Available Online at *http://www.aer-journal.info*

ISSN: 1727-8341

RESEARCH ARTICLE

Reproductive Behavior of *Oreochromis variabilis* (Boulenger, 1906) in Small Water Bodies: A Case Study of Lake Victoria Basin, Kenya

J. Maithya
School of Environmental Studies, University of Eldoret, P. O. Box 1125 – 30100 Eldoret, Kenya
jacmaithya@yahoo.com

J. B. Okeyo-Owuor
jbokeyo2003@yahoo.com

B. C. C. Wangila
bwangila@mmust.ac.ke

Abstract

Oreochromis variabilis (Boulenger), an endemic fish species to Lake Victoria, was abundant and of great economic importance in the 1950s. However, after early 1960s to this date, its catches disappeared from the lake's fisheries; the species became extremely endangered, and is now listed in the World Conservation Union (IUCN) Red Book of endangered species. Investigations of the reproductive ecology of resilient stocks revealed that sex-related morphormetric characteristics of these stocks are useful criteria for recommending strategies for stock enhancement, restoration and conservation of O. variabilis. There was preponderance of males over females in all populations; O. variabilis reproduced throughout the year; 50% of populations reached first maturity at sizes optimal for commercial exploitation; fecundity was high. These factors, coupled with large sizes of oocytes and excellent condition factor are enough ecological criteria for recommending increased captive propagation of the species in small water bodies in the Lake Victoria Basin.

Key Words: *O. variabilis*, Endangered, SWBs, Sex Morphometrics, Propagation, Restoration

Introduction

Oreochromis variabilis (Boulenger) and *O. esculentus* (Graham) are the only Tilapiine species of the genus *Oreochromis* that occurred naturally in Lake Victoria (Fryer, 1961). *O. variabilis* was abundant and assumed greater economic importance especially in commercial catches in the 1950s. The introduction of the gill nets, especially of small mesh sizes in 1956, led to increased exploitation of the inshore species, with the number of *O. variabilis* in the catches reaching a peak in 1958. This was followed by a drastic decline in its catches due to relaxed enforcement of fishing regulations. The species eventually became extremely rare in Lake Victoria. After early 1960s to this date, catches of *O. variabilis* have disappeared from both commercial and subsistence landings; the species has become extremely endangered with no contribution in the fisheries of Lake Victoria, and has already been listed in the World Conservation Union (IUCN) Red Book of endangered species (Kaufman, 1992). While *O. esculentus* is now extinct in Lake Victoria, some resilient populations of *O. variabilis* are found in some small water bodies (SWBs) refugia within the Lake Victoria basin. This study investigated the reproductive behaviour of these resilient stocks in their present refugia situated in different ecological zones (ecozones) within the Kenya Victoria Lake basin including the lake itself with the objective of identifying stocks that could be used as broodfish for mass culture, stock enhancement, conservation and commercial exploitation. Criteria used in sock identification and discrimination procedures in this study are based on sex-related morphometric characteristics, i.e. length at 50% maturity (Witte & van Densen, 1995), fecundity and egg size including intra-ovarian size distribution, gonosomatic index (GSI) (Ekanem, 2000) and condition factor (Weatherly & Rogers, 1978; Oni *et al.*, 1983).

Material and Methods

Field Data Collection

Research sites were selected based on availability of *O. variabilis* and elevation, after a reconnaissance survey that characterized them as representative refugia. Sampled refugia, plots shown in Figure 1, include Oele Beach region of Lake Victoria [a large water segment of Lake Victoria characterized by a dendritic, gently sloping shoreline defined at the landing point by location at 00° 03’ 55’’ N, 034° 08’ 13’’E and mean (± SD) elevation of 1138.12 ± 1.04 m.a.s.l]; Kalenyjuok Dam [a low altitude water body located at 00° 04’ 23’’ N; 034° 13’ 11’’E, mean elevation 1187.19 ± 2.81 m a.s.l. and gently sloping littoral edges with a surface area of approximately 340 x 118 m^2 and a maximum depth of 3.1 m]; Komondi Dam [a medium altitude water body, location 01° 07’ 33’’ S; 034° 26’ 12’’ E with a mean elevation of 1406.33 ± 2.21 m a.s.l. and gently sloping littoral edges, a surface area approximately 340 x 182 m^2 and maximum depth of 3.9 m]; and Mamboleo Dam [high altitude water body 00° 42' 47'' S; 035° 02' 46.1'' E elevation of 1841.67 ± 3.21 m a.s.l, gently sloping littoral zones characterized by muddy, clay bottoms with surface area approximately 483 x 132 m^2 and a maximum depth of 3.5 m]. In this study altitude zonation is defined as follows: low attitude includes areas located below 1300 m above sea level (a.s.l.), mid altitude zones are areas located between 1300-1600 m a.s.l., while high altitude is represented by areas between 1600-2000 m a.s.l. Above 2000 m a.s.l. is above optimal range for survival and reproduction of tilapias (Pullin, 1993; Prein *et al.*, 1993).

Fish samples were collected from refugia plots using monofilament gillnets of 30-255 mm mesh sizes from 2001 to 20025. Nets were set in a randomized complete block design in conformity with stratified sampling procedures with inshore, middle shore and offshore of each water body forming the blocks. All specimens caught were taken for determination of sex-related morphormetric characteristics. Specimens were measured to the nearest 0.1 cm, total length (TL) from the nose to the end of the longest caudal ray, weighed to the nearest 0.1 g and sexed. These measurements were later used to determine the condition factor, the fecundity-length and fecundity-weight relationships. After these measurements, ovaries were carefully excised from the body cavity of each gravid fish and preserved in modified Gilson solution in labeled 50ml sample bottles according to the method recommended by Simpson (1951) for later fecundity estimation and intra-ovarian oocyte measurements at the Biological Laboratory, School of Environmental Studies, Moi University. Sex and gonad maturity stages of specimens were recorded in the field and later used in determining population sex ratios and maturity frequencies.

Laboratory Preparation and Sample Analysis

Preserved ovaries from each individual fish were soaked in water for thirty minutes after which they were washed several times to get rid of the effect of the preservative, placed in clean wet petri dishes, opened, and eggs separated from ovarian tissues and finally transferred onto filter papers to remove excess water. Ripe and developing eggs were then separated. 0.1 g sub samples of ripe eggs were weighed using Mettler P1210 chemical balance. The mean number of ripe eggs in a sub sample gave the number of eggs per 0.1 g, which was converted to number of ripe eggs per gram of weight. Total ripe egg count was then calculated by multiplying the total weight of ripe eggs by the mean number of ripe eggs per gram of weight. The number of developing eggs was determined using the same procedure. The total number of ripe eggs was taken as absolute fecundity while all other eggs together with ripe ones were used to determine intra-ovarian oocyte frequency distribution. Size frequency distribution of intra-ovarian oocytes was calculated by measuring the diameter of 100 randomly selected ripe and developing oocytes (eggs) per female fish from preserved ovaries (Ekanem, 2000). The measurement of egg diameter was done with a calibrated eyepiece micrometer inserted on a compound microscope. Oocyte diameter was estimated by measuring the length and width of each egg to the nearest 0.1nm. The two measurements were added and their sum divided by two. The result was then multiplied by 100 to covert nanometers to millimeters.

Data Handling and Analysis

Size at first maturity *(Lm_{50})* in this study is defined following the method of Beverton and Holt (1957) as the length at which 50% of the fish in the population have reached at least stage 1V of gonadial development. This is related to the length of the fish population during development. Fish in stages 1, 11, 111 were considered immature while those in maturity stages 1V, V, V1 were taken as mature. Percentage maturity logistic curves were then fitted using the method of Garrod (1959). The percentage of mature individuals in each size class was described by a logistic curve as a function of the length of the fish (Witte & Densen, 1995). Fish were grouped into 2 cm class intervals ranging from 4.5 – 29.5 cm. Mid-classes were used in the graphical illustrations to estimate size at first maturity. Comparisons were made between different refugia using Single Classification ANOVA Model-1 and 11, Fisher F- and Student t-tests. Seasonal changes in maturity were evaluated. Sex ratios were determined for only those specimens whose gonads were identifiable as male and female. χ^2 –test was used to statistically evaluate the deviations of sex ratios from 1:1 (male: female) null hypothesis. Fecundity (F) in this study means absolute fecundity, estimated as the total number of eggs counted from the ovaries of the fish prior to spawning (maturity stages 1V-V1) (Bagenal, 1978). The Least Squares Method (95% confidence level) described by Healey and Nicol (1975) was used to calculate fecundity-length and fecundity- weight relationships. Analysis of covariance (ANCOVA) was done to compare the coefficients of these relationships between populations from the sampled refugia. Fulton's condition factor (CF) was calculated employing the formula recommended by Ricker (1975): $CF = 100W/L^3$, Where CF = condtion factor, W = total wet weight of individual fish samples in grams and L = total length of individual fish samples in centimeters. Gonosomatic index (GSI) of fish between maturity stages 1-V1 was calculated with gonad weight recorded as a percentage of total body weight, including gonads. Model–11 ANOVA was used to determine variations in GSIs among the refugia.

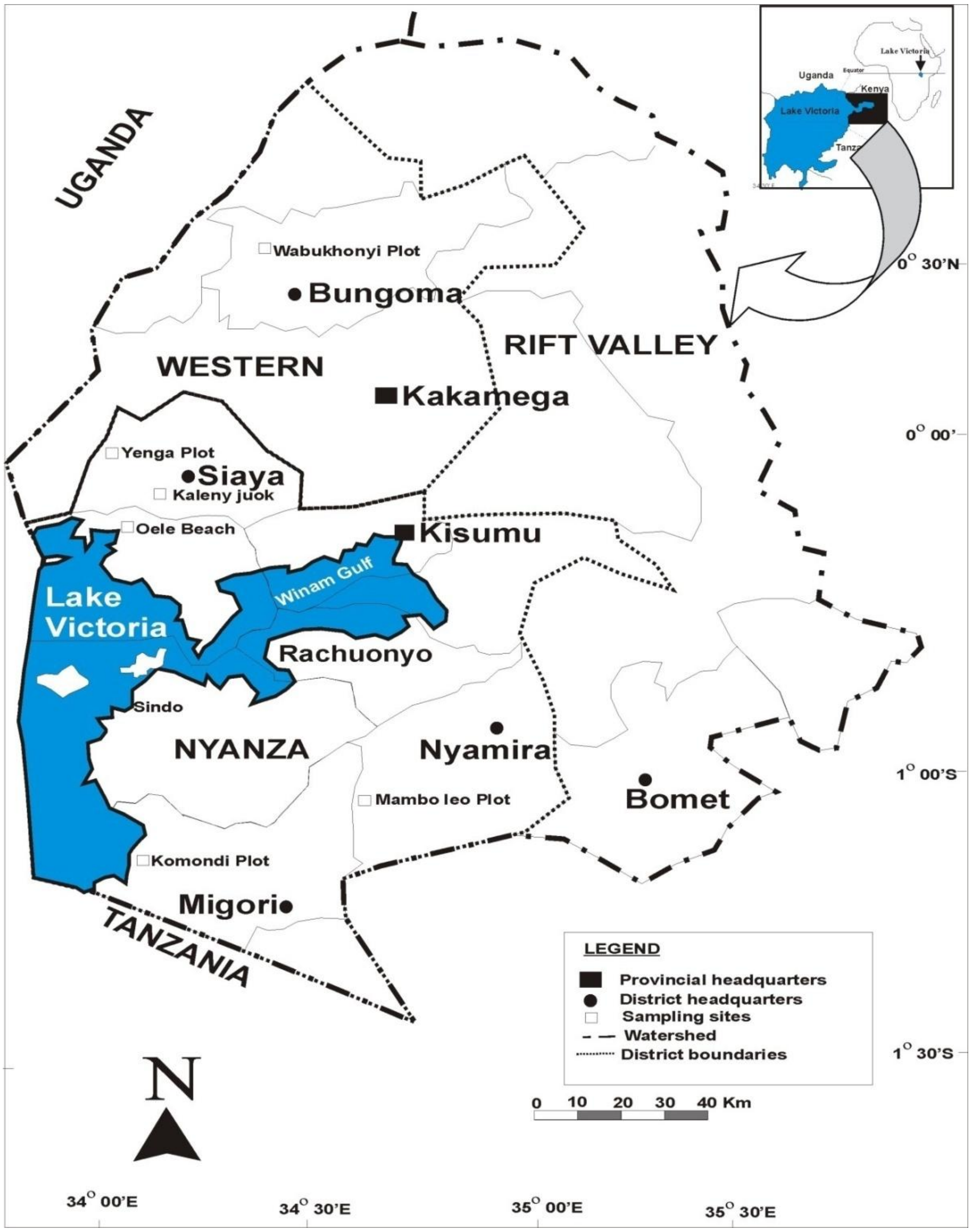

Figure 1. Map of Lake Victoria Basin, Kenya; Showing Sampled Research Sites

Results

Size at First Maturity

There were no significant variations in size at first maturity between males and females in the different refugia but females were found to have a much smaller size at fifty-percent maturity (Lm_{50}) than males (Figs.2a-d). Fish in high altitude refugia attained first maturity at sizes bigger than those in Lake Victoria, low and mid-altitude habitats (Figs. 2a-d) showing delayed gonadial development in the higher altitudes. The smallest ripe female was 12.5 cm TL from Kalenyjuok dam while the smallest ripe male was 13.0 cm TL found in populations from both Kalenyjuok and Lake Victoria (Table 1). The largest ripe male and fecund female, were 29.0 cm TL and 25.6 cm TL respectively, both from high altitude Mamboleo dam (Table 1). The highest number of mature fish stocks was recorded in low altitude Kalenyjuok dam, which contributed 69.08% mature males and 85.816% mature females, shown in Table 1. Overall, there was preponderance of mature males over females in all populations. Water bodies located in the lower altitude contained the highest number of mature fish populations but which were of smaller sizes than those in the high and mid altitudes. Single classification

Male and female fish stocks in mid and high altitudes had significantly larger mean lengths at 50% maturity (Lm_{50}) than male and female stocks in Lake Victoria and the low altitudes, [F-test; $F_{0.05\ (1,\ 5)} = 13.755$, p = 0.006]. There were no well-defined seasonal maturity peaks of fish stocks and the process of maturation was continuous.

Table 1. Mature Male and Female *O. variabilis* Populations (Stages 1V-V1) from Different Refugia and Ecozones in Lake Victoria Basin, Kenya (asterisks indicate significant differences in percentage numbers at L_{m50} (both male and female populations); ANOVA Model-II: * = p = 0.05; ** = p = 0.01; *** = p = 0.001)

Ecozone	Habitat	N (Male)	N (Female)	Mature male	Mature female	%mature male	%mature Female
Low altitude	L. Victoria	115	84	80	54	69.562	64.286*
	Kalenyjuok	207	141	143	121	69.082	85.816*
Mid altitude	Komondi	153	81	98	72	64.052	88.889*
High altitude	Mamboleo	167	41	112	33	67.066	80.488***
	Total	642	347	433	280	67.446	80.692**

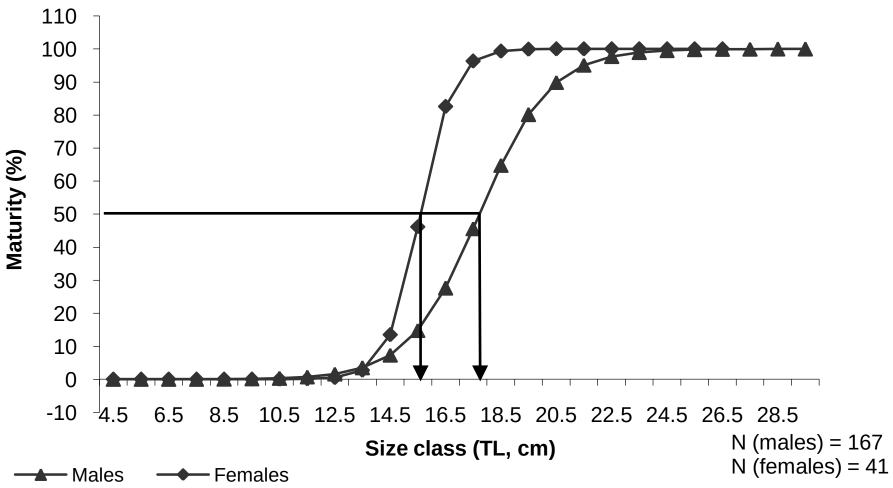

Figure 2a. Maturity Ogive for *O. variabilis* in Mamboleo Dam (High Altitude)

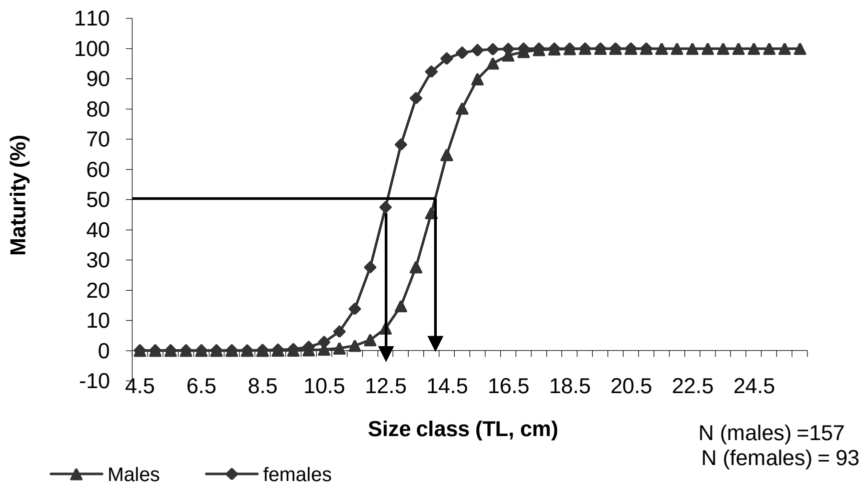

Figure 2b. Maturity Ogive for *O. variabilis* in Komondi Dam (Mid Altitude)

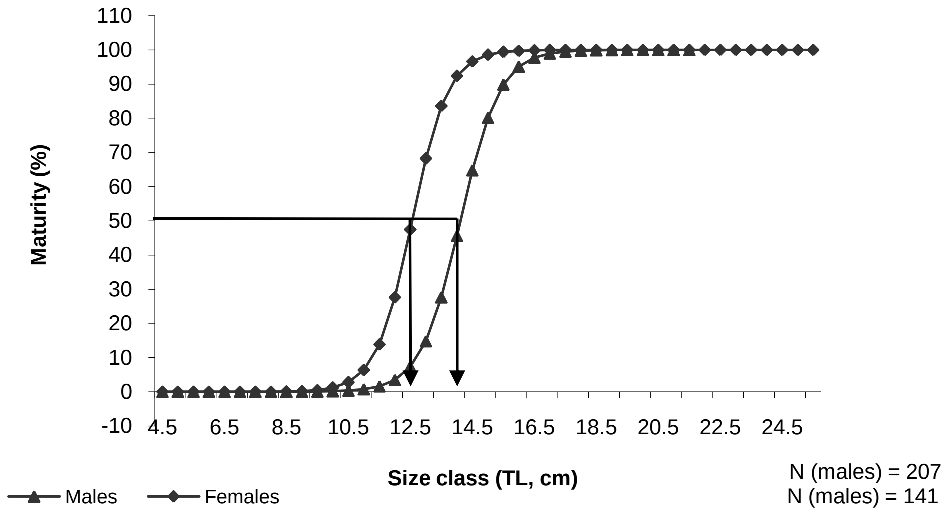

Figure 2c. Maturity Ogive for *O. variabilis* in Kalenyjuok Dam (Low Altitude)

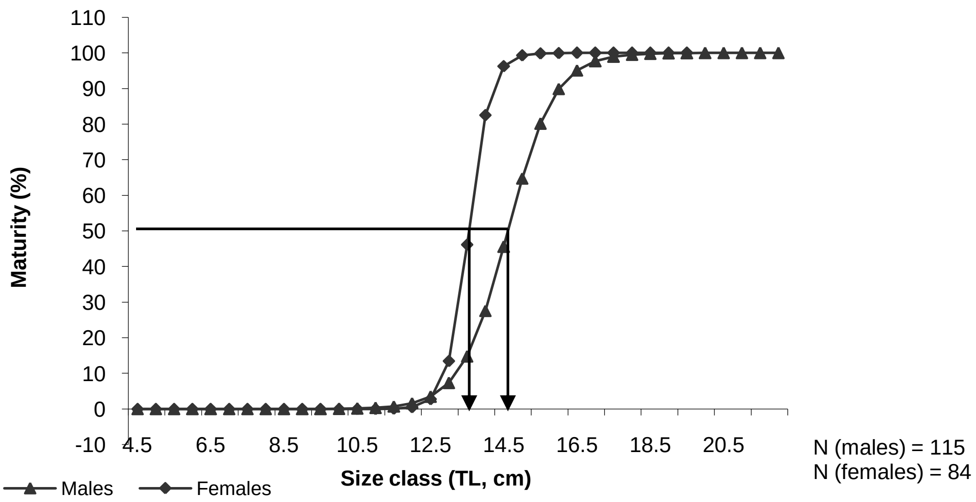

Figure 2d. Maturity Ogive for *O. variabilis* in Lake Victoria

Sex Ratio

Sex ratio varied considerably with maturity status, habitat and body size of the fish. Males were more abundant than females in all habitats and size groups. This male preponderance was also observed to follow a seasonal cycle (Figure 3). The male: female sex ratio in all habitats was significantly different from the hypothesized 1: 1; [$\chi^2_{7\,(1:1)}$ = 188.84, p=0.001] (Table 2) with a deficit of 40.61% females towards the upper limit of maturity distribution curve.

Table 2. Sex Ratio of Mature *Oreochromis variabilis* (*Lm₅₀*) in the Refugia Habitats of the Victoria Basin, based on Ecological Zonation (Ecozones)

Ecozone	Habitat	N	Male	Female	% Male	Sex ratio	$\chi^2_{7\,(1:1)}$
Low altitude	L. Victoria	159	107	52	67.3	1.000:0.486	32.82 $^{p > 0.001}$
	Kalenyjuok	296	174	122	58.8	1.000:0.701	9.54 $^{p < 0.1}$
Mid altitude	Komondi	151	104	47	68.9	1.000:0.452	37.86 $^{p > 0.001}$
High altitude	Mamboleo	149	40	40	73.2	1.000:0.367	43.04 $^{p > 0.001}$

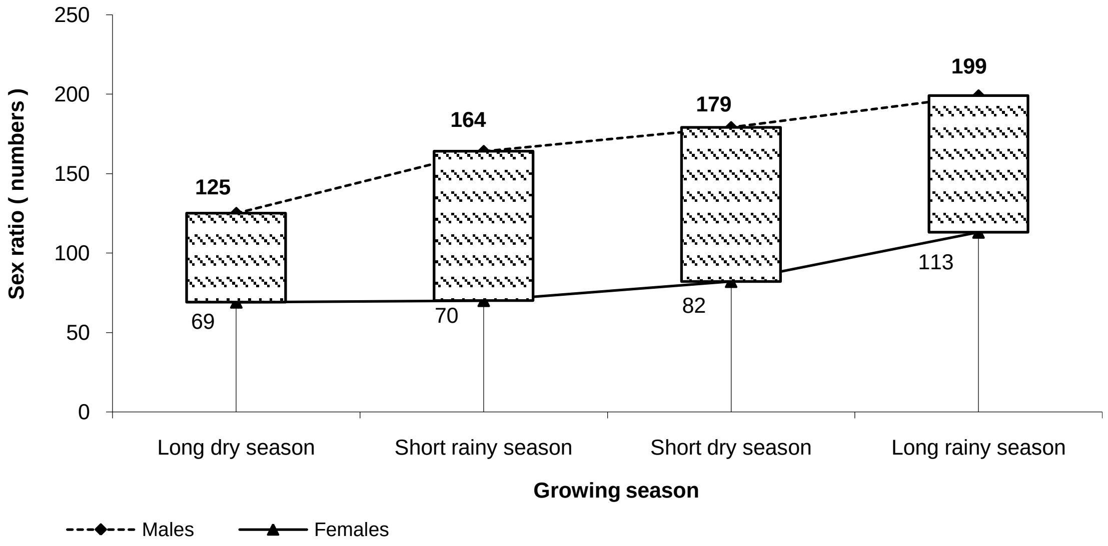

Figure 3. Example of Continuous Seasonal Variations in Sex Ratio of *O. variabilis* in the Refugia of the Victoria Basin

Fecundity

Absolute fecundity varied with individual fish from a minimum 68 eggs for a fish of 13.4 cm, TL and weighing 40 g to a maximum 14880 for a fish with 18.6 cm, TL and 135 g-body size (Table 3). Fish stocks from Lake Victoria had the highest overall fecundity. The smallest and largest sizes of gravid females were recorded in low altitude Kalenyjuok Dam (12.5 cm, TL 38 g and 24.5 cm, TL 295 g, respectively). A fecund specimen of 25.6 cm, TL from high altitude Mamboleo Dam weighed only 237 g with absolute fecundity of 942 eggs.

Table 3. Comparisons of Reproductive Potential of *O. variabilis* from Different Refugia Habitats in the Kenya Victoria basin: minimum and maximum fecundity in each habitat, minimum and maximum lengths and weights of gravid females (stage V1): Fmin and Fmax = minimum and maximum fecundity, Lmin, Lmax, Wmin, Wmax = minimum length, maximum length, minimum weight and maximum weight recorded for fecund individuals respectively

Habitat	Fmin	Fmax	Lmin, TL (cm)	Lmax,TL (cm)	Wmin (g)	Wmax (g)
L. Victoria	1192	14880	13.50	18.6	45	135
Kalenyjuok	98	1846	12.5	24.5	38	295
Komondi	105	1207	13.0	20.5	40	160
Mamboleo	73	942	13.5	25.6	40	237

Fecundity-Length and Fecundity-Weight Relationships

Fecundity-length and fecundity-weight relationships are given in Table 4. Analysis of covariance (ANCOVA) revealed significant differences in these relationships between gravid female populations in the lower and higher altitudes. Fisher- test showed that fecundity-length had a significantly higher coefficient than fecundity-weight relationships [$F_{0.05\,(1,\,112)}$ =84.942959, p = 6.59x10^{-9}], and that length, but not weight, is a reliable parameter for estimating fecundity in *O. variabilis*.

Table 4. Relationships between Fecundity (F) and other Body Parameters: Total Length (L), Body Weight (W). Slope values with the same superscripts indicate covariance in population fecundity characteristics (comparisons of slope-coefficient values): ANCOVA, p = 0.05)

Ecozone	Habitat	Relationship	r^2	N
Low altitude	L. Victoria	F = 0.06828.$L^{3.8935a}$	0.68	20
		F = 9.5940 $W^{1.3108d}$	0.72	20
	Kalenyjuok	F = 0.02382 $L^{3.5344a}$	0.79	58
		F = 2.87343 $W^{1.1686d}$	0.81	58
Mid altitude	Komondi	F = 0.16924 $L^{2.9153b}$	0.64	32
		F = 9.384259 $W^{0.9339e}$	0.64	32
High altitude	Mamboleo	F = 0.04074 $L^{3.145b}$	0.69	20
		F = 2.703958 $W^{1.0776e}$	0.68	20

Oocyte Diameter and Size Frequency Distribution of Intra-Ovarian Oocytes

Egg diameter was found to vary from 0.3 mm in gravid populations from Lake Victoria habitats to 5.19 mm in populations from the low altitude Kalenyjuok Dam. Neither did the largest egg belong to the biggest fish nor was the smallest egg found in the smallest fish. The smallest gravid fish (from low altitude Kalenyjuok dam) of length 12.5 cm TL and weighing 38 g had eggs had a mean egg diameter (± SD) of 3.44 ± 0.08 mm whereas the biggest fish (from high altitude Mamboleo dam) with length 24.5 cm, TL and weighing 295 g had a mean egg diameter (± SD) of 2.04 ± 0.6 mm. Intra-ovarian diameter defined as the mean of width and length of egg individual (Table 5), was largest in eggs from fish populations in the low altitude, where homogeneity in egg size and ripeness was observed. The smallest egg diameter was recorded in fish from the Lake Victoria, where egg size and ripeness were extremely heterogeneous. Lake Victoria fish eggs were found to be of significantly inferior size compared to eggs from fish populations in the low altitude. Increased heterogeneity in oocyte diameter of Lake Victoria fish populations was demonstrated by the high coefficient of variation, CV = 72.99 % (Table 5), a factor which could lead to further added variations in egg survival and hatching success. Low altitude fish populations had significantly larger eggs than those from mid and high altitude habitats and exhibited a higher homogeneity in egg size, with a 34.04 % coefficient of variation which would guarantee increased egg survival and high hatching success.

Table 5. Mean (± SE) and Coefficient of Variation (CV) of Intra-Ovarian Oocyte Diameter of *Oreochromis variabilis* Populations from the Kenya Victoria Basin

Ecozone	Habitat	Mean oocyte diameter (mm)	SE	CV (%)
L. Victoria	L. Victoria	1.37	1.00	72.99
Low altitude	Kalenyjuok	3.32	1.13	34.04
Mid altitude	Komondi	2.31	0.81	35.06
High altitude	Mamboleo	2.12	0.94	44.34

Intra-ovarian egg diameter (Figure 4a) of fish from high altitude Mamboleo Dam was distributed within 0.3 – 1.69 mm peak size range with the distribution reaching 3.44 mm mean size; mid altitude Komondi Dam oocyte distribution reached 3.79 mm with peak range 0.65 – 2.04 mm (Figure 4b). Fish eggs from low altitude Kalenyjuok Dam had a more symmetric intra-ovarian distribution of large sized oocytes with peak range 1.70 – 3.44 mm and larger oocytes reaching 5.19 mm (Figure 4c). Oocyte size distribution in Lake Victoria stocks was similar in pattern to that recorded for high altitude except that the distribution was much more skewed toward smaller sizes with clusters of larger eggs on the upper end of the distribution curve (Figure 4d).

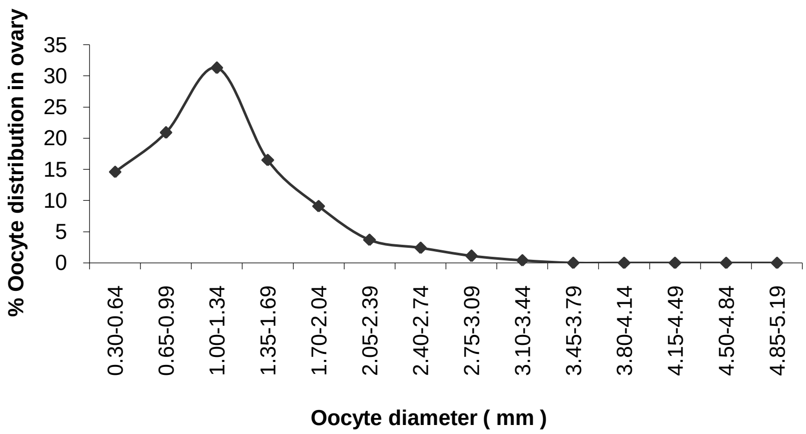

Figure 4a. Percentage Intra-Ovarian Oocyte Size Distribution in *O. variabilis* from Mamboleo Dam (High Altitude)

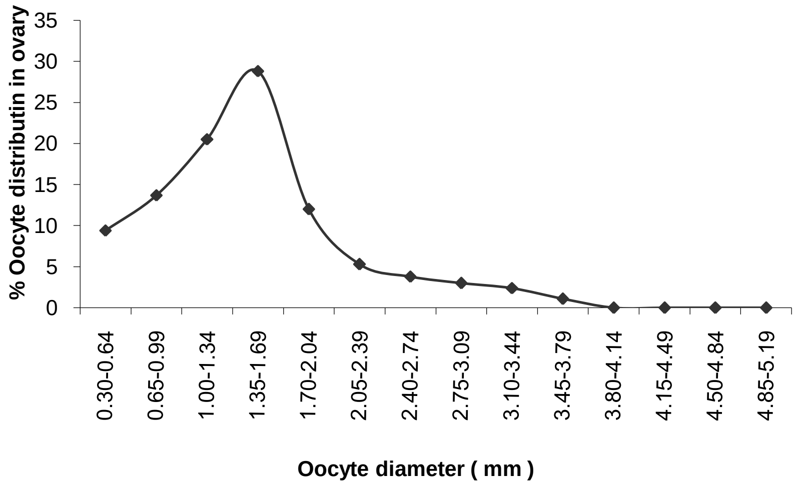

Figure 4b. Percentage Intra-Ovarian Oocyte Size Distribution in *O. variabilis* from Komondi Dam (Mid Altitude)

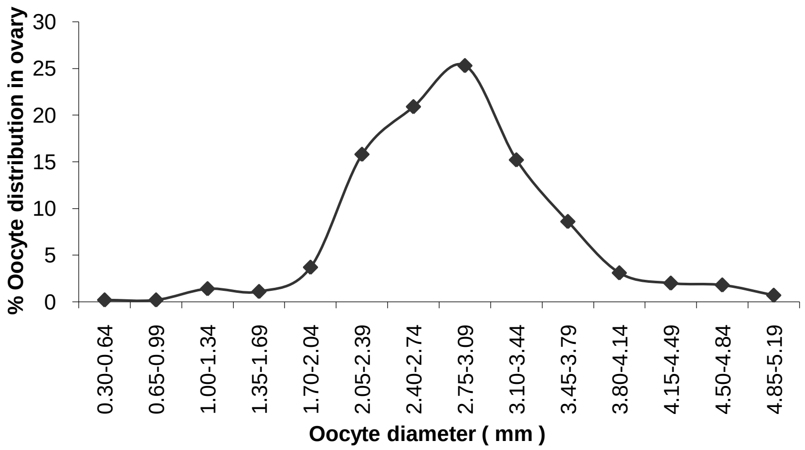

Figure 4c. Percentage Intra-Ovarian Oocyte Size Distribution in *O.variabilis* from Kalenyjuok Dam (Low Altitude)

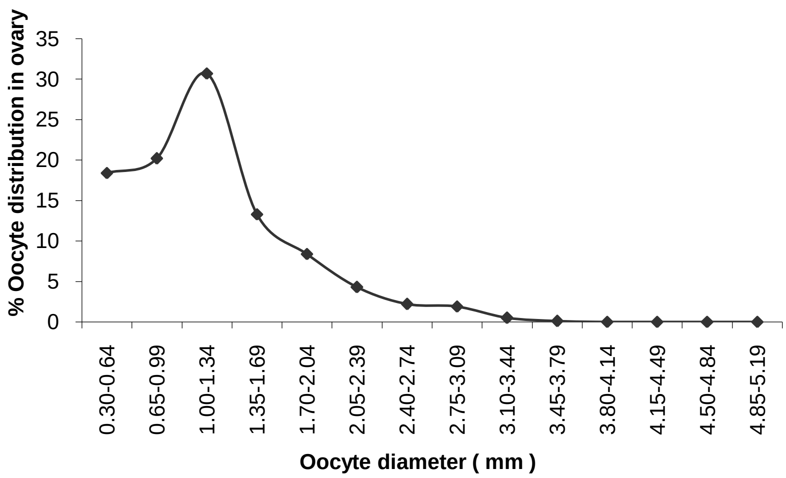

Figure 4d. Percentage Intra-Ovarian Oocyte Size Distribution in *O. variabilis* from Lake Victoria

Population Condition Factor (CF)

Condition factor varied considerably with body size, population sex and habitat from 1.31 [for a fish specimen measuring 18.3 cm TL and 80 g] to 4.35 (for a specimen of length 4.1 cm TL and weight 3 g). The worst mean (± SE) CF was recorded in high altitude Mamboleo (1.74 ± 0.05) while the best was 2.06 ± 0.04 from Lake Victoria populations (Figure 5). More than 50% of the samples from all refugia in this study had a CF greater than their respective population mean. Mean CF of female population was higher than that of male population in all populations (Table 6). Overall, CF was high in smaller fish and decreased with increase in body size.

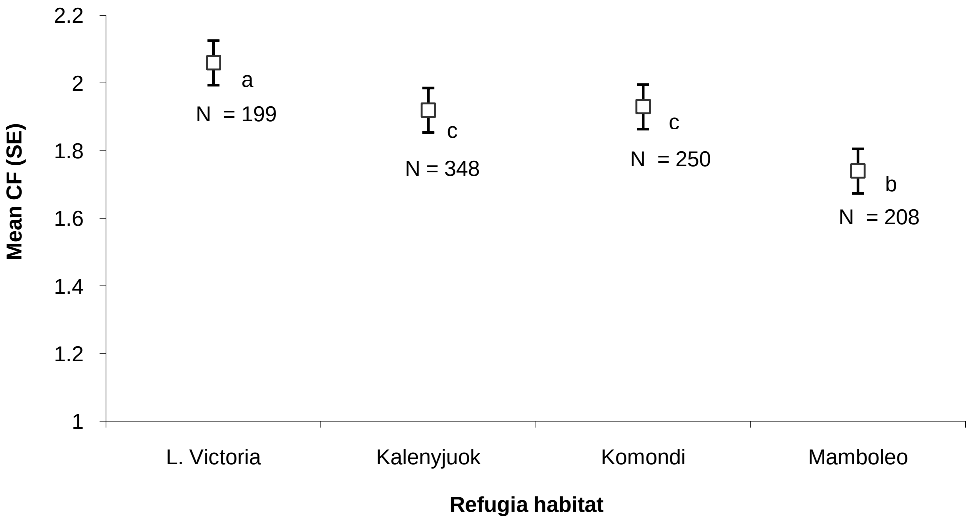

Figure 5. Population Mean Condition Factor (CF)) of *O. variabilis* from Refugia Habitats of the Victoria Basin, (N = sample size, values characterized by the same alphabets are not significantly different: Student t-test, p = 0.05)

Table 6. Mean Condition Factor (CF) of Male and Female *O. variabilis* , Coefficient of Variation (CV_s) in Male and Female CF , and Coefficient of Variation (CV_P) in Population CF

Refugia habitat	Mean CF male	SD	N	Mean CF female	SD	N	CV_s (%)	CV_p (%)
L. Victoria	2.03	0.19	115	2.09	0.39	84	1.94	13.17
Kalenyjuok	1.71	0.24	207	1.76	0.28	141	2.30	15.03
Komondi	1.92	0.22	153	1.94	0.19	81	1.93	10.88
Mamboleo	1.79	0.37	167	1.69	0.24	41	4.02	19.77

Gonosomatic Index (GSI) and Spawning Cycle

Lowest mean gonosomatic indices (GSIs) in both male and female developmental stages were recorded in the high altitude Mamboleo Dam while Lake Victoria fish stocks gave the highest values (Table 7). Female populations in all habitats exhibited significantly higher mean GSIs than males [$t_{0.05\,(17)} = -8.19$, $p = 1.3 \times 10^{-7}$]. Results of this study indicated that *O. variabilis* is a multiple spawner and that the species breeds throughout the year without any defined seasonal cycle. Besides, the intra-ovarian oocyte distribution reveal that in every mature ovary with ripe eggs (stage IV – VI) there are young and ripening oocytes (stage I – III), an indication that the ovaries contain oocytes of three or more size groups and that an individual fish may produce three or more broods in succession.

Table 7. Mean (± SE) Gonosomatic Index (GSI) of Male and Female *Oreochromis variabilis* from the Refugia Habitats of the Victoria Basin [GSI at Gonad Developmental Stage (I – VI)]

Habitat	Males											
.	I	SE	II	SE	III	SE	IV	SE	V	SE	VI	SE
Mamboleo	0.03	0.01	0.05	0.01	0.08	0.02	0.14	0.03	0.17	0.02	0.21	0.05
Komondi	0.06	0.01	0.08	0.01	0.1	0.01	0.14	0.02	0.19	0.03	0.25	0.03
Kalenyjuok	0.14	0.03	0.18	0.03	0.22	0.02	0.25	0.02	0.29	0.04	0.32	0.04
Lake Victoria	0.22	0.09	0.25	0.1	0.36	0.08	0.48	0.13	0.6	0.13	0.66	0.08
	Females											
	I	SE	II	SE	III	SE	IV	SE	V	SE	VI	SE
Mamboleo	0.22	0.04	0.26	0.02	0.32	0.08	0.71	0.22	0.85	0.16	0.98	0.18
Komondi	-	-	0.69	0.22	0.77	0.15	1.02	0.06	1.21	0.27	1.24	0.27
Kalenyjuok	1.77	0.4	1.98	0.31	2.3	0.1	2.47	0.35	2.53	0.33	2.91	0.32
Lake Victori	1.78	0.61	2.46	0.52	3.04	0.54	4.12	0.62	5.06	1.19	5.25	1.36

Discussion and Conclusions

Variations in size at first maturity between males and females of *O. variabilis* exist but are not significant. Lowe-McConell (1955) and Fryer (1961) observed that males reach first maturity at a larger size than females. However, the present study shows that both male and female populations attain first maturity at sizes smaller than those recorded earlier, suggesting a shift in development and reproductive strategies of the species, owing to probably changes in environmental conditions that may have taken place in the Lake Victoria basin over the decades. Influence of environmental factors could be discerned from delayed gonadial development in the high altitude. In aquaculture terms, results of size at first maturity in this study would mean that farming *O. variabilis* in the low altitude areas would result in faster growth of fishes that are of small sizes while in the high altitude the fishes will have a slow growth and longer developmental period that will yield bigger-sized individuals. Continuous gonadial development throughout all seasons gives the species a high aquaculture potential in terms of continuous regeneration and provision of fry.

Male preponderance over females indicates that there are more males at 50% maturity of the populations than females. This may be interpreted in aquaculture terms to mean increased potential of the species for culture practices, as it suggests that there are higher chances than less of stocking more males than females in any given batch of fry meant for rearing, and since males spent more energy in somatic growth than in reproduction, the yield (Kg/ha) would be expected to be high. Fecundity was found to be higher than that reported by earlier workers. This high fecundity together with the excellent condition factor and large egg size are enough criteria to conclude that *O. variabilis* has high potential for aquaculture and is a prime aquaculture candidate in the low altitude areas of the Lake Victoria basin. Although Lake Victoria fish populations recorded the highest fecundity, survival and hatching success of eggs cannot be guaranteed due to the small sizes of these oocytes. The low altitude fish populations were in good condition, with high fecundity and large-sized eggs. This large size of eggs could be attributed to the stable and homogeneous physico-chemical parameters found in the low elevation environments. This study showed that fecundity is proportional to fish size when length is considered but not weight, the exponent value obtained lying between 2.9 and 4.5, which is within the range 2.3 – 5.3, calculated for a variety of warm water fishes by Bagenal (1978). Since condition factor, fecundity and egg size are important in stock discrimination (Ekanem, 2000) and are used in aquaculture for separating populations of the same species (Weatherly & Rogers, 1978), it may be concluded that the low altitude Lake Victoria basin stocks of *O. variabilis* provide the best broodstock for aquaculture purposes. Hulata *et al.* (1974) pointed out that larger eggs enhanced fry and larval viability. It can be argued therefore that eggs produced by stocks from low altitudes of the basin stocks are superior and of better quality, hence, the low altitude SWBs are better repositories of aquaculture broodstock of *O. variabilis* than the high altitude counterparts and the lake itself. *O. variabilis* reproduces throughout the year and 50% of the population reaches maturity at a size that may be regarded as optimal for commercial exploitation, an important attribute for exploitation in aquaculture practices.

Acknowledgements

We are indebted to the World Bank for financial assistance that made possible this research through the Lake Victoria Environmental Management Program (LVEMP-IDA/GEF Grant). We are very grateful to the Deputy Director of Kenya Marine Fisheries Research Institute (KMFRI) Dr. E. Wakwabi and the former LVEMP Coordinator Dr. S.W. Njoka for keenly coordinating flow of funds to support this work. Walter Oyieko and Dismus Nyakiamo together with their mercantile team risked effects of adverse weather to make research cruises and field data collection possible.

References

Bagenal, T. B. (1978). Aspects of fish fecundity. pp. 75-101. In: S. D. Gerking (Ed). Ecology of freshwater fish production. *Blackwell Scientific Publications, Oxford.*

Beverton, R. J. H., & Holt, S. J. (1957). On the dynamics of exploited fish populations. Fish Invest. Ministry of Agriculture. Fish Food, London, G.B. (2 Sea Fish). 19, 533p.

Boulenger, G. A. (1906). *Catalogue of fresh-water fishes of Africa. Trustees British Museum Natural History.*

Ekanem, S. B. (2000). Some productive aspects of *Chrysichthys nigrodigitatus* (Lecépède) from Cross River, Nigeria. Naga, the ICLARM Quarterly, Vol. 23, No. 2; pp 24-28.

Fryer, G. R. (1961). Observations on the biology of the cichlid fish *Tilapia variabilis* Boulenger in the northern waters of Lake Victoria (East Africa). *Rev. Journal Zoology and Botany Africa.* 64: 1-33.

Garrod, D. J. (1959). The history of the fishing industry of Lake Victoria, East Africa, in relation to the marketing facilities. *East Africa Journal of Agriculture*. 27, 95-99

Healey, M. C., & Nicol, R. A. W. (1975). Fecundity comparisons for various stocks of Lake White fish, Coregonus clupeaformis. *Journal of Fisheries Research and Biodiversity*, Canada.. 32, 404-407.

Hulata, R., Moav, R., & Wohlfarth, G. W. (1974). The relationship of gonad and egg size to weight and age in the common carp, *Cyprinus carpio* L., *Journal of Fish Biology*, 6, 745-758.

Kaufman, L. (1992). Catastrophic changes in species-rich freshwater ecosystems: the lessons of Lake Victoria*. Bioscience* 42: 846-858.

Lowe-McConell, R. H. (1955). New fish species of Tilapia (Pisces, Cichlidae) from Lake Jibe and the Pangani River, East Africa. *Bulletin British Museum Natural History and Zool.ogy*. 2, 347-368.

Oni, S. K., Olayemi, J.Y., & Adegboye, J. D. (1983). Comparative physiology of three ecologically distinct freshwater fishes, Alestes nurse Ruppell, Synodontis schall Broch and Schneider and Tilapia zillii Gervais. *Journal of Fish Biology*. 22, 105-109.

Prein, M., Hulata, G., & Pauly, D. (Eds). (1993). *Multivariate methods in aquaculture research: case studies of tilapias in experimental and commercial systems*. ICLARM Stud. Rev. 20, 221p.

Pullin, R. S. V. (1993). An overview of environmental issues in developing country aquaculture, pp. 1-19. In: R. S. V. Pullin, H. Rosenthal and J. L. Maclean (eds*.). Environment and aquaculture in developing countries. ICLARM Conference Proceedings* 31, 359p.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of Fisheries Resources Board Canada. 191. Ottawa*, 282p.

Simpson, A. C. (1951). The fecundity of plaice. U.K. Ministry of Agriculture, Fisheries and Food Investment Services. 217, 3-27.

Weatherly, A. H., & Rogers, S. (1978). Some aspects of age growth. *In*: S.B. Gerking (Ed) *Ecology of freshwater fish production. Blackwell Scientific Publications*. Oxford. pp 52-74.

Witte, F., & van Densen, W. L. T. (1995). Fish stocks and Fisheries of Lake Victoria. Samara Publishing House, Samara House, Cardigan, Great Britain. 404p.