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George Owiti Osure
[1] Department of Biological Sciences, Pwani University, P.O. Box 195-80108, Kilifi, Kenya
[2] Faculty of Agriculture and Natural Resources Management, Kisii University, P.O. Box 408 - 40200 Kisii, Kenya

Albert Getabu
Faculty of Agriculture and Natural Resources Management, Kisii University, P.O. Box 408 - 40200 Kisii, Kenya

Christopher Mulanda Aura
Kenya Marine and Fisheries Research Institute (KMFRI), P.O. Box 1881 - 40100, Kisumu, Kenya

Reuben Omondi
Faculty of Agriculture and Natural Resources Management, Kisii University, P.O. Box 408 - 40200 Kisii, Kenya

Evans Basweti
Faculty of Agriculture and Natural Resources Management, Kisii University, P.O. Box 408 - 40200 Kisii, Kenya

Corresponding Author:
George Owiti Osure
[1] Department of Biological Sciences, Pwani University, P.O. Box 195-80108, Kilifi, Kenya
[2] Faculty of Agriculture and Natural Resources Management, Kisii University, P.O. Box 408 - 40200 Kisii, Kenya

Population parameters and exploitation rates of four commercial fish species of Awach Kibuon River: Towards sustainable management of riverine fisheries of the Lake Victoria Basin

George Owiti Osure, Albert Getabu, Christopher Mulanda Aura, Reuben Omondi and Evans Basweti

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Abstract

The study estimated population parameters of four leading commercial fish species of Awach Kibuon River in Lake Victoria Basin, Kenya to inform management interventions for sustainability. Length data were collected monthly from January to December 2020 and length-frequency analysis conducted in FiSAT II software utilizing ELEFAN I Routines. Exploitation rates (E = 0.63) for *Protopterus aethiopicus* (Heckel, 1851) and (E = 0.56) for *Clarias gariepinus* (Burchell, 1822) indicate overfished stocks ($E > E_{opt}$) whereas exploitation rates (E = 0.31) for *Synodontis victoriae* (Boulenger, 1906) and (E = 0.32) for *Oreochromis niloticus* (Linnaeus, 1758) signify optimal exploitation ($E = E_{\text{opt}}$). There were year-round recruitments with bi-modal annual pulses in the populations of *O. niloticus*, *S. victoriae*, and *P. aethiopicus*. These results are crucial for sustainable management of riverine fisheries in the Lake Victoria Basin. This study recommends reduction of fishing pressure on *P. aethiopicus* and *C. gariepinus* to enhance their sustainability.

Keywords: Population parameters, recruitment patterns, growth rates, mortality rates, exploitation rates

1. Introduction

Estimation of fish population parameters is important in understanding fish stock status and subsequent planning for their sustainable management [1, 2]. Natural fish populations are dynamic owing to varying environmental conditions and changing fishing pressures [3]. Recruitment-, growth-, and mortality rates are the main drivers of fish population dynamics [4, 5]. Fish populations increase in size if recruitment and growth rates exceed mortality losses and decrease if mortality rates are higher. Fish population parameters are influenced by environmental conditions and life-history strategies of the fish species [6]. Long-lived species exhibit bigger asymptotic lengths ($L\infty$), low natural mortality rates (M), and low growth curvatures (K) while short-lived species exhibit smaller asymptotic lengths ($L\infty$), high natural mortality rates (M), and high growth curvatures (K) [7].

Recruitment refers to the number of fish that survive the spawning and nursery grounds to enter the fishing grounds in a year. It is highly variable in natural fish populations, varying from year to year [1]. The causes of high variability are unclear but competition, cannibalism, predation, diseases, and water temperature are known to influence eventual recruitment to adult fish populations [9, 10]. Growth refers to increase in length or weight of fish in the population over time. Growth of individual fish in fish populations is described by the von Bertanlanffy growth model: $L(t) = L\infty \times \{1- \exp(-K\times(t-t_0))$, where $L\infty$ is the asymptotic length, K is the rate at which fish grows towards this size, and t_0 is the hypothetical age of fish at which the length of fish is zero [9]. In temperate fish species, growth is measured by use of annual and seasonal growth rings on scales, otoliths, vertebrae, and fin rays but in tropical fish growth is estimated by length-frequency analysis due to lack of distinct seasonal and annual growth rings. Commonly estimated growth parameters include asymptotic length ($L\infty$) and growth curvature (K) which are unique to each species but may vary for different populations of the same species [9].

Mortality in fish populations is partitioned into natural mortality and fishing mortality. Natural mortality is caused by predation, pollution, spawning exhaustion, senescence, diseases and other natural factors [9] whereas fishing mortality is attributed to fishing. Mortality is measured in terms of total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (F) [9]. Exploitation rate (E) is the fraction of total mortality (Z) that is attributable to fishing. It is calculated by the formula: $E = F/Z$. This ratio helps to assess whether the stock is overfished. E optimum (E_{opt}) is equal to 0.5 based on the assumption that sustainable yield is optimized when $F = M$ [11, 12].

The study of fish population dynamics is crucial for sustainable management of fish stocks globally. Fish population parameters have been estimated for key species in marine [6], lacustrine [7], and riverine ecosystems [2]. In Africa, such studies are common in lakes, reservoirs and large rivers [15]. In the Lake Victoria Basin, numerous fish population dynamics studies have been conducted [16, 17]. However, small to medium-sized riverine fish stocks remain largely unstudied globally. This study focused on the medium-sized Awach Kibuon River, Lake Victoria Basin, as a case study to inform management interventions for sustainable riverine fisheries. It specifically sought to determine: a) growth parameters; b) exploitation status; c) annual mortality rates (Z, M & F); and d) recruitment patterns of the four leading commercial fish species of the river.

2. Materials and Methods

2.1 Study Area

The study was conducted at the mouth of Awach Kibuon, a 52-km long medium-sized river that drains the southern part of the Lake Victoria Basin, Kenya (Figure 1). The catchment basin of the river straddles longitudes 34°58'48.0"E to 34°37'48.0"E and Latitudes 0°36'0.0"S to 0°21'0.0"S. The river provides breeding grounds to potamodromous fish species and refuge to endangered lacustrine species of Lake Victoria [18]. It also influences water quality of the lake through water discharge and deposition of sediments and nutrients from surrounding farm lands [19]. The watershed is characterized by subsistence farming which increases in intensity upstream [20]. The upper part of the river basin is densely populated exerting enormous pressure on land resources.

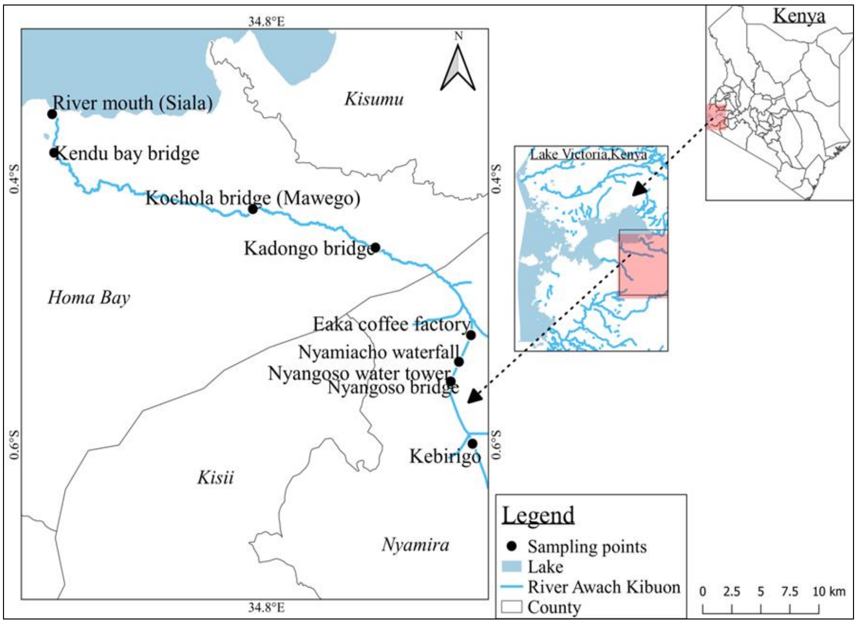

Fig 1: A map of Kenya (inset) showing the location of Lake Victoria Basin, River Awach Kibuon and the river mouth sampling site where fish length measurements were taken

2.2 Fish sampling and data collection

Total length data (TL, cm) of the four studied fish species were collected monthly from January to December 2020 from the catches of artisanal fishermen to provide data for length-frequency analysis and determination of fish population parameters. Fish samples were collected randomly every mid-month for consistency. To minimize errors associated with fishing gear selectivity, only catches from multi-mesh gillnets were sampled.

2.3 Data Analysis

Length data of each species were first entered into Microsoft Excel 2010 then arranged in length-classes with equal length intervals to meet the data requirements of the FAO ICLARM Stock Assessment Tools (FiSAT II) software. The electronic length frequency analysis I (ELEFAN I) in FiSAT II Software Version 1.2.2 was used to estimate the population parameters [21].

2.3.1 Growth parameters

Estimates of the growth parameters K (yr^{-1}) and $L\infty$ (cm) for each species were obtained using ELEFAN I routine in FiSAT II software [21] based on the von Bertalanffy growth function (VBGF): $Lt = L\infty\ (1 - \exp\ (-K\ (t - t_0))$, where Lt = predicted length at age t; $L\infty$ = asymptotic length; K = growth curvature; and t_0 = the hypothetical age of fish at zero length. Growth performance index (θ') was computed by the following equation [24]: $\theta' = \mathrm{Ln}\ (K) + 2\ \ln\ (L\infty)$.

2.3.2 Mortality and exploitation rates

Total mortality rate, Z (yr^{-1}), was estimated using the length-converted catch curve method in ELEFAN I, using the final estimates of $L\infty$ and K and the length distribution data for the species as inputs [22]. The natural mortality rate, M (yr^{-1}) was estimated with K (yr^{-1}), $L\infty$ (cm) and T (mean annual habitat temperature (22.7 °C) in this case), according to Pauly's empirical formula [23], as follows: $\mathrm{Ln}\ (M) = -0.0152 - 0.279$

$\ln(L\infty) + 0.6543 \ln(K) + 0.4634 \ln(T)$

Fishing mortality (F) (yr^{-1}) was computed from the relationship: $F = Z - M$

Exploitation rate (E) was calculated from the following equation [13]: $E = F/Z = F/ F+M$

2.3.3 Beverton and Holt Y′/R and B′/R analyses

The relative yield-per-recruit model used was based on the Beverton and Holt model [25], modified by Pauly and Soriano [26]. The option assuming knife-edge selection was utilized, using probabilities of capture. $Lc/L\infty$ and M/K ratios were used as inputs. The relative yield-per-recruit (Y'/R) was computed following equation:

$$Y'/R = EU^{M/K}\left\{1 - \frac{3U}{(1+m)} - \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

Where $U = 1 - (Lc/L\infty)$; $m = (1-E)/(M/K) = (K/Z)$; and $E = F/Z$

The relative biomass-per-recruit (B'/R) was estimated by the following equation:

$$B'/R = (Y'/R)/F$$

Biological reference points, E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated using the first derivative of this function. E_{max} is the exploitation rate at maximum sustainable yield (MSY), $E_{0.1}$ is the exploitation rate at maximum economic yield (MEY), and $E_{0.5}$ is the optimum exploitation rate.

2.3.4 Recruitment patterns

Recruitment patterns routine in FiSAT II software reconstructed recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse. Growth parameters $L\infty$ and K were used as inputs, by backward projection, along a trajectory defined by the VBGF, of the frequencies onto the time axis of a time-series of samples to obtain plots illustrating the seasonal patterns of recruitment per species.

3. Results

3.1 Growth parameters

The estimated growth parameters ($L\infty$ & K) and the growth performance indices (θ') of the four (4) exploited fish stocks are given in Table 1. The growth curvatures (K) for the four (4) species were 0.67 (*O. niloticus*), 0.70 (*C. gariepinus*), 0.83 (*S. victoriae*) and 1.1 (*P. aethiopicus*). Asymptotic lengths ($L\infty$) were 26.3 cm (*S. victoriae*), 46.2 cm (*O. niloticus*) 92.9 cm (*C. gariepinus*) and 153.7 cm (*P. aethiopicus*).

Table 1: Growth parameters ($L\infty$ and K) and growth performance index (θ′) of 4 commercially exploited fish populations in Awach Kibuon River, Lake Victoria Basin, Kenya.

Species Name	L∞	K	θ′	M/K
Oreochromis niloticus	46.2	0.67	3.16	1.7
Protopterus aethiopicus	153.7	1.10	4.42	1.0
Clarias gariepinus	92.9	0.70	3.78	1.3
Synodontis victoriae	26.3	0.83	2.76	1.8

3.2 Annual mortality rates (Z, M & F) and exploitation rates E, $E_{1.0}$, $E_{0.5}$ and E_{max}

Mortality rates Z, M and F and exploitation rates E, $E_{0.1}$, $E_{0.5}$ and E_{max} for the four (4) exploited fish stocks are shown in Table 2 whereas the length converted catch curves are presented in Figure 2. Total mortality rates Z (yr^{-1}) were 1.64 (*O. niloticus*), 2.15 (*C. gariepinus*), 2.17 (*S. victoriae*) and 2.94 (*P. aethiopicus*). Natural mortality rates M (yr^{-1}) were 0.94 (*C. gariepinus*), 1.09 (*P. aethiopicus*), 1.11 (*O. niloticus*) and 1.49 (*S. victoriae*). Exploitation rates (E) were 0.31 (*S. victoriae*), 0.32 (*O. niloticus*) 0.56 (*C. gariepinus*) and 0.63 (*P. aethiopicus*). These results show that *P. aethiopicus* and *C. gariepinus* stocks are overexploited but only *P. aethiopicus* is exploited above the E_{max} level.

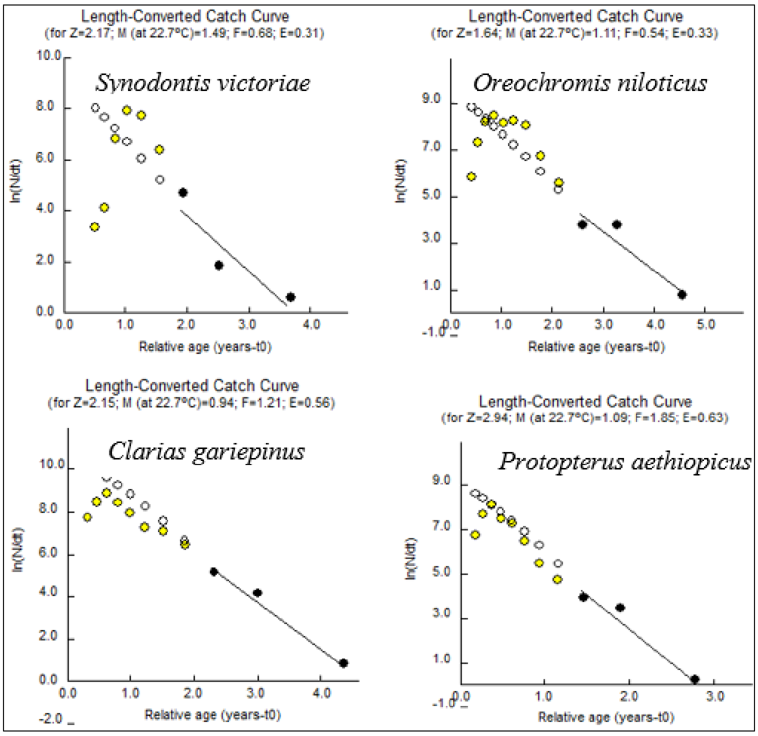

Fig 2: Length converted catch curves showing mortality rates (Z), (M), (F), and exploitation rate (E) of *S. victoriae, O. niloticus, C. gariepinus* and *P. aethiopicus* in River Awach Kibuon, Lake Victoria Basin, Kenya

Table 2: Estimates of mortality rates Z, M, F and exploitation rates E, $E_{0.1}$, $E_{0.5}$ and E_{max} of 4 exploited fish populations in Awach Kibuon River, Lake Victoria Basin, Kenya

Species Name	N/M	Class interval (cm)	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	$E = F/Z$	$E_{0.1}$	$E_{0.5}$	E_{max}
Oreochromis niloticus	1678/11	3	1.64	1.11	0.53	0.32	0.46	0.31	0.54
Protopterus aethiopicus	477/12	12	2.94	1.09	1.85	0.63	0.46	0.32	0.53
Clarias gariepinus	655/12	7	2.15	0.94	1.21	0.56	0.66	0.37	0.75
Synodontis victoriae	1632/12	2	2.17	1.49	0.68	0.31	0.61	0.35	0.70

N = total number of fish sampled; M = number of months sampled

3.3 Recruitment Patterns

Recruitment patterns showing year-round and bi-modal annual pulses are illustrated in Figure 3. The main recruitment pulses occurred from April to June while the second pulses were observed from September to October coinciding with long and short rainy seasons of the year, respectively.

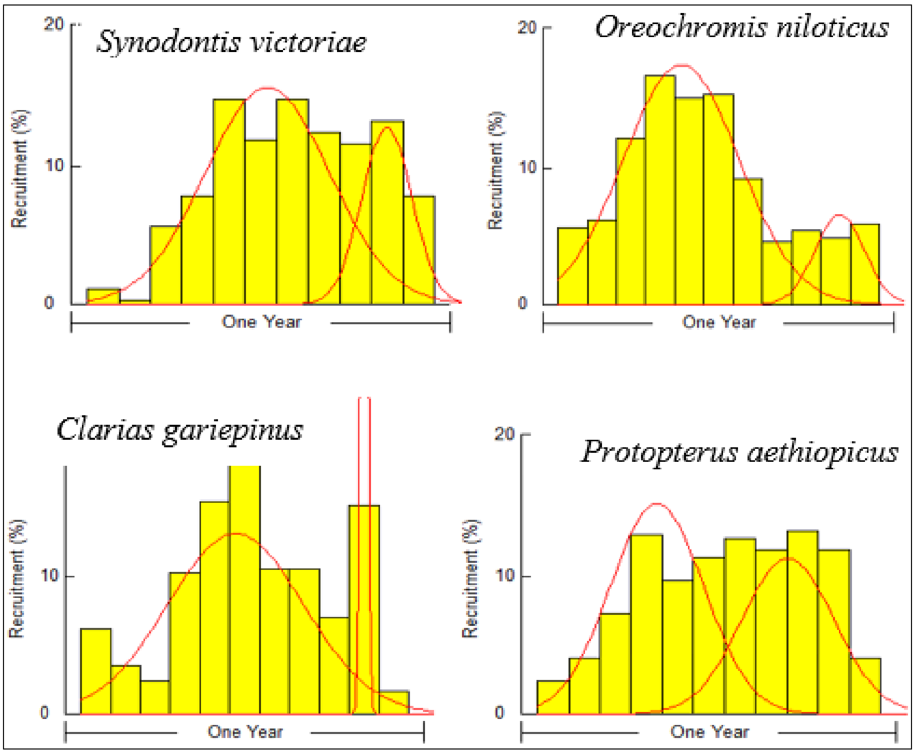

Fig 3: Estimated recruitment patterns of *S. victoriae, O. niloticus, C. gariepinus* and *P. aethiopicus* populations in River Awach Kibuon, Lake Victoria Basin, Kenya

3.4 Beverton and Holt relative yield and biomass per recruit models

The Beverton and Holt's relative yield-per-recruit and biomass-per-recruit model indices for sustainable yields for *S. victoriae*, *O. niloticus*, *C. gariepinus*, and *P. aethiopicus* are given in Table 2. The model indices for *O. niloticus* were 0.31 for optimum sustainable yield ($E_{0.5}$), 0.54 for the maximum sustainable yield (E_{max}) and 0.46 for maximum economic yield ($E_{0.1}$).

4. Discussion

The results of the current study compared to those of previous studies indicate notable changes in population parameters of the four studied species over the last four decades in the Lake Victoria Basin. Asymptotic length of *O. niloticus* ($L\infty$ = 46.2 cm) in the current study is exactly similar to 46.2 cm reported in another study [27] in 2016 but smaller than 64.6 cm, 63.1 cm and 58.8 cm reported in previous studies of lake Nile tilapia populations [28, 29, 16]. The asymptotic length of *C. gariepinus* ($L\infty$ = 92.9 cm) is equally smaller than the 114.3 cm reported in Lake Baringo in 2017 [30]. Similarly, the asymptotic length of *S. victoriae* ($L\infty$ = 26.3 cm) is much smaller than 40.0 cm reported in Lake Victoria [31] in 1988. These declines may be attributed to over-fishing and increasing habitat degradation within the Lake Victoria Basin [9].

Growth curvature (K) for *O. niloticus* has steadily increased from 0.25 yr^{-1} [28] in 1992, to 0.35 yr^{-1} [29] in 1994, to 0.59 yr^{-1} [16] in 2007 and to 0.67 yr^{-1} in the current study (2020). The same trend was also observed in growth studies of *S. victoriae* and *C. gariepinus* populations in Lake Victoria [31] and Lake Baringo [30], respectively. The high growth curvatures (K) imply fast growth rate and earlier attainment of asymptotic lengths ($L\infty$). The changes in asymptotic lengths ($L\infty$) and growth curvatures (K) indicate a decrease in average size of landed individuals of the four fish species over time. This may be attributed to stressful environments as a result of environmental degradation and overfishing [9]. This view is validated by widespread habitat/environmental degradation in Lake Victoria [32].

The total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (F) have all increased over the last four decades in all the four fish species investigated. Increase in fishing mortality rates in Lake Victoria Basin may be attributed to rapid increase in the fishing effort [33]. Environmental degradation of the Lake Victoria Basin by pollution, invasive weeds, eutrophication and climate change

[32] may also be responsible for high mortality rates. Overcapacity of fishermen, fishing gears and fishing crafts is also a widespread challenge in the entire basin [33].

Exploitation rate (*E*) of 0.32 for *O. niloticus* is comparable to 0.34 reported in another study [28]. However, the exploitation rate (*E*) of 0.56 for *C. gariepinus* is higher than 0.46 reported in Lake Baringo [30]. The higher *E* values may be attributed to increasing fishing pressure on the fish populations of Lake Victoria [33]. The impact of population parameters on the biomass and yield is best reflected in the Beverton and Holt's yield-per-recruit model [25]. At the reported mortality rates, the observed exploitation rate (*E*) of 0.32 for *O. niloticus* is close to the optimum exploitation rate $E_{0.5}$ of 0.31, but lower than E_{max} of 0.54 (MSY) and $E_{0.1}$ of 0.46 (MEY). This implies that the *O. niloticus* population in Awach Kibuon River is optimally fished. In contrast, the (*E*) of 0.63 for *P. aethiopicus* is much higher than $E_{0.5}$ (0.32), $E_{0.1}$ (0.46), and E_{max} (0.53) signifying overexploitation of *P. aethiopicus* stock and danger to sustainability of the stock.

Recruitment patterns showed all year-round recruitment with bi-modal annual pulses for three species (*S. victoriae*, *O. niloticus* and *P. aethiopicus*) and one pulse for *C. gariepinus* occurring during May-June and September-October months. The first pulse was usually more pronounced than the second and both recruitment pulses coincided with long and short rainy seasons of the year. These findings concur with Pauly's (1982) observations of two recruitment pulses occurring in tropical fish and short-lived species annually. These findings are comparable to those reported in a study of Nile perch populations in Lake Victoria [17].

5. Conclusions and Recommendations

From the results of this study, it is concluded that *P. aethiopicus* and *C. gariepinus* stocks in Awach Kibuon River are overexploited with high total and fishing mortality rates (*Z* & *F*). Fish populations in the river exhibited year-round recruitment with bi-modal annual pulses that characterize tropical species. Occurrence of overfishing is shown by small asymptotic lengths and high growth curvatures (*K*). There is a need to reduce fishing pressure on the overexploited *P. aethiopicus* and *C. gariepinus* stocks in order to enhance their sustainability in riverine fisheries of the Lake Victoria Basin.

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7. References

1. Quist MC. An Evaluation of Techniques Used to Index Recruitment Variation and Year-Class Strength. North American Journal of Fisheries Management. 2007;27:30-42.
2. Camargo M, Giarrizzo T, Isaac VJ. Population and biological parameters of selected fish species from the middle Xingu River, Amazon Basin. Brazilian Journal of Biology. 2015;75:112-124.
3. McRae BJ, Diana JS. Factors influencing density of age-0 brown trout and brook trout in the Au Sable River, Michigan. Transactions of the American Fisheries Society. 2005;134:132-140.
4. Gulland JA. Why Do Fish Numbers Vary? Journal of theoretical Biology. 1982;97:69-75.
5. Pope KL, Lochmann SE, Michael KY. Methods for Assessing Fish Populations. In W. A. Hubert & M. C. Quist (Eds.). Inland fisheries management in North America (3rd Ed.). Bethesda, Maryland, USA: American Fisheries Society; c2010.
6. Silvestre GT, Garces LR. Population parameters and exploitation rate of demersal fishes in Brunei Darussalam (1989-1990). Fisheries Research. 2004;69:73-90.
7. Sa-Oliveira JC, Angelini R, Isaac-Nahum VJ. Population parameters of the fish fauna in a long-established Amazonian reservoir (Amapa, Brazil). Journal of Applied Ichthyology. 2015;31:290-295.
8. Welcomme RL. Inland Fisheries: Ecology and Management. Food and Agriculture Organization of the United Nations, Blackwell Science; c2001.
9. Sparre P, Venema SC. Introduction to Tropical Fish Stock Assessment Part 1: Manual. FAO Fisheries Technical Paper. No. 306.1, Rev. 2. Rome FAO; c1998, p. 47-92
10. Nunn AD, Cowx IG, Frear PA, Harvey JP. Is water temperature an adequate predictor of recruitment success in cyprinid fish populations in lowland rivers? Freshwater Biology. 2003;48:579-588.
11. Gulland JA. The fish resources of the ocean. West Byfleet (UK): Fishing News (Books) Ltd; c1971.
12. Pauly D. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper No. 234; c1983. p. 52.
13. Mathews CP, Samuel M. Using the growth performance index θ′, to choose species for aquaculture: an example from Kuwait. Aquabyte.1990;3(2):2-4.
14. Pauly D. On the sex of fish and the gender of scientists: essays in fisheries science. Chapman and Hall, London; c1994. p. 250.
15. Payne AI, McCarton B. Estimation of population parameters and their application to the development of fishery management models in two African rivers. Journal of Fish Biology. 1985;27:263-277.
16. Njiru M, Okeyo-Owuor JB, Muchiri M, Cowx IG, van der Knaap M. Changes in population characteristics and diet of Nile tilapia *Oreochromis niloticus* (L.) from Nyanza Gulf of Lake Victoria, Kenya: what are the management options? Aquatic Ecosystem Health & Management. 2007;10:434-442.
17. Yongo E, Agembe S, Outa N, Owili M. Growth, mortality and recruitment of Nile perch (*Lates niloticus*) in Lake Victoria, Kenya. Lakes and Reservoirs: Research and Management. 2018;23:17-23.
18. Masese FO, Achieng' AO, Raburu PO, Lawrence T, Ives JT, Nyamweya C, *et al*. Distribution patterns and diversity of riverine fishes of the Lake Victoria Basin, Kenya. International Review of Hydrobiology. 2020;105:171-184.
19. Mwangi TJK, Maobe SN, Ondicho AR, Kidula NL, Magenya OV, Onyango M, *et al*. Reconnaissance Survey of the Kibuon and Tende River Catchment of Southwest Kenya. African Journal of Agriculture and Utilization of Natural Resources for Sustainable Development. 2015;1:22-37.
20. African Water Facility. Republic of Kenya integrated land and water management in the Kibuon and Tende

rivers. Appraisal report - African Development Bank; c2008.

21. Gayanilo FC Jr, Sparre P, Pauly D. Stock Assessment tools II. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy; c2005. p. 163.
22. Pauly D. Length-converted catch curves: a powerful tool for fisheries research in the tropics Part II. Fishbyte, Newsletter of the Network of Tropical Fisheries Scientists; c1984. p. 17-19.
23. Pauly D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil/ Permanent Council International I ‘Exploration pour.de la Mer. 1980;39:175-192.
24. Pauly D, Munro JL. Once more on the comparison of growth in fishes and invertebrates. Fish byte. 1984;2:21-22.
25. Beverton RJH, Holt SJ. Manual of methods for fish stock assessment. Part II. Tables of yield function. FAO Fisheries Technical Paper No. 38, Review 1; c1966.
26. Pauly D, Soriano ML. Some practical extensions to Beverton and Holt’s relative yield-per-recruit model. In: J. L. Maclean, L. B. Dizon, & L. V. Hosillo (Eds.), The first Asian fisheries forum. Manila, Philippines: Asian Fisheries Society; c1986. p. 491-496.
27. Yongo E, Outa N. Growth and population parameters of Nile tilapia, *Oreochromis niloticus* (L.) in the open waters of Lake Victoria, Kenya. Lakes and Reservoirs: Research and Management. 2016;21:375-379.
28. Getabu A. Growth parameters and total mortality in *Oreochromis niloticus* (Linnaeus) from Nyanza Gulf, Lake Victoria. Hydrobiologia. 1992;232:91-97.
29. Dache SAO. Observations on the fisheries, growth and mortality rate of *Oreochromis niloticus* (Tilapia) in the Nyanza Gulf of Lake Victoria. In: Okemwa, E; Wakwabi, E.O; Getabu, A (Eds.). Proceedings of the Second EEC Regional Seminar on Recent Trends of Research on Lake Victoria Fisheries, Nairobi: ICIPE SCIENCE; c1994, p. 59-65.
30. Macharia S, Obwoyere GO, Kirui BK, Manyala JO. Assessment of catfish (*Clarias gariepinus*) stock in Lake Baringo, Kenya. Lakes & Reservoirs: Research and Management. 2017;22:48-55.
31. Asila AA, Okemwa E. Growth parameters for *Lates niloticus* (L.), *Bagrus docmak* (Forsskål), *Oreochromis niloticus* (L.), *Clarias gariepinus* (Burchell) and *Synodontis* species derived from tag returns. In: I.G. Cowx and D. Tweedle (Eds.) Lake Victoria Fisheries Research Project Phase II. Report on fourth FIDA WOG workshop held at Kisumu, 16-20 August 1999. UNECIA Ltd; c1988. p. 204-207.
32. Njiru JM, Kazungu J, Ngugi CC, Gichuki J, Muhoozi L. An overview of the current status of Lake Victoria fishery: Opportunities, challenges and management strategies. Lakes & Reservoirs: Research and Management. 2008;13:1-12.
33. Njiru JM, van der Knaap M, Kundu R, Nyamweya C. Lake Victoria fisheries: Outlook and management. Lakes & Reservoirs: Research and Management. 2018;23:152-162.