Ferguson's gulf was attributed to high content of dissolved salts in Lake Turkana due to evaporative concentration resulting to accumulation. However, the lowest pH mean (8.86±0.45) at the beach seine gear sites was due to the waste discharge, microbial decomposition and organic matter from the fringing human settlements with no established waste treatment and disposal facilities. This, as explained by Nirmala *et al.* [19] and Winter *et al.* [20], could be due to the fact that organic matter degraded by microbes, produces high concentrations of dissolved carbon dioxide which lowers the pH by increasing the carbonic acid (H_2CO_3) concentration in the water.

The study established significant variation of total dissolved solids in Ferguson's gulf with highest mean (1922.15±105.93mg/l) recorded in gill net gear sites while the lowest mean (1681.5±51.77mg/l) was recorded in control sites. The highest TDS mean in gill net gears was due to the fact that gill nets gear sites were mainly set close to vegetated gulf shore with littoral macrophytes and Prosopis juliflora. As explained by Raspopov *et al.*[21] and Murphy [22], littoral vegetation produce organic matter destroyed by bacteria leading to the release of dissolved organic particles contributing to the increased TDS concentration in gill net sites while the low TDS mean in control site was attributed to undisturbed condition due to lack of fishing activity and an open shore with no littoral vegetation. The lowest secchi depth mean (21.63±4.20cm) at the gill net gear sites was due to presence of littoral vegetation including Prosopis juliflora which produced and added organic materials into the water column while high secchi depth mean (26.97±7.57cm) at control indicated clear waters with high light penetration due to less pertubation due to absence of fishing activity. The study established no significant spatial and seasonal differences in temperature was concurrent with Nirmala *et al.* [19], KMFRI [11], Kolding [23] and Avery [24] and attributed to atmospheric temperature, weather conditions and near-proximity to the equator.

Seasonal variation of Physico-chemical parameters

Lack of significant difference in DO between dry and wet season could be attributed to the fact that dissolved oxygen enters through the air and it can be mixed quickly through aeration which can be caused by creating waves or mechanical agitation concurrent with EPA [12] that reported increased dissolved oxygen through aeration caused by creating waves or mechanical agitation. Thus, the use of purse seine gears increased dissolved oxygen during the study period. Moreover, salinity and conductivity also varied significantly during the wet and dry season. The highest conductivity mean (4600±940µS/cm and salinity mean (2.2±0.31) were recorded during the dry period while the lowest conductivity mean (3900±560µS/cm) and salinity mean (1.74±0.29) were recorded during the wet period consistent with Perlman [25] that reported a decrease in salinity and conductivity at the beginning of the wet season and increase during the dry season. Concurrent with Manikannan *et al.*[18] and KMFRI [11], the high degree of evaporation during the dry season could cause ion concentrations to rise resulting to higher salinity and conductivity values during the dry period in Ferguson's gulf. On the other hand, heavy rainfall and large quantity of freshwater inflow majorly from Omo River was responsible for low salinity and conductivity during the wet season. However, the conductivity mean (4200±841µS/cm) in Ferguson's gulf were outside the normal range of 150-500µS/cm established by EPA [12] for freshwater bodies which support diverse range of fish species. Therefore, the survival, distribution and movement of fish species in Ferguson's gulf could be highly determined by the tolerance range to high salinity levels thus favouring survival of fish species such as Oreochromis niloticus with broad range of tolerance.

The established higher pH mean (9.49±0.41) recorded in wet season and lower mean (8.84±0.45) in dry season concurred with Manikannan *et al.* [18]. The seasonal variation in the pH could be due to the presence of hard-water minerals, bicarbonate ions in run-off resulting from limestone deposits which react with the water to produce OH– ions, thus raising the pH values during the wet season in Ferguson's gulf. The findings concurred with Manikannan *et al.* [18] that reported seasonal variation of physico-chemical parameters of the great Vedaranyam swamp, South-east coast of India selected rivers of India. Nevertheless, the mean pH (9.2±0.54) was within the range found in the previous study by Kolding [23] and KMFRI [11] of 7.8-9.8 and also slightly above the optimal pH range of 6.5-9.0 for survival of most aquatic organisms. Consistent with the study findings, Avery [24] concluded that Lake Turkana is a sodium carbonate lake with a high pH level and within ionic composition typical of East African lakes. Therefore variation of pH level during the dry and wet seasons could be a limiting factor in growth and survival of most fish species in Ferguson's gulf. Moreover, significant differences in TDS levels of the dry season from the wet season was established in Ferguson's gulf with highest mean (1883.9±119.4mg/l) recorded during the wet season and the lowest mean

(1782.7±130.6 mg/l) during the dry season. This could be due to large amounts of sediment load transported from the watershed into Ferguson's gulf since Lake Turkana is located in arid area with sparse vegetation. This variation agreed with Patel and Dakar [26] and Vaishali and Punta [27] and Simpi [28] that TDS varied during the wet and dry seasons and attributed the high TDS levels during the wet season to large amount of sediment load transported from the watershed during the wet season.

The seasonal variation in secchi depth with recorded low mean (22.7±6.4cm) during the wet season was due to increased the level of total suspended solids through run-off and resuspension of bottom sediments with increased flow rate further raising the total suspended solids concentrations. This was consistent with Michaud [29], EPA [12], Perlman [25] and Washington State Department of Ecology [30] that reported low water clarity during wet season due to increased turbidity and suspended solids resulting from run-off and erosion into the water body. The highest secchi depth recorded during the dry season was attributed to the reduced sediment load into the gulf. However, the secchi depth mean was below the range obtained by KMFRI [11] for Lake Turkana, an indication of increased sedimentation and suspended particulate matter resulting into low transparency in Ferguson's gulf, with implication on fish species survival and distribution. The study established significant differences in temperature in beach seine, purse seine and gill net gears and control sites (Table 1) and further no seasonal variation (Table 2). The high temperature recorded in gill net gear sites was attributed to high suspended solids, and relatively shallow nature of these sites. These findings concurred with Washington State Department of Ecology [30] and EPA [11] that reported higher temperatures of shallow water bodies and increase in temperature with increased suspended solids in the water column as they absorb solar radiation more effeciently than water. Lack of seasonal variation as observed by the study was due to stable weather conditions and atmospheric pressure and near proximity of Lake Turkana to the equator concurrent with KMFRI [11], Kolding [23] and Avery [24] that reported lack of variation in temperature of Lake Turkana similar to other East African Lakes.

Correlations of physico-chemical parameters

Significant positive correlation of TDS with salinity and conductivity can be attributed to the fact that TDS and salinity can be derived from conductivity hence showing positive correlation and increased TDS constant with increasing conductivity and salinity concurrent with Vaishali and Punta [27] and Scannell and Jacobs [14] that pointed out the positive correlation between salinity and conductivity. The change in the level of salt concentration during wet and dry season therefore led to cyclic change in salinity and conductivity in Ferguson's gulf with recorded low value and high value during the wet season and dry season. Significant negative correlation of secchi depth to pH, salinity, conductivity and TDS agreed with EPA [11] and Michaud [29], Washington State Department of Ecology [23] that reported decreased water clarity with increased dissolved and suspended solids in water column and as well as inonic concentration in water responsible for increased TDS, pH, conductivity and salinity. The low secchi depth mean (14-41.5cm) of Ferguson's gulf obtained by the study, according to Fuller and Minnerick [31], were indicative of hypereutrophic conditions characterized by excessive nutrient concentrations and with waters undesirable for human drinking and other need. However, this was contrary to the findings of Odada *et al.*[15] for the entire Lake Turkana and within the secchi depth values of Ferguson's gulf value (50 cm) obtained by KMFRI [11] and similarly lower than those from the main lake (255 cm) due to high turbidity and therefore the poor light penetration. Low Secchi depth value at Ferguson's gulf has implications for fish movement distribution since fish rely on sight and speed to catch their prey; they are affected by low water clarity and therefore often flee the affected areas for new territories. This could therefore explain the low overall species diversity and variation of fish abundance in Ferguson's gulf as established by this study.

CONCLUSION

The use of purse seine gears contributed to increased dissolved oxygen while other physico-chemical parameters such as pH, salinity, conductivity, total dissolved solids and secchi depth were mainly influenced by seasons. However, temperature and dissolved did not show seasonal variation. Salinity and conductivity levels within Ferguson's gulf followed a gradient with values decreasing towards the mouth of the gulf due to mixing with dilute water of the main lake. However, with exception of salinity and conductivity, all the physico-chemical parameters were within the optimal range for survival of fish species in Ferguson's gulf.

RECOMMENDATION

A regular monitoring programme of physical and chemical parameters should be carried out to investigate their influence on fish movement and distribution. The sources of nutrient load into Ferguson's gulf leading to hypereutrophic conditions should also be established.

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