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Research Article

Influence of Artisanal Fishing gears on Fish Abundance and Species Diversity in Ferguson's Gulf of Lake Turkana, Kenya

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Abstract: Fish abundance and species diversity of gill net, purse seine and beach seine gears was assessed based on fish samples obtained from artisanal fishermen in Ferguson's gulf. Longitudinal study design was used with data collection done during dry and wet seasons. The data generated was analyzed using One-way ANOVA at $p<0.05$ and Student's t-Test at $p<0.05$ to establish significant differences among the fishing gears and seasonal differences respectively. One-way ANOVA, $F_{(2,159)} = 6.672$, $P=0.002$ indicated significant differences in fish abundance for all the fishing gears, with purse seine (49%) accounting for the highest proportion, while gill nets contributed the least (14%). Significant difference in Shannon-wiener diversity (ANOVA, $F_{(2,159)} = 891.33$, $P=0.0001$) and Evenness indices (ANOVA, $F_{(2,159)} = 6974.188$, $P<0.0001$) was established for all the fishing gears with higher values recorded in beach seine gears indicating high species diversity. Student's t-Test established significantly high Shannon-wiener diversity ($P=0.003$) and evenness ($P=0.029$) indices during wet season than dry season. However, no significant seasonal differences in fish abundance was established (Student's t-Test, $P=0.471$). Despite the high abundance and diversity of the fish species caught by purse seine and beach seine gears in that order, most of the catch was dominated by Oreochromis niloticus indicating low overall species diversity of Ferguson's gulf. The study revealed that purse seine accounted for high fish abundance, while beach seine captured highest number of fish species. Introduction of quotas to limit the abundance of fish landed by purse seine gears in Ferguson's gulf is recommended by the study.
Keywords: Artisanal fishing gears, Fish abundance, Fish species diversity, Ferguson's gulf, Lake Turkana.

INTRODUCTION

Fishing equipment can determine what species they catch as different types of gears used can target different families of fish leading to significant difference in fish abundance and species diversity associated[1]. Purse and beach seine fishing gears are largely unselective in what families they target, catching whatever is in the way while selective gears such as gill nets, in contrast, are highly selective as they are used to catch whatever the fisherman wants. Moreover, beach seines account for the highest number of fish landed as well as smaller fish compared to gill nets with beach seines catching the highest number of species [2]. However, this high diversity of catch is likely to explain the rapid decline in catch at high levels of fishing effort and allows more resources to be utilized but the ultimate consequence of this versatility is a potential for total fisheries collapse at high levels of fishing effort[3].

Studies have established that heavily exploited species decline in abundance, spatial ranges and degree of overlap with other species, while populations of weakly exploited species increased [4,5]. Furthermore, fishing grounds where beach seines were still in use have a significantly lower density than where beach seining was not used [6]. The capture and landing of high number of fish and species diversity by beach seines could result in decline in herbivorous fishes, which has serious consequences for recovery and resilience of the ecosystem[2, 7]. Therefore, exploitation strongly modifies species interactions through alterations in species composition thus raising concerns on the possible fishery collapse at high fishing effort.

The area of Ferguson Gulf of Lake Turkana has several fishing gears such as gill nets, long lines, hooks and spears [8]. However, beach seines, purse seines and gill nets are the mostly used gears in the artisanal fisheries of Ferguson's gulf. Gill nets capture mostly tilapia, whereas, purse and beach seines capture all sizes of many different fish species. There is noted increased number of artisanal fishers using seine and gill nets with increasing fishing intensity, fishing effort and increased number of fish landed without

regulations. 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 [9]. However, the potential influence of these fishing gears on fish abundance and species diversity remain unknown. Several studies undertaken by among others [10, 11]. Kenya Marine and Fisheries Research Institute (KMFRI) [12], and Musvka *et al.;* [13] instead concentrated on fisheries resources, limnology, productivity of Lake Turkana and fish assemblage. Therefore this study comparatively assessed the fish abundance and species diversity of beach seine, purse seine and gill net gears used in Ferguson gulf in Lake Turkana.

It is interesting to note that most of studies on influence of artisanal fishing gears on fish abundance and species diversity have been conducted in marine environments [14,15,16]. Of particular concern is that most of the studies are non-empirical and have given less attention to fish abundance and species diversity in freshwater environments. Therefore there is need to conduct research on the influence of artisanal fishing gears on species diversity and abundance in freshwater environment to fill the knowledge gap.

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. 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 (Figure 1). 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.

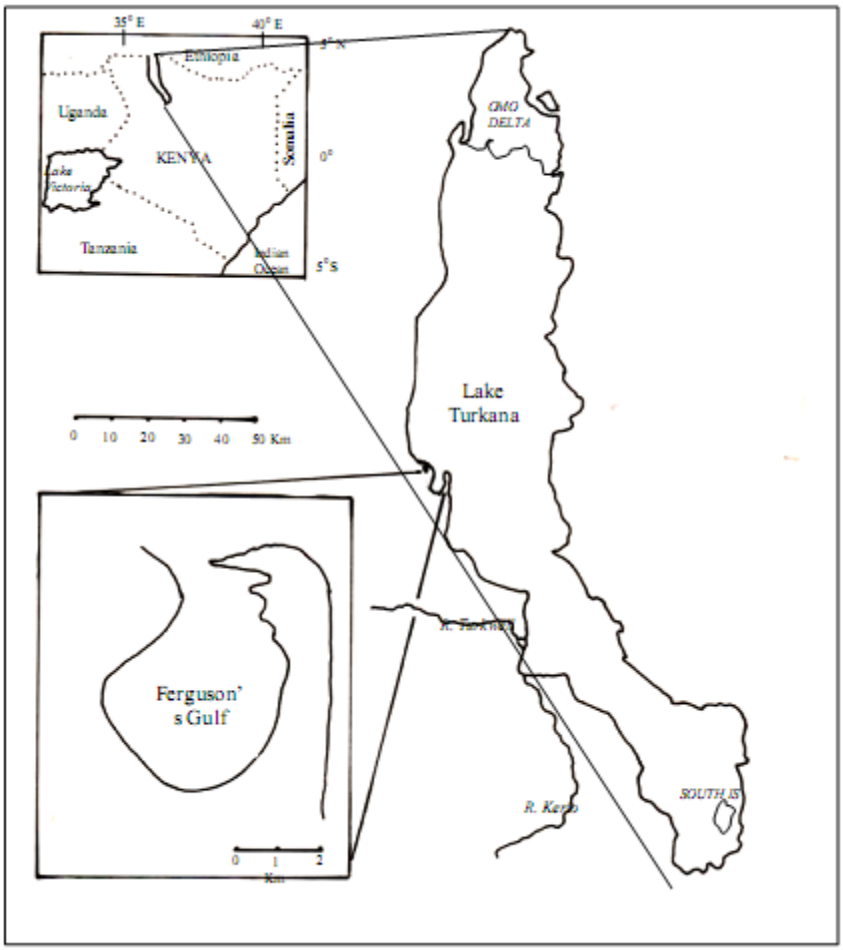

Fig 1. Map of Kenya (Upper Inset) showing location of Lake Turkana and Ferguson's Gulf (Lower Inset).

Study design and Sample collection

Longitudinal research design was used for this study with data collection done in Ferguson's gulf from the month of June to November, 2014 representing dry and wet seasons. For each sampling month, nine replicate fish samples were obtained from artisanal fishing gears for fish abundance and species diversity from each gear resulting into 162 counts for each variable during the entire study period. For each fish sample obtained from the fishing gear, the total weight and number of all fish landed was determined so as to obtain abundance. The total weight and number for each individual category was recorded and then put in separate boxes or heaps according to species for determination of species diversity. Each group was weighed as soon as possible to avoid desiccation. The Shannon-Weiner (H') Diversity (1949) and Shannon-Wiener Evenness indices (E) were worked out to determine the species diversity per fishing gear using the formula below:

Shannon-Wiener Diversity Index

$$H = \sum_{i=1}^{S} P_i * logP_i$$

Where: H' = Shannon-Wiener Diversity Index
S = Number of species
Pi = proportion of total sample belonging to species i

Shannon Evenness Index:

$$E_H = H / H_{max} = H / \ln S$$

Where: E: Evenness index
H: Shannon Diversity Index
S: Number of the species

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 fish abundance and species diversity in beach seine, purse seine and gill net gears. For differences fish abundance that were found significant at $p<0.05$, post hoc separation of means was done by Duncan's Multiple Range Test (DMRT) to find true differences in means. Student's t-Test at $p<0.05$ was used to determine whether fish abundance and species diversity differed significantly between wet and dry seasons.

RESULTS

Fish abundance and species diversity were analyzed for different fishing gears and were presented in Table 1 and 2.

Fish abundance and fishing gears

The fish abundance per fishing gear varied significantly (One-way ANOVA, $F_{(2,159)} = 6.672$, $P=0.002$) with Duncan's Multiple Range Test further showing significant differences in fish abundance mean of gill net gears from that of purse seine and beach seine gears. The purse seine gears contributed the highest proportion (49%) of fish abundance while beach seines contributed 47% and gill nets contributed the least proportion (4%). However, there were no differences in fish abundance between purse seine and beach seine gears.

According to Table 1, Oreochromis niloticus dominated the fish abundance in all the fishing gears constituting 70% in gill net, 99% in purse seine and 96% in beach seine gears. Hydrocynus forskahlii (0.24%), Schilbe uranoscopus (22%), Bagrus bayad (0.85%), Labeo horie (0.3%), Synodontis schall (1.1%), Chrysichthys turkana (0.04%), Citharinus citharus (0.28%), Lates niloticus (0.23%), Alestes baremoze (5.1%) constituted the remaining 30% in gill net gears. Hydrocynus forskahlii (0.1%), Schilbe uranoscopus (0.03%), Bagrus bayad (0.06%), Labeo horie (0.16%), Synodontis schall (0.16%), Chrysichthys turkana (0.01%), Sarotherodon galileaus (0.05%), Citharinus citharus (0.2%), Lates niloticus (0.03%), Alestes baremoze (0.09%), Distichodus niloticus (0.02%) and Tilapia zillii (0.05%) constituted the remaining 1% in purse seine gears. Likewise, in beach seine gears the remaining 5% consisted of Hydrocynus forskahlii (0.22%), Schilbe uranoscopus (0.27%), Bagrus bayad (0.03%), Labeo horie (1.12%), Synodontis schall (0.05%), Chrysichthys turkana (0.01%), Sarotherodon galileaus (2.48%), Citharinus citharus (0.02%), Lates niloticus (0.07%), Alestes baremoze (0.21%), Distichodus niloticus (0.14%), Tilapia zillii (0.19%), Tetraodon lineatus (0.01%) and Clarias gariepinus (0.06%).

Overall, fish abundance was dominated by Oreochromis niloticus constituting 96% while Hydrocynus forskahlii (0.1%), Schilbe uranoscopus (0.1%), Bagrus bayad (0.08%), Labeo horie (0.6%), Synodontis schall (0.16%), Chrysichthys turkana (0.01%), Sarotherodon galileaus (0.19%), Citharinus citharus (0.04%), Lates niloticus (0.06%), Alestes baremoze (0.4%), Distichodus niloticus (0.07%), Tilapia zillii (0.11%), Tetraodon lineatus (0.004%) and Clarias gariepinus (0.029%) formed the remaining 4%.

Table 1: Gear-based fish species composition and abundance in Ferguson's gulf

Fish species	Fish abundance(g) per fishing gear			
	Gill net	**Purse seine**	**Beach seine**	**Overall abundance**
Oreochromis niloticus	526875	8580750	7879088	16986713
Hydrocynus forskalii	1792	9518	18540	18540
Schilbe uranoscopus	163256	2236	22487	174229
Bagrus bayad	6384	5320	2712	14416
Labeo horie	2781	14008	92856	109645
Synodontis schall	8512	16704	3730	28946
Chrysichthys turkana	264	660	660	1584
Tetraodon lineatus	-	-	648	648
Sarotherodon galilaeaus	-	3920	205380	209300
Clarias gariepinus	-	-	5216	5216
Citharinus citharus	2125	2772	1650	6547
Lates niloticus	1700	2608	5805	10113
Alestes baremoze	38665	7514	17200	63379
Distichodus niloticus	-	1875	11250	13125
Tilapia zillii	-	4508	15480	19988
Total weight per gear	752354	8652393	8282702	17662389
Dash (-) means absence of fish species				

Fish diversity and fishing gears

The data in Table 1 shows that of the 15 fish species recorded in all the fishing gears, 10 were recorded in gill net gears, 13 in purse seine gears while all the 15 fish species were recorded in beach seine gears representing twelve families: Oreochromis niloticus, Schilbe uranoscopus, Hydrocynus forskahlii, Citharinus citharus, Bagras bayad, Labeo horie, Chrysichthys turkana, Lates niloticus, Alestes baremoze and Synodonitis schall fish species occured in all the fishing gears. Clarias gariepinus and Tetraodon lineatus occurred only in beach seine gears. The Cichlids, Sarotherodon galilaeus and Tilapia zillii occurred only in purse seine and beach seine but not in gill net gears.

According to data in Table 2, Shannon-wiener index showed significant difference in beach seine, purse seine and gill net gears (one-way ANOVA, $F_{(2,159)}$ = 891.33, P=0.0001). Duncan's Multiple Range Test showing significant difference in all the fishing gears, with established the highest value (0.4871±0.0912) recorded in beach seine gears than in purse seine (0.053±0.008) and gill net gears (0.1865±0.0244). Likewise, there was significant difference in Shannon-Evenness index in all the fishing gears (one-way ANOVA, $F_{(2,159)}$ = 6974.188, P<0.0001). DMRT showed the highest (1.31±0.104) Shannon-Evenness index in beach seine gears than in purse seine (0.0204±0.0025) and gill net gears (0.0376±0.04398). However, there was no significant difference in Shannon-Evennes index of purse seine from gill nets.

Table 2: Variation of fish species diversity indices with artisanal fishing gears in Ferguson's gulf

Diversity Indices (Mean±SD)	Fishing gears		
	Gill net	Purse seine	Beach seine
Shannon-Wiener (H')	0.1865 ± 0.0244^{A}	0.053 ± 0.008^{B}	0.4871 ± 0.0912^{C}
Shannon-Evenness (E)	0.0376 ± 0.04398^{B}	0.0204 ± 0.0025^{B}	1.31 ± 0.104^{A}

Means with different superscripts in the same row are significantly different at P<0.05. (Data analyzed by DMRT)

Student's t-Test showed significant difference of Shannon-Wiener (P=0.029) and Shannon-Evenness (P=0.003) indices between wet and dry season, with higher indices recorded in wet season than dry season (Table 3).

Table 3: Seasonal variation of fish species diversity indices in Ferguson's gulf

Diversity Indices (Mean±SD)	Seasons	
	Dry	Wet
Shannon-Wiener Index (H')	0.2191 ± 0.1616^{A}	0.2655 ± 0.2132^{B}
Shannon-Evenness Index (E)	0.4244 ± 0.5703^{B}	0.4879 ± 0.6481^{B}

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

DISCUSSION

The high fish abundance in purse seine (49%) and beach seine (47%) gears was attributed to their non-selectivity and high number of nets per gear while selectivity and low number of nets per gear acounted for low fish abundance in gill net gears. These findings are similar to Ibrahim *et al.;* [17] that reported significant variation in the mean weight of fish landing for these fishing gears. Studies by Fondo [18] and Mc Clanahan and Mangi [2] conducted at Kenyan coast and gulf of Mexico also recorded the highest catch for purse seine followed by beach seine and least in gill net. Therefore, non-selective gears such as purse seine and beach seine could lead to subsequent decline in fish stocks and trophic shifts with serious consequences for recovery and resilience of Ferguson's gulf ecosystem due to potential capture of juvenile and non-target fish species. Okeyo [19], Squires *et al.;* [20] and DFO [21] also noted that purse seine has the effect of trapping any encircled fish with higher catch per unit effort compared to other fishing gears and harvest pelagic (surface-dwelling) species which contribute significantly to most of the fish landed interms of weight. However, because of their non-selectivity, Okeyo [19] noted that seine nets are responsible for the decreasing catches and have reportedly been banned in Kenyan coast by consensus with local fishers in some landing sites ganging up against their use. Despite the ecological implications, seine nets are currently used in Ferguson's gulf thus, raising the questions of sustainability of Lake Turkana fisheries resources. It is in this respect that Lake Turkana fisheries managers and the fishers should explore ways of banning or controlling the use of such gears inorder to manage the fish resources.

Nile Tilapia, Oreochromis niloticus, dominated the fish landed by all fishing gears and overall fis abundance in Ferguson's gulf. This was attributed to the hypereutrophication of Ferguson's gulf and declined water quality as established by the study and consistent with Novaes & Cavalho [22] and Odada *et al.;* [23] that reported dominance of Nile Tilapia in hypereutrophic water bodies. Furthermore, the dominance of Blue-green algae, Anabaenopsis arnoldii in Ferguson's gulf, as reported by Odada *et al.;* [23] was responsible for increased dominance of Nile Tilapia in the water body. It is noteworthy that Nile Tilapia is an opportunistic species with an exceptional ability to adjust to environmental conditions inhospitable to other species. The declined water quality, could have caused the depletion or dispersal of fish species with low tolerance to these conditions resulting into low overall species diversity of Ferguson's gulf.

Except for one endemic fish species, Chrysichthys turkana, the rest of the fish species caught were native species. Oreochromis niloticus, Schilbe uranoscopus, Hydrocynus forskahlii, Citharinus citharus, Bagras bayad, Labeo horie, Chrysichthys turkana, Lates niloticus, Alestes baremoze and Synodonitis schall occurred in all fishing gears. Clarias gariepinus and Tetraodon lineatus occurred only in beach seine gears while Sarotherodon galilaeus and Tilapia zillii and Distichodus niloticus occurred only in purse seine and beach seine gears. These results agree with Odada *et al.;* [23] that Lake Turkana's ichthyofauna is little modified with a low level of endemicity and a few cichlids and only 36 species occur in the main lake, thus accounting for small number of fish species recorded by the study. Furthermore, previous research by Kolding [11] in Lake Turkana reported that Clarias gariepinus was rarely distributed and occured in small rock pools and very rare in gill nets and mostly caught by demersal nets which was consistent with the study. Clarias gariepinus and Tetraodon lineatus are benthic fish species mostly found on shallow waters near the shore and they can survive in low pH levels and are able to live in turbid waters thus, accounting for their presence in beach seine gears unlike gill net and purse seine gears which target pelagic species. Although Tetraodon lineatus is regarded as widely distributed, it is suspected that the species may be extirpated from the water bodies, as it is no longer caught in the fishery catches[24], therefore supporting the findings of this study which established rarity of this species interms of occurrence and total abundance. Consistent with the results of this study, Kolding [11] and Lae [25] also reported less abundance of Sarotherodon galilaeus and Tilapia zillii compared with Oreochromis niloticus in Lake Turkana and River Niger. Furthermore, MuŠvka *et al.;* [13] also established that Synodontis schall, Lates niloticus and Schilbe uranoscopus, Hydrocynus forskahlii and Bagrus bayad dominated the gill nets catch in Lake Turkana.

According to the study, the highest (15) number of species was recorded in beach seine and lowest number in gill net (10) (Table 1) with diversity and evenness for both fishing gears relatively low (Table 2). Likewise beach seines had a higher Shannon-Weiner Diversity index value than gill net and purse seine and also a higher Shannon-Wiener Evenness index to that of gill net and purse seine. The low species diversity and evenness for fishing gears was attributed to the increased dominance of Nile Tilapia in Ferguson's gulf due to hypereutrophic condition and poor water quality unfavourable to other fish species. Consistent with this findings, Mc Clanahan and Mangi [2] and Hicks and Mc Clanahan [26] reported high species diversity in beach seines compared to purse seines and gill nets. The high species diversity in beach seine gear in Ferguson's gulf was attributed to non-selectivity and low salinity and conductivity values resulting from mixing with waters from the main lake which has low salt concentration therefore favouring survival of many fish species. However, despite the high diversity of the species caught, most of the catch

was dominated by Oreochromis niloticus due to favourable hypereutrophic conditions. The higher species diversity during wet season was due to low salinity levels and increased sediment load resulting into increased detritus and planktons which are important food source for most fish species of Ferguson's gulf. Concurrent to the study, Okeyo [19] and Lloret *et al.;* [27], pointed out that gill net gears are selective and the mesh size of gill nets depends on the target species, thus accounting for low species diversity in Ferguson's gulf. However, McClanahan *et al.;* [7] noted high diversity of catch as responsible for rapid decline in catch at high levels of fishing effort with a potential consequence of total fisheries collapse. The relatively higher fish abundance and species diversity coupled with non-selectivity indicate the destructive potential of beach seine gears on fisheries resources of Ferguson's gulf. This therefore warrants the need to manage the widespread and use of beach seine gear observed in Ferguson's gulf inorder to avert the collapse of the Lake Turkana fishery.

CONCLUSION

Fish abundance was mainly related to fishing gear type with beach seine and purse seine recording higher proportions due to their non-selectivity and higher number of nets joined together. In addition, beach seine gears recorded higher fish species diversity compared to other gears with established low overall species diversity in Ferguson's gulf of Lake Turkana. Orechromis niloticus was the predominant species landed, thus formed the bulk of fish landed by all fishing gears.

RECOMMENDATION

Quotas should be introduced to limit fish abundance of purse seine and beach seine gears to avert fishery collapse at high fishing effort. In addition, recovering the populations of fish species other than Oreochromis niloticus is imperative for resilience of Ferguson's gulf ecosystem.

REFERENCES

1. Frontier Madagascar; An assessment of local fisheries in Diego-Suarez bay, Madagascar. In: Narozanki AJ, Steer MD, Fanning E (Eds.), Frontier Madagascar Environmental Research Report Number 22. Society for Environmental Exploration: London, 2009.
2. McClanahan TR, Mangi SC; Gear-based management of a tropical artisanal gears based on species selectivity and capture size. J. *Fish.* Manag. Ecol. 2004;11: 51-60.
3. Rueda M, Defeo O; Linking gears management and conservation in a tropical estuarine lagoon: Biological and physical influence of an artisanal fishing gear. J. Estuar. Coast. Shelf Sci. 56: 935-942.
4. Link SJ, Garison LP (2002). Changes in piscivory associated with fishing induced changes to the finfish community on Geoges Bank. J. Fish. Res. 2003; 55: 71-86.
5. Bianchi G, Gislason H, Graham K, Hill L, Jin X, Koranteng K, *et al.;* Impact of fishing on size composition and diversity of demersal fish communities. Ices J. Mar. Sci. 2000; 57: 558–571.
6. Mangi SC, Roberts CM; Quantifying the environmental impacts of artisanal fishing on Kenya's coral reef ecosystem. Mar. Pollut. Bull. 2006; 52(12): 1646-1660
7. McClanahan TR, Sebastian CR, Cinner J, Maina J, Wilson S, Graham, NAJ; Managing fishing gear to encourage ecosystem-based of coral reefs. In: Proceedings of the 11th International Coral Reefs Symposium, Ft. Lauderdale, Florida, 7th -11th July, 2008. Retrieved from http://www.coralcoe.org.au/all-scientifc-publications/
8. McMillan J; The ultimate fishing safari, 1985. Retrieved from http://www.seacatch.com
9. Hopson AJ; Lake Turkana: A report on the findings of the Lake Turkana project 1972-1975 (Volumes 1-6). London: Overseas Development Administration, 1982.
10. Harbott BJ, Ferguson AJD, Hopson AJ; The Lake Turkana Fisheries research project 1972-1975. A summary of the findings. Paper presented at the seminar on the future of Lake Turkana Fisheries, Kalokol, Kenya 20th -25th September 1982.
11. Kolding J; The fish resources of Lake Turkana and their environment, 1989. (Thesis for the cand. scient. degree, University of Bergen, Norway). Retrieved from http://www.academia.edu/676514/
12. KMFRI; Fisheries, people and the future. Nairobi: GoK, 2007.
13. MuŠvka M, VaŠek M, Modrý D, Jirku M, Ojwang WO, Malala JO, *et al.;* The last snapshot of natural pelagic fish assemblage in Lake Turkana, Kenya: A hydroacoustic survey. J. Great Lakes Res. 2012; 38: 98-106
14. Coen LD; A review of the potential impacts of mechanical harvesting on sub tidal and Intertidal Shellfish Resources, 1995. Retrieved from http://www.dnr.sc.gov/marine
15. Churchill JH; The effect of commercial trawling on sediment resuspension and transport over the middle Atlantic Bight continental shelf. Cont. Shelf Res. 1989; 9(9): 841-864.
16. Kumar AB, Deepthi GR; Trawling and By-Catch: Implications on Marine Ecosystem. J. Curr. Sci. 2006; 90(7): 922-931.
17. Ibrahim BU, Auta J, Balogun JK; A survey of the artisanal fisheries of Kontagora Reservoir, Niger State, Nigeria. Bayero J. Pur. Appl. Sci. 2009; 2 (1): 47-51.
18. Fondo EZ; Assessment of the Kenyan marine fisheries from selected fishing areas. Skulagata: United Nations University, 2004.
19. Okeyo B; Artisanal fisheries of Kenya's south coast. A transdisciplinary case study of socio-

ecological system transition. A doctoral dissertation submitted to the University of Bremen, Bremen, 2010.
20. Squires D, Grafton RQ, Alam MF, Omar IH; Technical efficiency in the Malaysian gillnet artisanal fishery, 2002. Retrieved from http://een.anu.edu.au//
21. DFO; Potential impacts of fishing gears (excluding mobile bottom-contacting gears) on marine habitats and communities. DFO Can. Sci. Advis. Sec. Rep. 2010/003. Retrieved from http://www.dfo-mpo.gc.ca/CSAS/Csas/publications/sar-as/2010/2010_003_e.pdf
22. Novaes JLC, Cavalho ED; Artisanal fisheries in a Brazilian hypereutrophic reservoir. Barra Bonita Reservoir middle Tiete River, Brazil. J. Bio. 2011; 71(4): 821-832.
23. Odada EO, Olago DO, Bugenyi F, Kulindwa K, Karimumuryango J, West K, *et al.;* Environmental assessment of the East African Rift Valley lakes. J. Aquat. Sci. 2003; 65: 254-271
24. FishBase; List of freshwater fishes reported from Kenya, 2004. Retrieved from http://www.fishbase.org/countrychecklist.php?what
25. Lae R; Climatic and anthropogenic effects on fish diversity and fish yields in the central delta of the Niger River. J. Aquat. Living Resour. 1995; 8: 43-58.
26. Hicks CC, Mc Clanahan TR; Assessing gear modifications needed to optimize yields in a heavily exploited multi-species, sea grass and coral reef fishery. PLoS ONE, 2012; 7(5):1-12
27. Lloret J, Casadevall M, Munoz M; A survey of artisanal fishing in the Cap de Creus Natural Park 2008-2010 study. University of Givona: Catalunya, 2010.