
Population characteristics of *Oreochromis esculentus* in the Victoria and Kyoga lake basins. Implications for conservation and improvement of the stocks

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Abstract

The tilapia fish *Oreochromis esculentus*, is endemic to only lakes Victoria and Kyoga and a few satellite lakes in the two lake basins. It was the most important commercial fish species during the first half of the 20th century in the two lake basins but because of over-exploitation and competition with introduced tilapiines, its stocks declined and, by 1980s, *O. esculentus* was virtually absent from the two main lakes. Lakes Mburo, Kachera, Kanyanja and Kayugi in the Lake Victoria basin, and Nabisojjo, Kawi and Lemwa, in the Lake Kyoga basin, where remnants of the species survived were investigated using experimental fleets of gillnets from 1997 to end of 2002 with the objective of determining the species length frequency distribution, condition factor, feeding and breeding to guide its management, conservation and enhancement. Fish caught in Lake Kayugi, where diatoms dominated in the stomach contents attained the largest size, were most fecund and had a high value of condition factor K. These findings suggest that diatoms were vital in the survival of *O. esculentus*. However, with the recent shift of algal communities from diatoms to blue-green algae in most aquatic systems, assimilation of blue-green algae by *O. esculentus* should be investigated.

Key words: conservation, improvement, *Oreochromis esculentus*

Résumé

Le tilapia *Oreochromis esculentus* est endémique des seuls lacs Victoria et Kyoga et de quelques lacs satellites dans leurs deux bassins. C'était la plus importante espèce com-

merciale pendant la première moitié du 20^{ème} siècle dans ces deux bassins mais, en raison de la surexploitation et de la compétition avec des autres espèces de tilapias introduites, les stocks ont décliné rapidement et, au cours des années 1980, *O. esculentus* a pratiquement disparu des deux lacs principaux. Les lacs Mburo, Kachera, Kanyanja et Kayugi, dans le bassin du lac Victoria, et les lacs Nabisojjo, Kawi et Lemwa, dans le bassin du lac Kyoga, où il reste quelques survivants de l'espèce, ont été étudiés de 1997 à la fin de 2002 en utilisant des flottes expérimentales de filets maillants, dans le but de déterminer la distribution de la fréquence des tailles de l'espèce, les facteurs déterminant sa condition, son alimentation et sa reproduction, pour orienter sa gestion, sa conservation et sa consolidation. Les poissons pêchés dans le lac Kayugi, où les diatomées dominent dans le contenu stomacal, atteignaient la plus grande taille, étaient les plus féconds et avaient une valeur élevée du facteur K de condition. Ces découvertes suggèrent que les diatomées sont vitales pour la survie d'*O. esculentus*. Cependant, avec le récent glissement des communautés d'algues des diatomées vers les algues bleues dans la plupart des systèmes aquatiques, il faudrait étudier l'assimilation des algues bleues par *O. esculentus*.

Introduction

Freshwaters have suffered the most intense interventions of all ecosystems over the past 100 years and many fish species are now extinct, rare or endangered and the need for conservation action is therefore paramount (Cowx & Collares-Pereira, 2002).

Oreochromis esculentus Graham, 1929, is endemic to lakes Victoria and Kyoga and a few satellite lakes in the two lake basins (Ogutu-Ohwayo, 1993). Together with *Oreochromis*

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variabilis the two were the most important commercial fish species and supported the fisheries of these two lakes up to the mid-1960s. Till then, the fisheries of Lake Victoria were exploited solely by small scale fishermen (Jansen, 1997) and Lake Victoria contained large stocks of *O. esculentus*. With improved fishing technology in different parts of the lake, coupled with the growth of urban centres, the fishing industry assumed a commercial role with *O. esculentus* as one of the main target species (Keenleyside & Miles, 1991; Balirwa, 1992). The catch subsequently dropped and the fish became smaller because of increased fishing pressure (Fryer & Iles, 1972; Fryer, 1973) and increasing use of small mesh sized gill nets (Frans & van Densen, 1995). An increase in human population growth resulted into increased scarcity of land and lack of employment opportunities and, as a result a larger number of the men left the originally subsistence/part-time mode of exploitation and became full-time fishermen. This made *O. esculentus* one of the most threatened fish species and deprived the people who depended on it for food and employment. In addition, the Nile perch (*Lates niloticus*) upsurge coincided with the eventual total disappearance of the species from the main lakes Victoria and Kyoga.

In the earliest survey of Lake Victoria, *O. esculentus* of 30 cm total length (TL) were recorded in Kavirondo Gulf and 31 cm TL in the open lake, while specimens of 40–50 cm TL were caught in the southern waters of the lake (Graham, 1929). According to Greenwood (1966), the modal adult size of *O. esculentus* in Lake Victoria was 30–32 cm TL. In Lake Kyoga *O. esculentus* never exceeded 26 cm TL (Worthington, 1929). Overall weight was proportional to the cube of the length ($100W = 2L^3$) and the condition factor *K* was 2 in Lake Victoria (Graham, 1929), and was smaller in Lake Kyoga.

In Lake Victoria, *O. esculentus* fed on planktonic material collected from suspension (Fryer & Iles, 1972) especially diatoms (Fish, 1955). Schools of *O. esculentus* followed concentrations of diatoms in the lake (Gee & Gilbert, 1967) suggesting that diatoms were its preferred food item, although maximum growth in aquaria could be obtained on an unnatural diet of chopped worms such as *Stuhmannia* spp. (Cridland, 1964). The diatom *Aulacosira* previously known as *Melosira*, were usually the most abundant item in the gut contents and were 48.75% of the total cells present in all fish stomachs examined (Payne, 1971).

The size at initial breeding seemed to be determined by the environment. While in aquaria, breeding occurred at 10 cm TL, at the age of 5 months (Garrod, 1956), in a

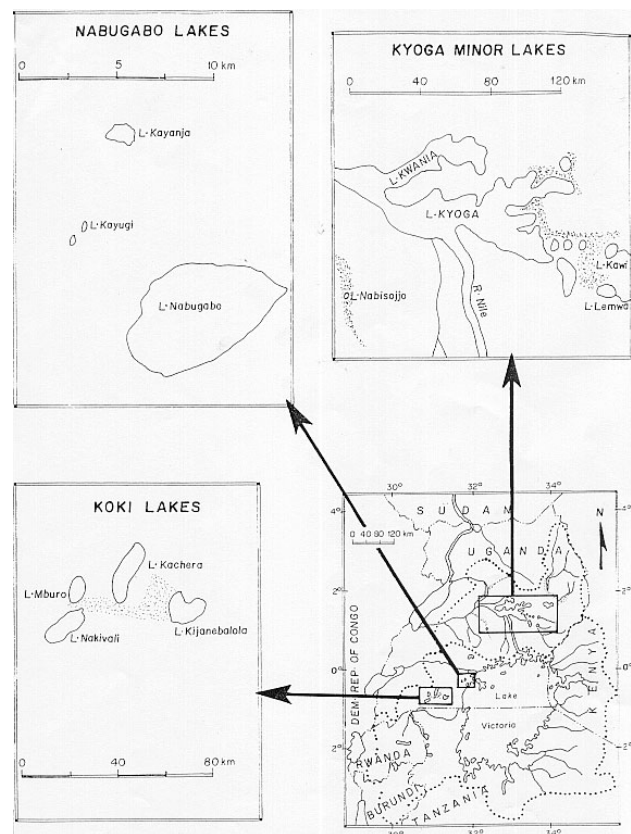
pond at Korongwe, Lowe-McConnell (1955) found that both sexes had bred at 16–19 cm in length when they were <7 months. In Lake Victoria, the smallest mature *O. esculentus* was 20 cm and at a length of 25–27 cm TL, 50% of both sexes were sexually mature (Graham, 1929; Greenwood, 1966). *Oreochromis esculentus* is a female mouth-brooder, without well marked spawning seasons. Highest breeding activity occurred between September and May (Greenwood, 1966), although breeding fishes were found throughout the year (Trewavas, 1983). Females could have a succession of three or more broods in a spawning period and fewer eggs were produced in the last brood of a series than the first. The average interval between broods in *O. esculentus* in aquaria was 2 months, 28 broods being recorded from ten pairs in 23 months. The number of eggs produced increased with the size of the female, ranging from 324 eggs in a fish of 17 cm TL to 1672 eggs in a fish of 36 cm TL (Graham, 1929; Trewavas, 1983).

Because of its high economic value, and its endemism in the lakes Victoria and Kyoga basins, *O. esculentus* was one of the first fish species to be extensively studied in two lakes. The species' ecology and biology in Lake Victoria were investigated by Graham (1929) and in Lake Kyoga by Worthington (1929). However, there remained a knowledge gap regarding the survival of *O. esculentus* in the satellite lakes which justified this investigation to document the population characteristics of the species in the satellite lakes. A comparison was made between the sampled lakes and the available data for the main lakes Victoria and Kyoga. These two lake basins were sampled for comparison because they share a common evolutionary history, have a similar native fish fauna (Graham, 1929; Worthington, 1929), have also had similar impacts by introduction of Nile perch and therefore could be considered to be similar for ichthyogeographical studies.

Materials and methods

The study was carried out on lakes Mburo, Kachera, Kayanja and Kayugi in the Lake Victoria basin and on lakes Nabisojjo, Kawi and Lemwa, (Fig. 1) in the lake Kyoga basin from 1997 to end of 2002. Lake Mburo occurs furthest in Western Uganda followed by Kachera and Lemwa furthest to in the east. Sampling was carried out using three fleets of identical multifilament nylon gill nets, with each fleet made up to ten gill nets of

Fig 1 Map of Uganda showing the study areas. The insets illustrate in details the sampled lakes



graded mesh sizes in approximately 12.5 mm increments from 51 mm to 178 mm (stretched knot to knot).

Total lengths (TL) and standard lengths (SL) of captured fish were measured to the nearest millimetre and weighed to the nearest gram. The specimens were then dissected and the stomach fullness, sex and maturity stages of the gonads determined according to Nilkolsky (1963). Female gonads at maturity stages V and VI and stomachs that contained any food were removed and preserved in 40% ethanol and 5% formalin solution respectively, in separate numbered bottles. The stomach contents were allotted a number of points according to the scheme modified from Hynes (1950) and the food categories were rated in proportion to their relative percentage volumes as spread out in a Petri dish or slide, to determine their relative importance in the species' diet. All the eggs in the two gonads of an individual fish were counted and were taken as the 'absolute fecundities' *F*. The data were analysed using Ms excel for variances, means, modals and percentages. *T*-tests and two way ANOVA were used to test the relationship of the findings in the sampled lakes up to 95% level of significance.

Results

Length frequency distribution of O. esculentus

A total of 2495 *O. esculentus* were examined from all the sampled lakes. The fish ranged from 7.7 to 38.7 cm TL (Fig. 2) with a modal size of 16–20 cm TL. The biggest fish (38.7 cm TL) was encountered in Lake Kayugi and the smallest (7.7 cm TL) in Lake Kanyanja. Lake Kayugi fish had the largest modal size (24–27 cm TL) followed by Lake Nabisojo (20–22 cm TL) and the smallest (12–14 cm TL) fish was from Lake Lemwa.

Condition factor K

The overall mean condition factor *K* was 1.79 ± 0.02 pooled data for all the sampled lakes. *K* was highest (1.92 ± 0.02) in *O. esculentus* from Lake Kawi, followed by lakes Kachera (1.89 ± 0.03) and Kayugi (1.89 ± 0.02) and lowest (1.50 ± 0.01) in from Lake Kanyanja fish (Fig. 3). ANOVA (single factor), showed no significant

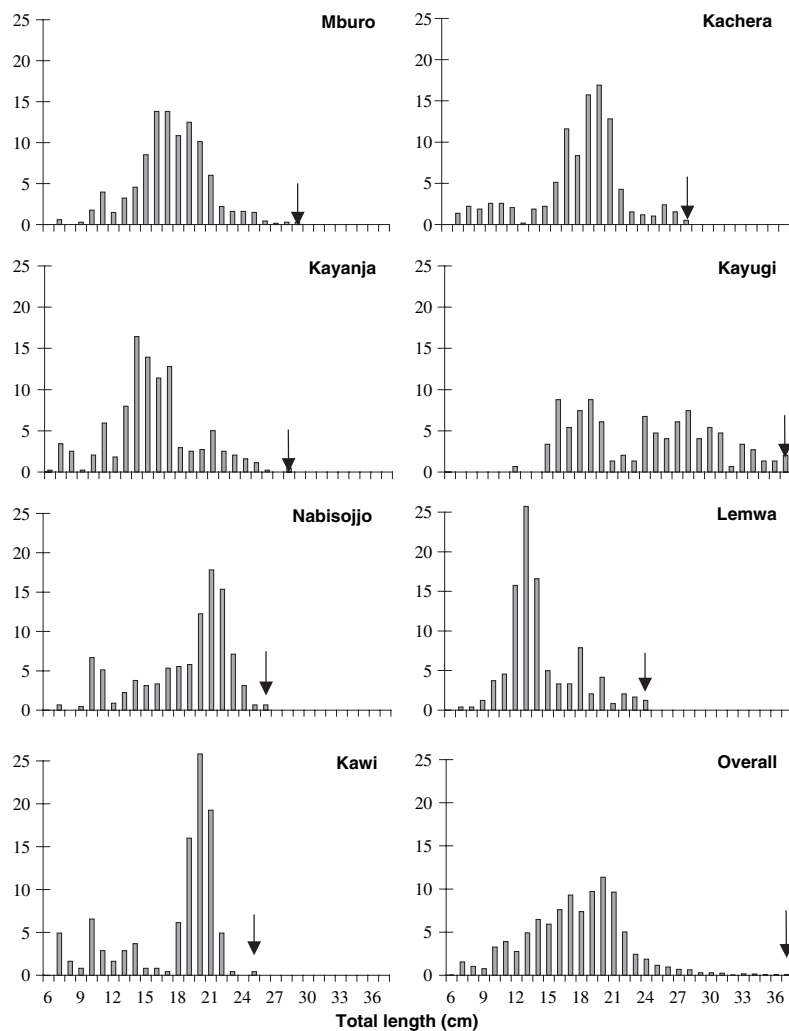


Fig 2 Length frequency distribution of *O. esculentus* in the different lakes. The arrow indicates the size of the largest fish caught per lake

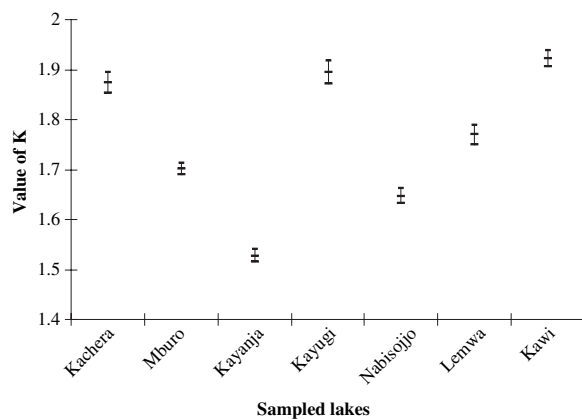


Fig 3 Comparison of the value of the overall condition factor K per lake

differences in the condition factor of *O. esculentus* between the sampled lakes ($P = 0.05$).

Food of *O. esculentus*

A total of 615 stomachs of *O. esculentus* were examined (51 from lake Mburo, 157 from Lake Kachera, 91 from Lake Kayanja, 16 from Lake Kayugi, 84 stomachs from Lake Nabisojjo, 118 from Lake Lemwa and 98 stomachs from Lake Kawi). The stomach contents comprised mostly of green algae (Chlorophyceae), blue-green algae (Cyanobacteria) and diatoms (Bacillariophyceae). *Microcystis* (Cyanobacteria) were the most abundant (26.2%), followed by *Aulacosira* (Bacillariophyceae; 15%) and the rest comprised a mixture of detritus, fish eggs, insect remains,

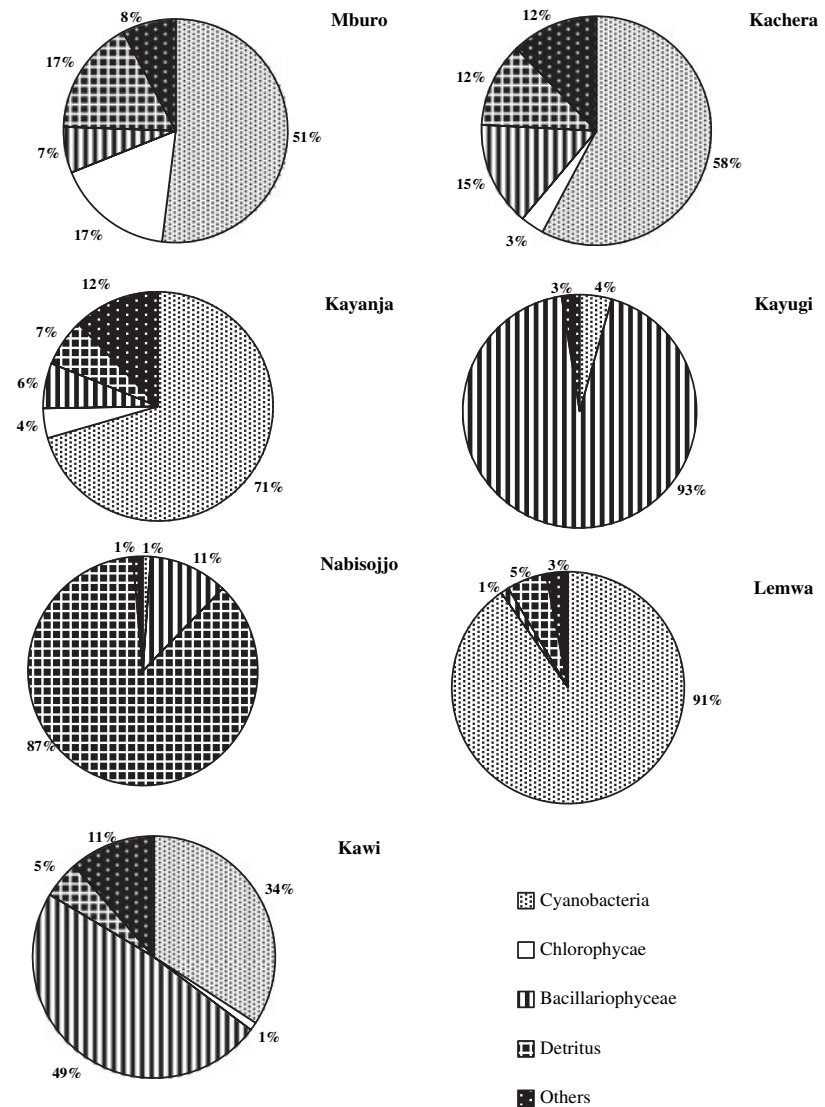


Fig 4 Relative contribution of the different food groups in the stomachs of *O. esculentus* in the different sampled lakes

Rotifer and chironomids which were encountered occasionally (Fig. 4).

Size at first maturity

The size at which 50% of the fish were mature was estimated by plotting the size distribution of fish against percentage of maturity; the point at 50% was taken as the size at first (50%) maturity. Highest size (20.5 cm TL) was recorded in Lake Kayugi and the lowest (12.5 cm TL) in Lake Kawi fish (Table 1).

Table 1 Shows the variations in the sizes at which 50% of the fish were mature in the sampled lakes

Lake	Size cm TL (50% maturity)
Kachera	16.8
Mburo	16.8
Kayugi	20.5
Kayanja	15.5
Nabisojjo	19.5
Lemwa	14.1
Kawi	12.5

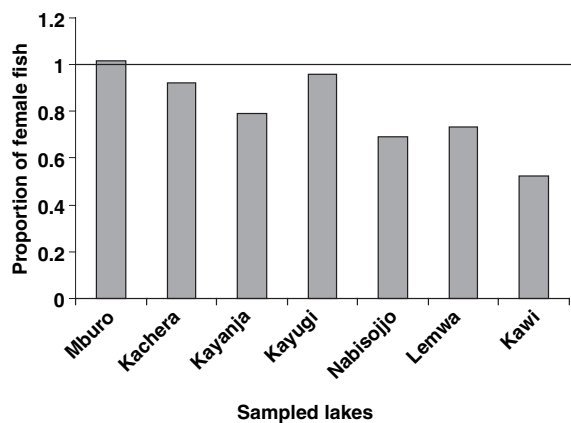


Fig 5 Comparison of sex ratios of *O. esculentus* from different lakes (The line at one shows how many females there is per male)

Sex ratio

There were more males than females (M : F = 1 : 0.96) for most lakes except Lake Mburo where the females were more than males (Fig. 5).

Fecundity of *O. esculentus*

One hundred and twenty-eight ripe female gonads were examined from all the sampled lakes of which 26 from gonads were from Lake Mburo, 42 gonads from Lake Kachera, six gonads from Lake Kayanja, eight from Lake Kayugi, 29 from Nabisojo, nine from Lake Lemwa and thirteen from Lake Kawi. Total egg counts per fish were regarded as the absolute fecundity which was used to establish fecundity–length and fecundity–weight relationships. The examined gonads were from fish ranging from 14.6 cm to 30.2 cm TL. The lowest number was 157 eggs in a fish of 14.6 cm TL from Lake Kayanja and the highest was 1364 eggs in a fish of 28 cm TL from Lake Kayugi.

The above results showed that absolute fecundity was nearly similar in lakes Kachera, Kawi and Lemwa ranging from 501 to 532 eggs with the mean fecundity being lowest in Lake Mburo 351 ± 19 and highest in Lake Kayugi 772 ± 18 . A remarkable contrast was observed between weight and length specific absolute fecundity. Fecundity per length ($F \text{ cm}^{-1}$) ratio was considered the best yardstick for comparison of the reproductive potential. Generally, bigger fish were more fecund when length ($F \text{ cm}^{-1}$) was considered. A general power and linear curve showing the relationship between absolute fecundity

and size (length and weight respectively) revealed that the fecundity–length relationship was $F = 4.0193L^{1.5438}$, $R^2 = 0.3316$, $n = 155$ and the linear curve for the fecundity–weight relationship was $F = 1.54W + 187.48$, $R^2 = 0.052$, $n = 155$ [where F is fecundity, L the total length (cm) and W the weight (g)]. Absolute fecundity was positively correlated with size.

Discussion and recommendations

Many of the threats to freshwater fish and fisheries focus on gross changes to the habitat or community structure; for example pollution, flow regulation, loss or change in aquatic habitat, over-exploitation and introduction of exotic species. These have all contributed towards the critical situation facing many freshwater fish species. Although, action has been taken to address this situation, traditional methods of conservation management for example regulation of exploitation, nature reserves, captive breeding programmes, do not seem to be as effective for freshwater fishes as for terrestrial flora and fauna (Cowx, 2002).

Lake Kayugi where diatoms were the most abundant in the stomach contents contained the largest fish with the highest value of the condition factor and most fecund *O. esculentus*. This may explain why diatoms especially *Aulacosira* were very important in the survival of the species as recorded by Graham (1929). However, there was a general reduction in the values of the different population characteristics examined in the satellite lakes as compared with available historical data in the main lakes Victoria and Kyoga. For example, the value of condition factor (1.79) recorded in the satellite lakes is lower than (2) Graham (1929) recorded in Lake Victoria. In addition the fish were smaller (with a modal size 16–20 cm TL) compared with recorded data in Lake Victoria by Greenwood, 1966 where the modal adult size was 30–32 and Graham (1929) recorded specimens of 40–50 cm TL. This reduction in size could be attributed to limited resources in terms of oxygen, nutrients and over exploitation from the fact that the size of the satellite lakes is much smaller as compared with the size of the main lakes Victoria and Kyoga where the species existed. The satellite lakes are just the size of a big pond and therefore this may mean that the fish have limited space and are exposed to decomposition of the surrounding microphytes in addition to excessive pressure from over exploitation by the increased human population.

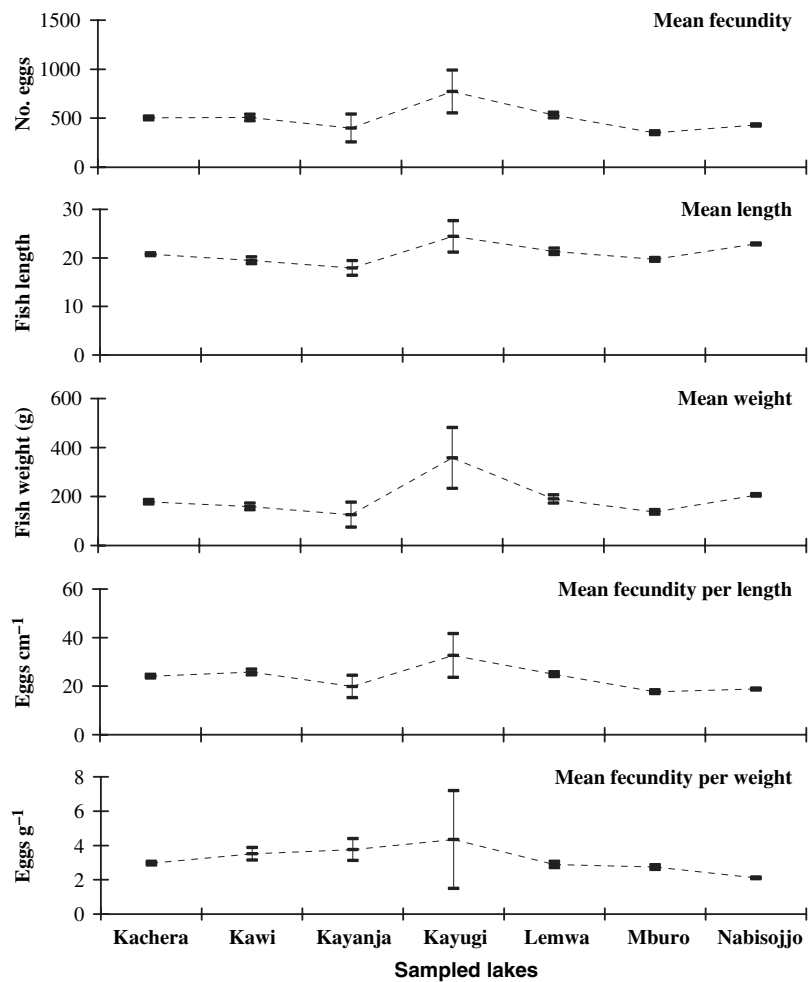


Fig 6 Illustrative presentation of the variation of the different parameters (size and weight) with fish fecundity

All the water bodies where *O. esculentus* was examined were all free of the predatory Nile perch, an indication that the species does not co-exist with Nile perch anywhere. The fish from Lake Kayugi exhibited the best strains of the species probably because of the fact that the lake experiences limited human influence because of the very extensive papyrus swamp surrounding the lake and the traditional norms controlling the amount of fishing effort on the lakes. Such norms include refusal of use of boats on this lake apart from rafts which indirectly reduce the fishing effort on the lake, denial of access to the lake unless permitted by the care taker of the lake, denial of access to the lake by children and women. In addition, however the lake catchment area is very sparsely populated because of the extensive papyrus

swamp and this limits the agricultural and domestic run-off into the lake.

From the information derived above, it is showed that *O. esculentus* is threatened by extinction because of over-exploitation. Therefore there is need to conserve the species and even improve its stocks. This can be done effectively through aquaculture and restocking of the main lakes, dams and satellite lakes and creation of reserve parks for the threatened species. This is evidenced from analyses carried out by Mosquera *et al.*, 2000, which demonstrated that the overall abundance of fishes inside reserves was on average 3.7 times higher than out side reserve boundaries and would enhance increased abundance of species. Lake Kayugi which had the best strains of the species would therefore provide an important source of the parent stock.

Furthermore, the research results from the fish stomach analyses showed that the algal communities had shifted to scarcity of diatoms and abundance of blue-green algae, which would therefore necessitate further research to investigate the capacity of *O. esculentus* to digest and assimilate the blue-green algae.

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