SOME REPRODUCTIVE CHARACTERISTICS OF *LATES STAPPERSII* IN THE SOUTHERN PART OF LAKE TANGANYIKA, ZAMBIA

BY

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DECLARATION

I. Felix Fisamu Musonda hereby declare that this dissertation represents my own work and that it has not been previously submitted for a degree at this or any other University.

Signature

13/08/02

Date

APPROVAL

THIS DISSERTATION BY ......Musonda Felix Bisandu...... IS APPROVED AS FULFILLING THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF ......Science...... BY UNIVERSITY OF ZAMBIA.

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To my Mum. Emmah Chitembo and Dad. Safeli Musonda for their unfading love.

ABSTRACT

The following aspects of reproduction of *Lates stappersii* caught in the Zambian sector of Lake Tanganyika were studied: stages of maturity and spawning season: sizes at maturity: sex ratios and fecundity. Fish samples were collected from September. 1999 to February. 2000

This study shows that. the mean gonado-somatic index (GSI) increases from stage I (immature or inactive) to stage IV (ripe-running) in both sexes. and then drops for stage V for females. as a result of release of sexual products. Monthly evolution of proportions of stages of maturity and mean GSI indicate that spawning was taking place mainly between December. 1999 and February. 2000.

The estimated sizes at maturity are 21.68 cm TL for males and 24.89cm TL for females and the maturity ranges were 7.68 cm and 11.70 cm respectively.
The overall sex ratio of 53% females: 47% males for *Lates stappersii* in the Zambian waters of Lake Tanganyika is not significantly different from the theoretical one. i.e. 50% females: 50% males. This parameter exhibits significant differences among sexes in January and February. 2000. and for length classes larger than 32 cm. where females are predominant.

Fecundity in *Lates stappersii* must be high because of small eggs. Partial fecundity ranges from 46 000 to 839 000 eggs per fish (average 273 000eggs). Relative partial fecundity varies from 441 to 1685 eggs * g-1 of fish (average 914 eggs * g-1 of fish). Exponential functions fit better the relationships between total length and partial fecundity ($R2$ = 0.861). and between body weight and partial fecundity ($R2$ = 0.857). A linear association exists between partial fecundity and gonad weight ($R2$ = 0.993). There is no correlation between fish sizes (i.e. total length and body weight) and relative partial fecundity.

Key words:
Lates stappersii. Zambian waters of lake Tanganyika. spawning season. size at maturity. sex ratios. fecundity.

RÉSUMÉ

Les aspects suivants de reproduction chez *Lates stappersii* pêché dans le secteur zambien du lac Tanganyika ont été étudiés: stades de maturité sexuelle et saison de ponte; tailles à la maturité; sex-ratios et fécondité. Les échantillons de poissons analysés ont été réalisés de septembre 1999 à février 2000.

En plus des caractéristiques habituelles des stades de maturité, il se trouve que le rapport gonado-somatique (RGS) moyen augmente du stade I (immaturité ou repos sexuelle) au stade IV (préponte) chez les deux sexes de L. *stappersii*. Il diminue au stade V (post-ponte) chez les femelles, probablement à la suite de l'émission des produits sexuels. Les variations mensuelles des proportions des stades de maturité et du RGS moyen sont similaires et indiquent que la ponte avait lieu entre décembre 1999 et février 2000.

Les tailles à la maturité estimées pour *L. stappersii* dans les eaux zambiennes du lac Tanganyika sont 21.68 cm et 24.89 cm de longueur totale pour les males et les femelles respectivement. Les longueurs totales auxquelles 25% (L25) et 75% (L75) d'individus sont matures sont L25 = 17.84 cm pour les males et 19.04 cm pour les femelles; L75 = 25.52 cm et 30.74 cm pour les deux sexes respectivement. Ceci conduit aux rangés de maturité de 7.68 cm pour les males et 11.70 cm pour les femelles.

Dans les eaux zambiennes du lac Tanganyika, le sex-ratio global pour *L. stappersii* est 53% de femelles: 47% de males. Celui-ci n'est pas significativement différent du sex-ratio global théorique, à savoir 50% de femelles: 50% de males. En revanche, ce paramètre montre des différences significatives entre sexes en janvier et février 2000, et pour les classes de longueur totale supérieure à 32 cm. Auxquels cas, les individus femelles sont prédominantes.

La petite taille des ovocytes suggère que la fécondité doit être très élevée chez *L. stappersii*. La fécondité partielle de cette espèce varie de 46 mille à 839 mille ovocytes par femelle (moyenne: 273 mille ovocytes). La fécondité partielle relative varie de 441 à

1685 ovocytes*g-1 (moyenne: 914 ovocytes*g-1 de femelle). Les relations exponentielles s'ajustent mieux que les autres fonctions testées aux données de fécondité partielle et de longueur totale (R2 = 0.861), et à celles de fécondité partielle et de poids totale (R2 = 0.857); une forte association linéaire existe entre la fécondité partielle et le poids des gonades (R2 = 0.993). La fécondité partielle relative est indépendante de la longueur totale et du poids total, mais elle présente une association linéaire significative avec le poids des gonades.

Mots clés: *Lates stappersii*; eaux zambiennes du lac Tanganyika; stades de maturité; saison de ponte; tailles à la maturité; sex-ratios; fécondité

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TL	Total Length
GSI	Gonadosomatic Index
W	Body Weight
w	Gonad Weight
n	Sample Size
CI	Confidence Interval
Pfec	Partial Fecundity
RelPfec	Relative Partial Fecundity
MI	Males at stage I
FI	Females at stage I
K	Condition Factor
L_{50}	Size at maturity
H_0	Accepted null hypothesis
H_1	Rejected null hypothesis
nF	Number of females in the sample
e_{pfec}	residual of partial fecundity

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1.0. INTRODUCTION

Lake Tanganyika is a home of about 252 fish species and sub species (Bell-Cross and Kaoma 1971). six of which stand out as commercially important. and are all endemic to the lake. These are two small-sized Clupeids: *Stolothrissa tanganicae* Regan. 1917 and *Limnothrissa miodon* (Boulenger. 1906) and four *Latid* predators. of which *Lates stappersii* (Boulenger. 1914) is the smallest in terms of size. The other three namely *Lates mariae* Steindachner. 1909. *Lates microlepis* Boulenger. 1898 and *Lates angustifrons*. Boulenger. 1906 are generally referred to as large *Lates*.

Lates stappersii. locally referred to as 'Bukabuka' or 'Nvolo.' is one of the most abundant species exploited from Lake Tanganyika. It is attracted by fishing lights at night and mainly caught by artisanal (e.g lift nets) and semi-industrial (i.e purse seine) fisheries. Together with the Clupeids. ('Kapenta'). they form an important commercial fishery resource and contribute greatly to the well being of the people in the region. This is at two levels. Firstly it is a source of income to fishermen and fish traders. Secondly. it provides an excellent and perhaps the cheapest animal protein. *L. stappersii* is the mainstay of Mpulungu Fishing Industry from late 1980s (Sinyinza. 1998). It has also contributed greatly to the status of the lake as being the largest producer of fish in Zambia (Hanek and Everett. 1995). The species is unique in that it is pelagic throughout its life and as stated above. endemic only to Lake Tanganyika (Coulter. 1991: Mannini. 1998a and 1998b: Phiri and Shirakihara. 1999).

Figure 1.1 shows the geographical location of Lake Tanganyika. The lake is 630 km long and has an average maximum width of 50 km (Welcomme. 1972: Mwape. 1998). It is situated approximately in the north-south direction between the latitudes 3°20'S and 8°45'S and between 29°00'E and 31°00'E longitude. The lake is part of the East African rift valley (Degens *et al.*. 1971. Rosendahl. 1987). It is shared by four countries. the Democratic Republic of Congo (DRC) having the largest share of the lake (45%). followed in order by Tanzania (41%). Burundi (8%) and Zambia (6%) (Welcomme. 1972: Mikkola and Lindqvist. 1989).

Lake Tanganyika is the largest of the East African rift lakes and is the second deepest. oldest. and most diverse lake in the world (after Baikal). containing about 18% of the world's fresh surface water. The lake covers an area of 32.900Km^2 with a maximum depth of 1470 m and a mean depth of 700 m (Welcomme. 1972). It has a very wide diversity of organisms of which some have no closely related organisms outside its basin. Recent estimates suggest that over 1.300 species of vertebrates and invertebrates inhabit Lake Tanganyika. of which over 500 are endemic to it (Cohen. 1991: Lowe Mc Connel. 1975).

The Lake is divided into three types of habitats: the littoral. benthic and pelagic zones. The littoral zone is the water body between the land and waters of 10 to 20 m depths. The benthic zone is the deep-water body of about 40 m or more. supporting life. The pelagic zone. a home of *L. stappersii*. is the open water of which the deeper layers of over 200 m or more do not support life. (Lowe Mc Connel. 1975).

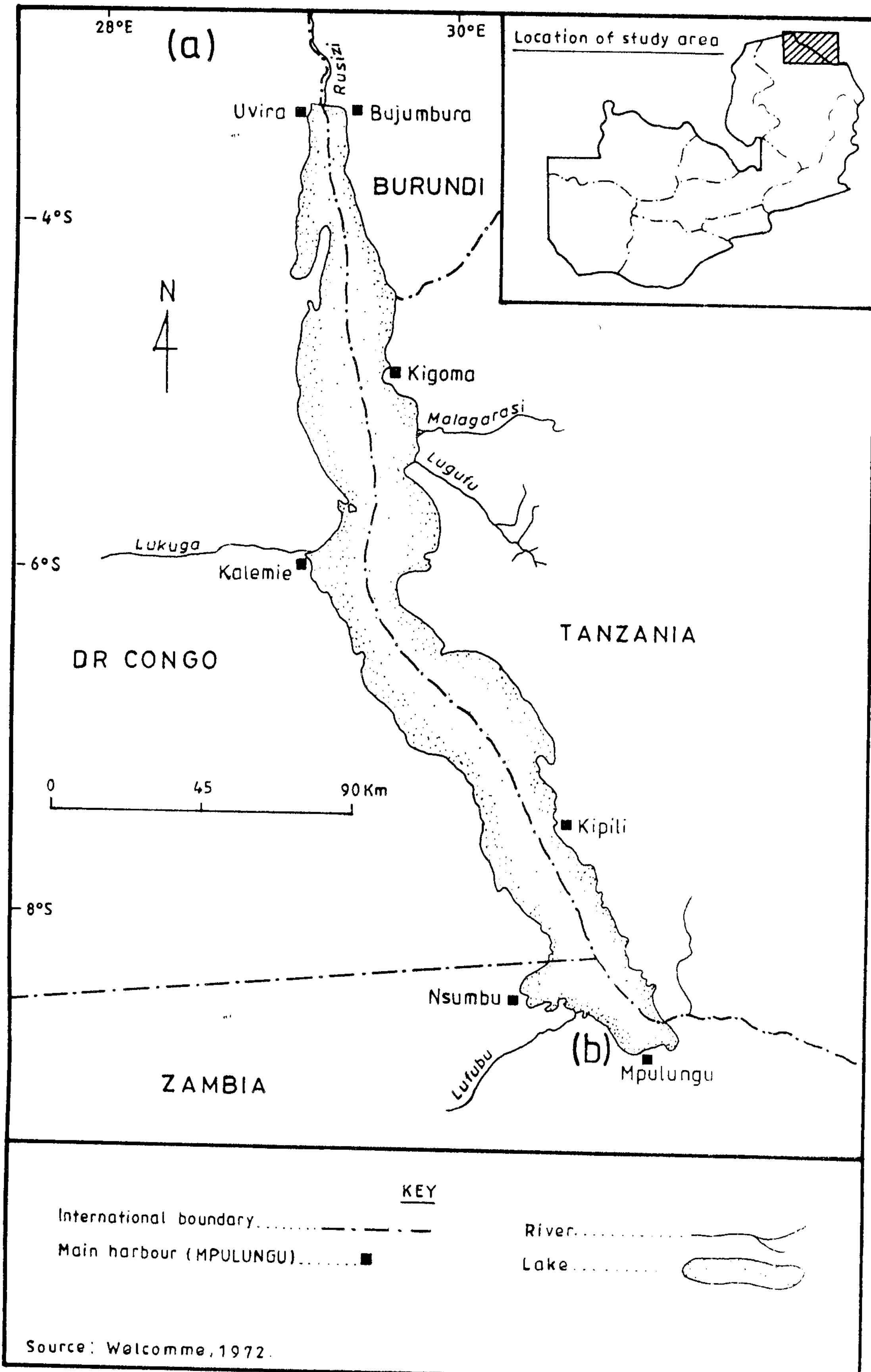


Fig. 1.1 Location map of Lake Tanganyika (a) and of its Zambian sector (b).

Since 1960s, fishing pressure on the Zambian side of Lake Tanganyika has decreased the stocks of the three large *Lates*, whereas catches of *L. stappersii* were increasing (Coulter 1965-66, 1970, 1976). At present there are seven active fishing companies on the Zambian waters of Lake Tanganyika with a total of 25 fishing vessels (Mwape, Pers. comm.). Their activities may affect in one way or another the dynamics of the exploited resources. It is for example well known that under a certain exploitation pattern, a strong decrease in the stock spawning biomass and a smaller spawning stock biomass per recruit value threaten the stocks renewal. The assessment of the reproductive status of *L. stappersii* finds here its justification if the stock of *L. stappersii* has to be properly managed.

Because of its commercial importance, *L. stappersii* has been subjected to a number of biological and ecological investigations designed to properly assess and manage the related resources (Ellis, 1978; Coulter, 1991; Pearce, 1985a; Kinoshita, 1995; Mannini *et al.*, 1996; Mannini, 1998a and 1998b). The current contribution focuses on the refinement of characteristics of stages of maturity, the implication of their monthly variations and those of the Gonado-Somatic Index (GSI) and condition factor (K), with a view to check the spawning activity. It also looks at the sizes at maturity, sex ratios and fecundity. The study of fecundity is original in that it aims to generate information that was not previously investigated.

Some authors have determined the spawning periodicity in *L. stappersii* using the monthly variations of proportions of stages of maturity (e.g. Ellis, 1978; Chapman and

Van Well. 1978: Aro and Mannini. (1995). These studies generally concluded that spawning activity of the species is continuous throughout the year. but its peak can vary from area to area and from year to year. Thus. the highest spawning activity occurs between December and March in the Burundian waters of Lake Tanganyika (Ellis. 1978). from November to January and June to August in the Tanzanian waters (Chapman and Van Well. 1978) and between November and April (Aro and Mannini. 1995) or November and May (Pearce. 1985) in the Zambian waters. Kinoshita (1997) used larvae abundance criterion to assess the spawning peak. There were no significant differences between months in larvae abundance of all the four *Lates* species throughout the one-year sampling period. On the northern part of the lake. the spawning peaks of *L. stappersii* occur at least twice per year (Mukirania *et al.*. 1988) and these peaks tend to shift from year to year (Roest. 1988). Spawning occurs in deeper water. even at the bottom (Kinoshita. 1995). Spawning seasons generally coincide with maxima in condition factor and gonadosomatic index (Pearce. 1991). In both sexes of *L.stappersii* in the Mpulungu area. the gonadosomatic index increases with both gonad maturity and size (Pearce. 1991). More information is needed to supplement the previous findings on the spawning activity of *L. stappersii* in the Zambian waters of Lake Tanganyika.

The size at maturity of *L. stappersii* relative to the whole Lake Tanganyika ranges between 26-27cm total length (TL) for females and 28-29 cm (TL) for males (Aro and Mannini. 1995). It is 23.7cm TL for females and 25.5cm TL males in the Zambian sector of the lake (Mannini *et al.*. 1996). Females tend to reach maturity much younger than males. However. Chapman and Van Well (1978) found that in the Tanzanian waters.

males matured much earlier than females. The smallest ripe male measured 15 cm Fork length (FL) while the female was 17 cm (FL). These contrasting findings are indicative of either differences in studying methods or variability in the achievement of *L. stappersii*'s maturity from zone to zone or from year to year.

As for *L. stappersii*'s sex ratios. its overall lake wide value is 1 female: 1 male (Coulter. 1976. 1991: Nyakageni. 1995: Mannini *et al.*. 1996). In the Zambian waters. the sex ratios of 54.5% female: 45.5% male (Aro and Mannini. 1995) and 52% female: 48% male (Pearce 1985a). suggest that at first glance. there are more females than males. More information is required about monthly variations in sex ratio of *L. stappersii* in the southern part of the lake. Two contrasting views exist about the variations of sex ratio as the size of fish increases. In Burundian waters. neither sex dominates particular length class (Ellis. 1978): in Zambian waters. the number of males decreases with increase in length class and vice versa (Pearce 1991). The latter was subjected to re-assessment in this study.

Another major reproductive aspect. which has not yet been adequately addressed. is the fecundity of the *Lates* species in general and *L. stappersii* in particular. Fecundity assessment of fishes has been useful in various fundamental and applied studies such as the life history. egg production capacity. racial distinction. stock evaluation and aquaculture-based induced spawning and egg incubation (Bagenal. 1978b: Coates. 1988: King. 1997).

The simplest definition of fecundity is the number of ripening eggs found in the female prior to the spawning act (Bagenal. 1978a). Other types of fecundity include: (1) absolute partial fecundity (APF). defined as the number of larger eggs whose diameter is that of largest modal distribution at one spawning act (Bagenal. 1978a): (2) annual total fecundity (ATF). defined as the overall number of eggs which can be spawned during the protracted spawning season or the product of the absolute partial fecundity and the number of spawning acts: and (3) relative fecundity (RF). which is the number of eggs per unit weight of fish.

For a given fish species. fecundity varies greatly for individuals of the same weight. length and age. but in many species it increases in proportional to size of the fish (Lowe-Mc Connell. 1975). Each kind of fecundity is particularly a function of fish body size and age. The length-Fecundity relationship is a critical allometric function in fisheries biology due to the relevance of the parameters in various pragmatic applications. Some of these are assessment of population fecundity (Bagenal. 1978b): estimation of the average fecundity of fish of a given size or age group: interspecific and interpopulational comparison of egg production capacity as growth proceeds (Roff. 1986). Using 14 specimens Pearce (1985a) estimated the fecundity of *L. stappersii* to range between 7.600 and 287.000 (average 107.000) and estimated the total number of eggs spawned by a female fish each year to probably range between 100.000 and 1.000.000. No size fecundity relationships have yet been investigated in *Lates* species in general and *L. stappersii* in particular. This aspect was analysed in this study for *L. stappersii*.

2.0. RESEARCH OBJECTIVES

As outlined above, the objectives of the study are the following:

1. To refine the characteristics of stages of maturity of *L. stappersii* and assess their monthly variations as well as those of gonadosomatic index (GSI) and condition factor (K), in order to check the spawning activity during the study period.

2. To determine the size at maturity for *L. stappersii* in the Southern part of Lake Tanganyika.

3. To determine the overall sex ratio and investigate the variations of this parameter in *L. stappersii* with regard to months and length classes.

4. To estimate fecundity and establish relationships between fecundity and body sizes and gonad weight of *L. stappersii*.

3.0. MATERIALS AND METHODS

3.1 The study area

Mpulungu. located in the far northern part of Zambia. is a major port on the Zambia coastline of Lake Tanganyika. It lies on the extreme southeast arm of the Lake. The Zambian coastline is 215km long (Hanek et al..1993).

The study was carried out in the Zambian sector of Lake Tanganyika (Fig. 1.1b). The sector has a water area of $2000km^2$ and water volume of $1140km^3$ (Mikkola and Lindqvist. 1989). It is part of the south lake basin with an average depth of 700m. and lies between longitudes 29^0 00' E and 31^0 31' E and between latitudes 3^0 00' S and 9^0 00' S. The average water temperature is usually slightly above 25^0 C.

3.2 Sampling method and recording of basic data

Samples of *L. stappersii* were collected from landings of some semi-industrial fishing units operating in the pelagic waters of the Zambian sector of Lake Tanganyika. These units. based in Mpulungu. belong to five fishing companies (i.e Samaki. St. George. Sopelac. Mpulungu and Andreas). Table 3.2.1 shows the sampling design followed: samples were collected in the third and fourth week of each month when active industrial fishing occurred.

After fish was caught by commercial operators. it is packed into boxes regardless of sizes. Upon landing. a box of fish was picked at random. The following information was recorded for every specimen: the total length (TL. cm). total weight (W.g). sex. gonads state and weight (w. g). Length of *L. stappersii* was measured using a measuring board. The anterior extremity of the fish was put against a stop at the beginning of the measuring scale and was made to lie on its side with the jaws closed in a normal position. TL of the fish was taken as the distance from the tip of the snout to the furthest end of its caudal fin. The weight of the fish was measured using a balance weighing up to two decimal places. For gonads. a sensitive balance weighing up to four decimal places was used.

Table 3.2.1. Sampling design. (Numbers in the boxes indicate sampling dates).

Weeks	**Sept. 99**	**Oct. 99**	**Nov. 99**	**Dec. 99**	**Jan. 00**	**Feb. 00**
FIRST						
SECOND						10
THIRD	20. 21	18	16. 19	16	15	
FOURTH		29		28	27	29

3.3 Reproductive aspects investigated.

A. Stages of maturity, gonadosomatic index, and condition factor

After recording length and weight, the belly of each fish was carefully cut open to determine the sex and gonad state (maturity stage). This step is essential because no secondary sexual dimorphism helps in recognizing sexes in *L. stappersii*. Different stages of gonad development (Appendix A) were categorised on the basis of macroscopic observations taking into consideration the general aspect in terms of colour, shape,size, transparency and vascularisation of gonads (Table 3.3.1), as described by Kesteven (1960) and Nikolsky (1963).

The state of each stage of maturity was refined using the gonado-somatic index (GSI) – related statistics (i.e. variation range, average, standard deviation and confidence interval). This index is defined as:

$$GSI = 100w / W \qquad (1)$$

where w = weight of gonads, W = the total body weight of fish.

An ANOVA test was carried out to check whether the mean GSI was significantly different between stages

Table 3.3.1. Observed characteristics of stages of gonad development in *L. stappersii* in the southern part of L. Tanganyika (Based on Kesteven. 1960 and Nikolsky. 1963)

(a) Females

STAGE	STAGE QUALIFIER	CHARACTERISTICS
I	Immature	Very small slender ovaries transparent and filled with clear colourless liquid. Ova invisible to the naked eye.
II	Active	Small slender ovaries extended halfway of the body cavity. Reddish in colour due to increased blood supply. Small ova may be seen forming with magnifying glass.
III	Ripe	Well developed ovaries extended three quarter way of the body cavity. Reddish yellow in colour (not completely ripe). Reduction in blood vessels. Ova seen with naked eye but not running when light pressure is applied on the belly.
IV	Ripe running	Ovaries well developed big and long. Extended nearly the length of body cavity. Completely ripe and yellow in colour. Ova seen with naked eye and loosely connected Slight pressure applied on the belly of fish results in some ova being extruded.
V	Spent	Ovaries well developed but appear flaccid or more deflated Reddish in colour

(b) **Males**

STAGE	STAGE QUALIFIER	CHARACTERISTICS
I	Immature	Testes not well developed. They are very small and contain a colourless liquid that comes out when cut and pressed.
II	Active	Testes small flat and appear translucent. When cut and pressed a dirty whitish watery liquid comes out
III	Ripe	Testes well developed and flat, cream white in colour. White milt comes out only when cut and pressed. The white milt is viscous and does not flow easily.
IV	Ripe running	Testes well developed, cream white in colour and flattened. White milt flows easily when testes are cut and when light pressure is applied on the belly of fish.

The monthly proportions (expressed in percentages) of maturity stages were estimated. and their monthly variations analysed in order to check the spawning activity during the study period. This information was completed with the monthly variations of the mean GSI and average condition factor (K). The latter parameter is defined as:

$$K=100W/L^3 \qquad (2)$$

where W = body weight (in g) and L = Total body length (in cm). The use of the GSI and condition factor which are quantitative parameters are as essential as the information provided by macroscopic observations of maturity stages.

B. Sizes at maturity.

In put data for estimating this parameter were extracted from appendix A. The size at maturity (L_{50}) was defined as the average length of the class within which 50% of males and females *L. stappersii* were mature (i.e ripe and ripe-running). The average lengths at which 25% (L_{25}) and 75% (L_{75}). of males and females *L. stappersii* were mature as well as the maturity ranges for both sexes were also estimated. The average length at maturity is usually fitted following a logistic model (or cumulative distribution function). by which is plotted a sigmoid curve called "ogive of maturity". The logistic model while using length data. is of the form:

$$O(i) = 1 / [1 + \exp(-a(x_i - L_{50}))] \qquad (3)$$

where O(i) is the probability for a fish in length class i to be mature (i.e. to be ripe and ripe running): it indicates the achievement of sexual maturity within the i^{th} length class: a is a constant: exp means "e to the power": e is the base of natural logarithms: X_i is the average of length class i. and is defined by: $X_i = (l_i+l_{i+1})/2$ with l_i and l_{i+1} the lower and upper limits of length class i. respectively: $l_{i+1} = l_i + \delta l$. δl being the length class interval (in this study. δl = 1 cm). Hence. X_i is the i^{th} length class mid-point.

The parameters of the ogive of maturity were estimated using the FISHPARM software (Prager *et al*.. 1989). As $a = 2^* \ln 3 /(L_{75} - L_{25})$. the maturity range. $L_{75} - L_{25}$. is given by $L_{75} - L_{25} = 2 \ln 3/a$. Since L_{25} and L_{75} are symmetrical around L_{50}. $L_{25} = L_{50} - (L_{75} - L_{25})/2$ and $L_{75} = L_{50} + (L_{75} - L_{25})/2$. Algebraically. L_{25} is also given by $L_{25} = (aL_{50} - \ln 3)/a$. and L_{75} by $L_{75} = (aL_{50} + \ln 3)/a$ (Sparre and Venema. 1992).

The analysis employed pooled data over the whole study period. Both the conventional and the adjusted coefficients of determination. R^2 and R^2_{adj}. respectively. were calculated. The t- test for significance of coefficient of correlation was determined (Sokal and Rohlf. 1981: Bless and Kathuria. 1998).

C. Sex-ratios

1539 males (M) and females (F) of *L. stappersii* were recorded in all monthly samples collected from September 1999 to February 2000 (Appendix A). The sex ratio was defined as the proportion of sexes. and expressed in percentage. The overall sex ratio (over 6 month of sampling) and monthly values of this parameter were calculated. The sex ratio was also calculated for each length class of 2-cm interval using the overall length frequency distribution of *L.stappersii* as obtained by combining the monthly length frequency data. For the analysis of sex ratio by length class, a total of 1538 fish was used. From these information, it was therefore possible to analyse the monthly variations and variations with length of the sex ratio. For the overall sex ratio, monthly sex ratios, and sex ratio per length class, the confidence interval at the probability level of 95% were estimated. The null hypothesis (Ho: p=50%) "*observed sex-ratio is equal to the expected sex-ratio p=50%*" was tested against the hypothesis H_1: "*observed sex-ratio is different from the expected sex-ratio, p= 50% (H_1: p≠50%).*" The Chi-square (χ^2) test was used, keeping in mind that the sex-ratio in fish populations usually follows the binomial distribution (Mead and Curnow, 1990). In theory, males and females of a fish species have the same probability (p = 0.5) of hatching and surviving throughout their life span.

D. Fecundity

Females of *L. stappersii* at stage (IV) were collected, measured and weighed. Their ovaries were then collected and weighed, after removing excess water on the filter paper. They were then preserved in ten percent formalin. Eggs were later counted using gravimetric subsampling technique (Bagenal, 1978b). This involves the weighing of the ovaries and then a weight- subsample is taken from it (according to the size of eggs).The eggs in the subsample are counted under a lens or by means of a special apparatus. The number of eggs in the subsample is multiplied up to the weight of the ovary (Nikolsky. 1963: Bagenal. 1978b). An automatic fish egg counter can also be used (Parrish *et al.*.1960). In the current study a subsample of 0.01g was taken from the known weight of the ovaries and the eggs in it counted under the dissecting microscope. at magnification 40x.

Eggs of *L. stappersii* are very small and numerous. and were arbitrarily subdivided into three size groups: big. medium and very small sized-eggs. Only big-sized eggs (about 0.5mm – 0.6 mm in diameter) were counted. They were assumed to be ripe and considered to represent the partial fecundity.

The representative-ness and distribution of big-sized eggs in the whole ovary were checked by cutting the ovary at three different zones (anterior. middle and posterior) and from each zone. the number of big sized eggs contained in 0.01g sub-sample were counted. There were no significant differences in the number of big-sized eggs contained in 0.01g sub-sample obtained from the lumen of the ovary at three different points ($p=0.05$).

For each ovary. big-sized eggs were counted in three replicates of 0.01g subsample. Then their mean number was calculated and used in the estimation of partial fecundity for the female in question.

The average total number of eggs contained in both ovaries were estimated using the formula:

$$Pfec = n * (W/w) \quad (4$$

where Pfec = Partial fecundity

n = mean number of eggs counted in 0.01g sub-sample

W = Total weight of both ovaries

w = weight of sub-sample (0.01g)

In all. 77 pairs of gonads obtained from female *L. stappersii* of different body lengths and weights were examined (Appendix B). From these, relationships between body length and fecundity, body weight and fecundity, and gonad weight and fecundity were established.

Using the visual inspection of the scatter diagrams, the following relationships were fitted and those providing the highest value of R^2 were retained:

For length-partial fecundity relationship

Power function: $Pfec = a\ TL^b$ (5)

Exponential function: $Pfec = a\ e^{bTL}$ (6)

where Pfec = partial fecundity; TL = total length ; a and b are constants; e base of natural logarithms.

For weight-partial fecundity relationship

Linear function: $Pfec = a + bw$ (7)

Power function: $Pfec = aw^b$ (8)

Exponential function: $Pfec = a\,e^{bw}$ (9)

where Pfec = partial fecundity; W = body weight; a and b are constants. e base of natural logarithms.

For gonad weight-partial fecundity relationship, the scatter diagram suggests the linear relationship between partial fecundity (Pfec) and gonad weight (w):

$Pfec = a + bw$ (10)

where a and b are constants.

Moreover, the relationship between fish body sizes (i.e. TL and weight) and relative partial fecundity on one hand and between gonad weight and relative partial fecundity on the other were assessed. Fitting models and plotting were performed using the Excel spread sheet. The coefficient of determination R^2 was calculated and the t-test for significance of correlation was used on the basis of the standard error of R at $p = 0.05$ (Sokal and Rohlf, 1981).

4.0. RESULTS

4.1 Stages of maturity and spawning activity during the study period

Macroscopic observations of stages of gonad development in *L. stappersii* (Table 3.3.1) were supplemented with gonado-somatic index (GSI) related statistics. i.e. the mean gonadosomatic index. standard deviation. variation range and 95% confidence interval (Table 4.1.1). These statistics are in percentage.

The mean gonado-somatic index increases progressively from stage I to stage IV as shown in Table 4.1.1. Stage V in females shows a drop in mean gonado-somatic index due probably to the release of some ovarian products. In males. stage V was practically difficult to distinguish since all fully mature gonads that were cut and squeezed had sperms. The ANOVA test showed significant differences in mean gonado-somatic index among maturity stages. ($p<0.05$). Moreover. apart from stage IV in males. the 95% CI of mean gonado-somatic index increases from stage I onwards in both sexes. This seems to indicate that microscopic determination of maturity stages in *L. stappersii* is more precise with lesser developed gonads.

Table 4.1.1 Some refinements on the stages of gonad development in *L.stappersii* in the Zambian waters of Lake Tanganyika.

(a) Females

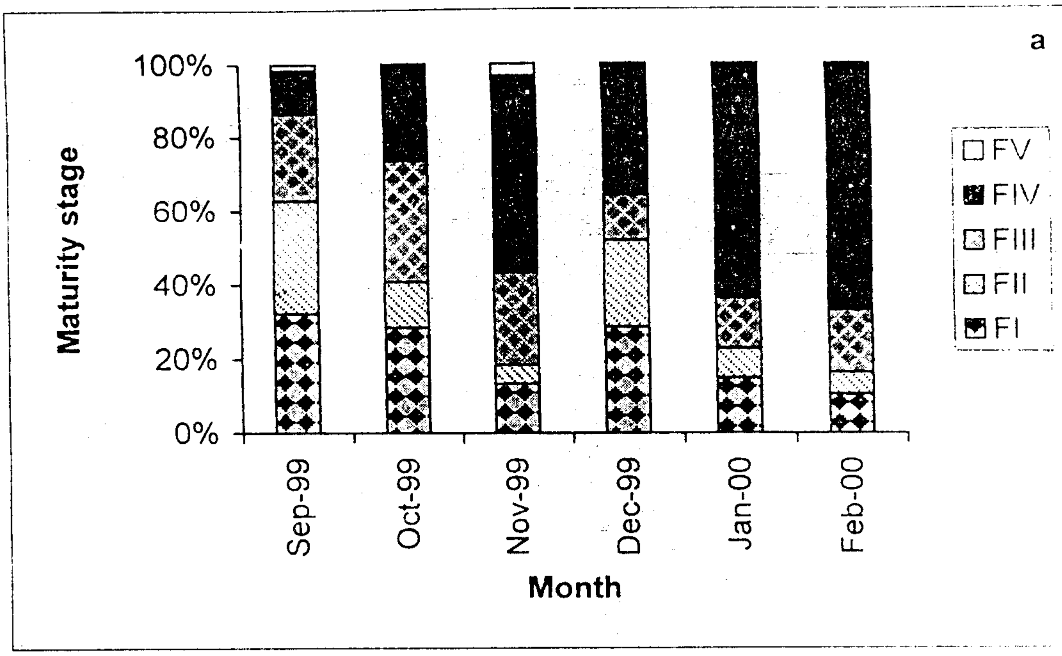
Stages	Mean GSI(%)	Standard deviation(%)	n	Variation range (%)	95% CI
I	0.3708	0.2631	169	(0.019, 0.817)	(0.331, 0.410)
II	0.6412	0.3869	98	(0.161, 1.577)	(0.564, 0.718)
III	1.5704	0.7003	173	(0.469, 3.979)	(1.466, 1.675)
IV	2.1187	0.8613	369	(0.869, 6.141)	(2.031, 2.206)
V	0.8342	0.6582	8	(0.240, 1.603)	(0.378, 1.290)

(b) Males

Stages	Mean GSI(%)	Standard deviation(%)	n	Variation range (%)	95% CI
I	0.7362	0.4081	53	(0.338, 1.235)	(0.626, 0.846)
II	1.5435	0.6678	181	(0.415, 2.368)	(1.446, 1.641)
III	2.0158	0.8864	248	(0.806, 4.55)	(1.905, 2.126)
IV	2.6678	1.0805	239	(1.035, 6.286)	(2.531, 2.805)

The monthly proportions (percentages) of maturity stages generally showed a similar evolution trend from September 1999 to February 2000 in both sexes of *L. stappersii* (Fig.4.1.1). The proportion of fish at stage IV has been progressively increasing over this period. In January and February 2000, over 60% of females were at ripe running stage (IV). Over 50% of males also were at the same stage from November 1999 to February 2000. Whereas proportions of fish at stage III were high in September, October and November 1999, their decline was clear from December 1999 to February 2000. This could be attributed to the progressive maturation of fish from stage III to stage IV. The proportions of fish at stage I and II generally kept on fluctuating monthly with fewer being recorded in January and February 2000. Fish at stage V were scarce and were only recorded for females in September and November 1999. Overall, stages of maturity I to IV in *L. stappersii* were available each month over the study period. However, high proportions of fish at stage IV observed between November 1999 and February 2000 suggest that spawning activity of *L. stappersii* in the Zambian waters of Lake Tanganyika was taking place over this period and was rising in January and February 2000.

The previous findings are confirmed more by the evolution trend of the mean gonado-somatic index (Fig 4.1.2 a) than that of the mean condition factor (Fig 4.1.2.b). In fact the mean gonado-somatic index generally increased from November 1999 to February 2000. For both sexes it was highest in January and February 2000. As for the monthly variations of the mean condition factor, they also showed a similar trend for both sexes: they were relatively high in October 1999, unimodal from November 1999 to February 2000 with a peak in December 1999.



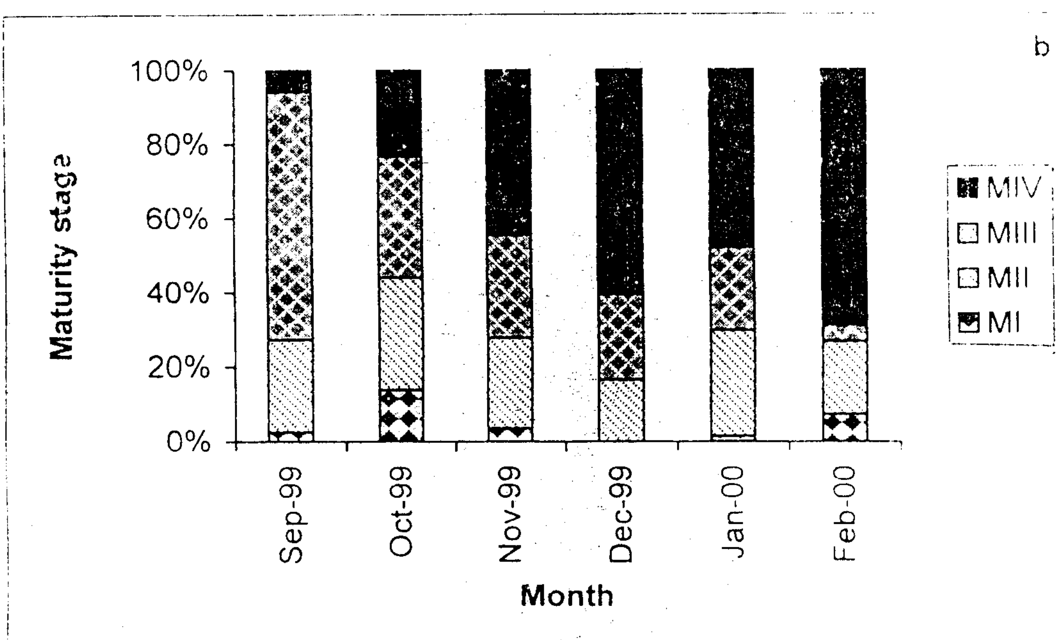
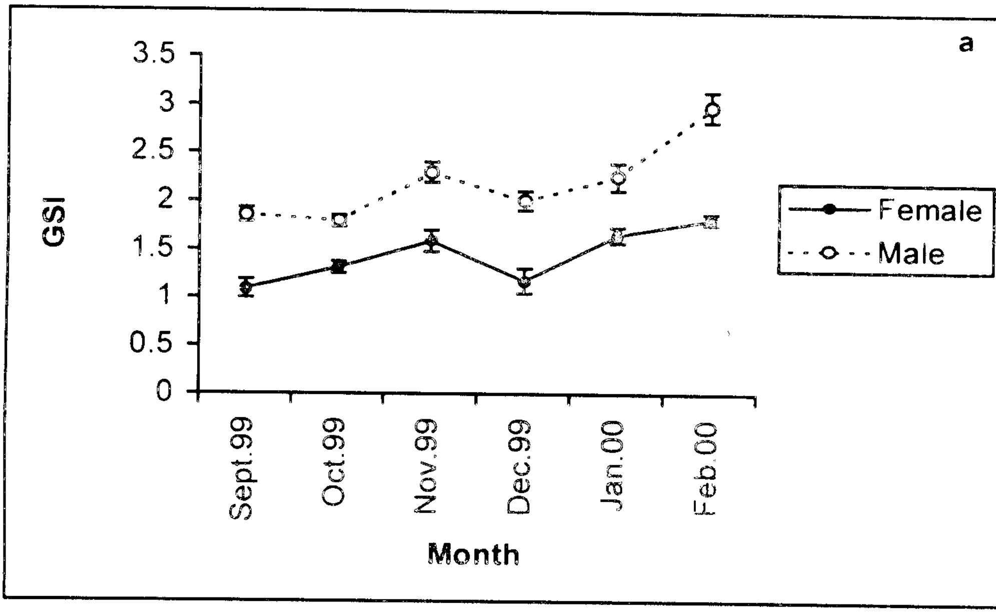


Figure 4.1.1 Monthly variations of maturity stages in females (a) and males (b) *L. stappersii* in the Zambian waters of Lake Tanganyika.



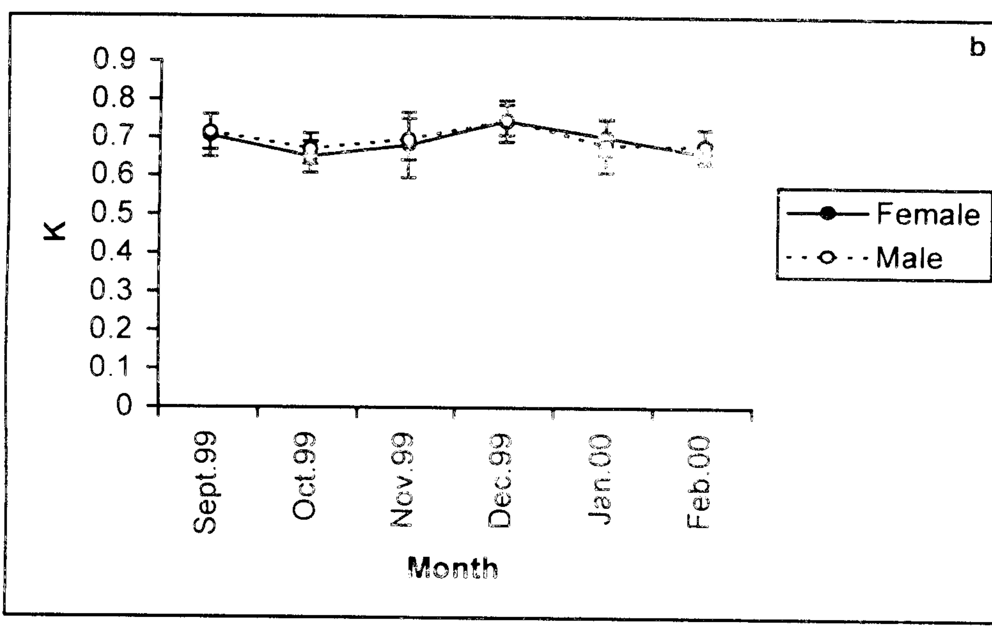


Figure 4.1.2 – Monthly mean gonado somatic index (GSI (a) and condition factor (K) (b) for *L. stappersii* in the Zambian_waters of lake Tanganyika. Bars indicate the 95% confidence interval.

4.2 Sizes at maturity

The overall size at maturity is 24.89 cm TL for females (Fig. 4.2.1) and 21.68 cm TL for males (Fig. 4.2.2). The average length at which 25% and 75% (i.e. L_{25} and L_{75}) of individuals of *L stappersii* mature were also estimated. L_{25} is 19.04 cm TL for females and 17.84 cm TL for males: L_{75} is 30.74 cm TL for females and 25.52 cm TL for males. The range of maturity for *L. stappersii* in the southern part of L. Tanganyika is 11.70 cm for females and 7.68 cm for males. This range and the plots indicate that males (Fig 4.2.2) reach maturity younger than females. This statement holds true under the hypothesis that males and females have the same rate of growth within the range of length classes for which proportions of mature fish were used to fit the logistic model. The correlations between TL and the probability for male and female *L. stappersii* to get mature are significant ($p < 0.05$).

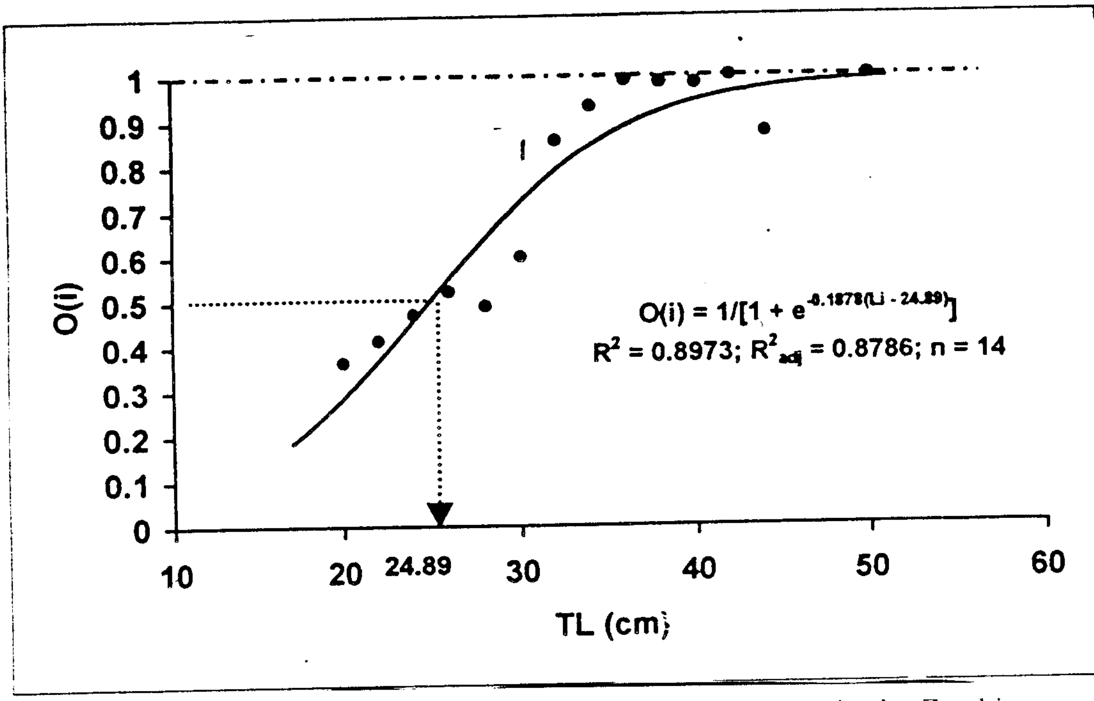


Figure 4.2.1. – A plot of size at maturity for female *L. stappersii* in the Zambian waters of Lake Tanganyika.

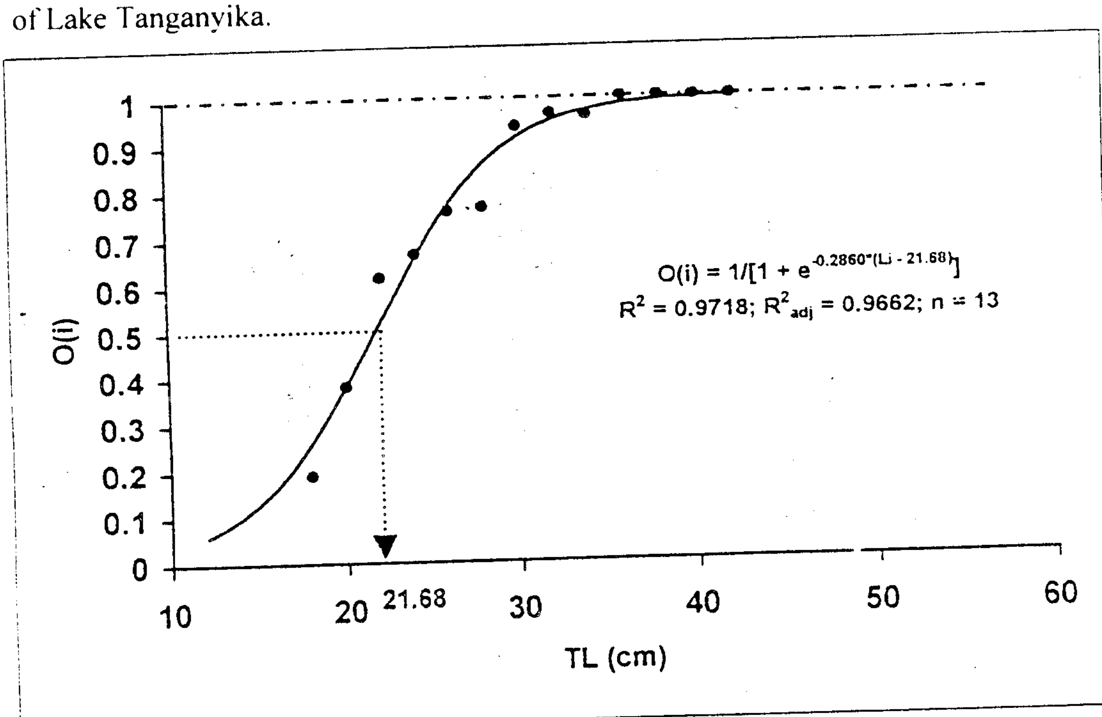


Figure 4.2.2. – A p lot of size at maturity for males *L. stappersii* in the Zambizn waters of Lake Tanganyika.

4.3 Sex-ratios

The overall sex ratio for *L. stappersii* is 53% females: 47% males. The χ^2 test shows no significant difference from 1:1 ratio for males and females at 95% probability level. The analysis of monthly variations of sex ratios (Table 4.3.1: Fig.4.3.1) show that females were dominant in catches in January and February 2000, whereas no significant difference was observed each month between males and females from September to December 1999 (χ^2 test : $p > 95\%$). Whatever the kind of sex-ratio considered (i.e. the overall and the monthly ones) results from both the χ^2 test and CI agree. Generally when the null hypothesis is accepted. CI for both males and females overlap and contain the sex-ratio 50%, and vice versa when it is rejected.

Table 4.3.1 Monthly sex ratio of female *L. stappersii* in the Zambian waters of Lake Tanganyika. nF: number of females: % F: Female percentage: CI: confidence interval at the probability level of 95%: N: Total sample size. The accepted null hypothesis (H_0) or rejected hypothesis (H_1) (P>0.95)

Month	**nF**	**%F**	**CI**	**N**	**Hypothesis**
Sept. 99	120	43.8	(37.90. 49.67)	274	H_1
Oct. 99	192	40.76	(36.34. 45.18)	471	H_1
Nov. 99	58	51.79	(42.54. 61.04)	112	H_0
Dec. 99	97	45.97	(39.25. 52.69)	211	H_0
Jan. 00	153	69.55	(63.47. 75.63)	220	H_1
Feb. 00	197	78.49	(73.41. 83.57)	251	H_1
Overall	817	53.09	(49.92. 56.26)	1539	H_0

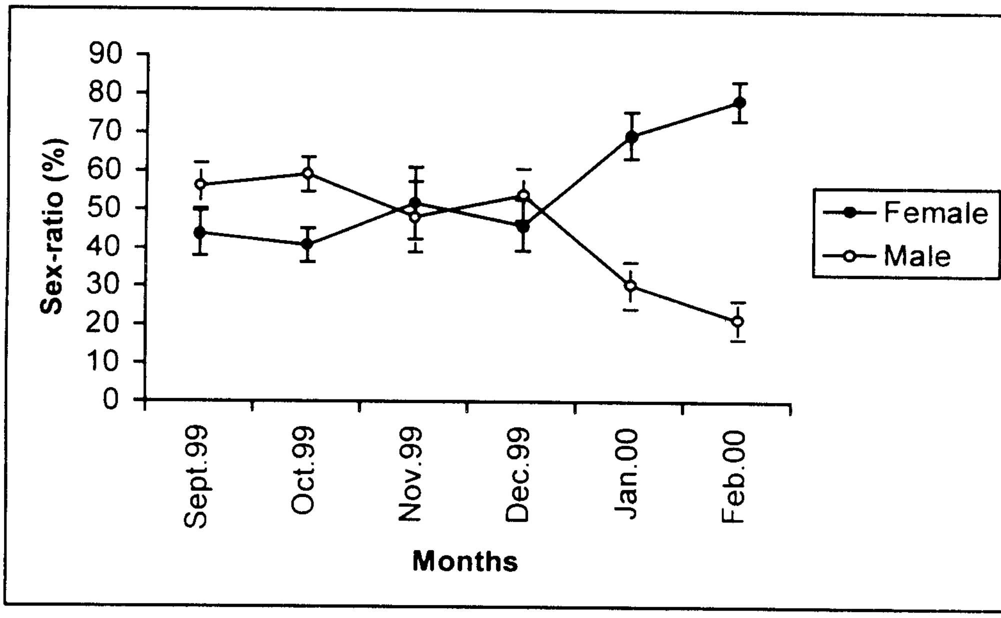


Figure 4.3.1 – Monthly sex ratios for *L. stappersii* in the Zambian waters of Lake Tanganyika. Bars indicate 95% confidence interval.

Table 4.3.2: and Figure 4.3.2. shows the sex ratio by length class for *L. stappersii* in the Zambian waters of Lake Tanganyika using data collected from September 1999 to February 2000. The number of females and males are equal in length class 17- 19 cm up to 31- 33 cm. From 33 cm TL onwards. the sex ratios are bias towards females: the number of females increases with increase in length of fish. It is even likely that. provided random samples. male *L. stappersii* tend to be absent in the stock from 42 cm TL. This might come from a differential growth rate for male and female for larger fishes. The longest female fish measured 50 cm TL while the longest male fish measured only 42 cm TL. Here. also. there is agreement between results from the χ^2 test and the estimation of CI.

Table 4.3.2. Proportions of females in each length class of 2 cm interval of *L. stappersii* in the Zambian waters of Lake Tanganyika. nF: number of females in sample: %F: Female percentage: CI: Confidence interval of 95%: N: sample size: Accepted null hypothesis (H_0) or Rejected hypothesis (H_1) ($P > 0.95$).

Length Class (cm)	nF	%F	CI	N	Hypothesis
13 – 15	1	50.00	-	2	-
15 – 17	2	66.67	-	3	-
17 – 19	12	36.36	49.5. 82.75	33	H_0
19 – 21	55	34.38	27.02. 41.74	160	H_1
21 – 23	121	41.30	35.66. 46.94	293	H_1
23 – 25	136	49.10	43.21. 54.99	277	H_0
25 – 27	67	44.67	36.71. 52.63	150	H_0
27 – 29	49	44.95	35.61. 54.29	109	H_0
29 – 31	30	65.22	51.46. 78.98	46	H_1
31 – 33	35	55.56	43.29. 67.83	63	H_0
33 – 35	59	70.24	60.46. 80.02	84	H_1
35 – 37	93	74.4	66.75. 82.05	125	H_1
37 – 39	68	82.93	74.79. 91.07	82	H_1
39 – 41	57	76.00	66.33. 85.66	75	H_1
41 – 43	23	85.19	71.79. 98.59	27	H_1
43 – 45	8	100.0	-	8	-
45 – 47	1	100.0	-	1	-

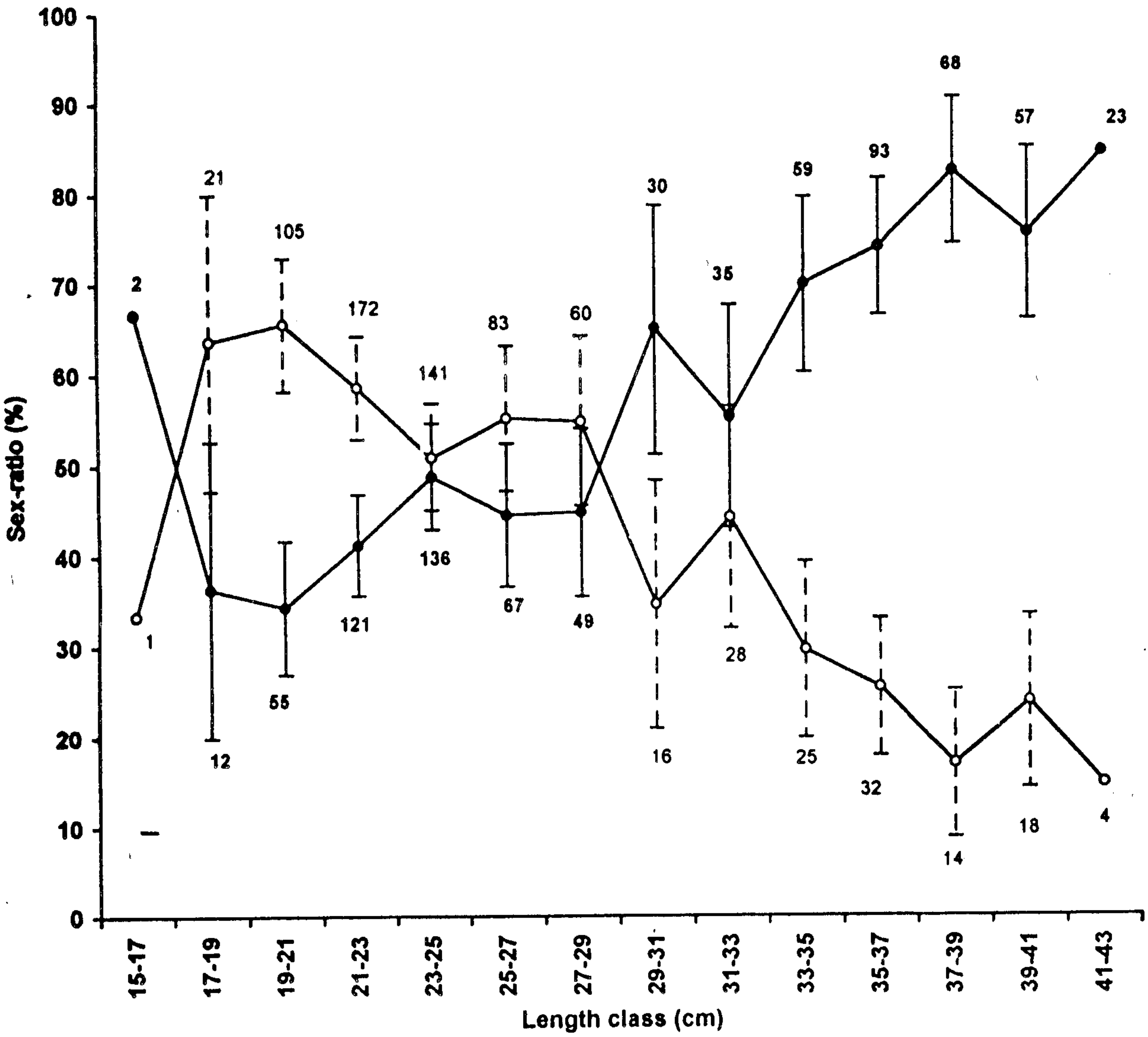


Figure 4.3.2. Sex ratio by length class of *L. stappersii* in the Zambian waters of Lake Tanganyika using data collected from September. 1999 to February. 2000. Bars indicate 95% confidence interval.

4.4 Fecundity and eggs

L. stappersii eggs are small. numerous and spherical in shape. Three egg size groups were visible. The largest eggs measured about 0.5-0.6 mm in diameter. The medium sized eggs were about 0.3 mm and the smallest about 0.1 mm or less. Appendix B shows partial fecundity data of *L. stappersii* in the Zambian waters of Lake Tanganyika. The partial fecundity in *L. stappersii* ranges from 46. 000 eggs for a fish of 20.20 cm TL and 57g to 839. 000 eggs for a fish of 50 cm TL and 1064 g. (average 273.000): the relative fecundity ranges from 441 to 1.685 eggs * g^{-1} of fresh fish (average 914 eggs * g^{-1} of fresh fish. These figures refer to one modal group of eggs consisting of large eggs of about 0.5-0.6 mm.

4.5. Fecundity-body size and gonad weight relationships.

Table 4.5.1 shows the parameters obtained from fitting different models tested for the relationships between the partial fecundity and body size and the partial fecundity and gonad weight in *L stappersii* from the Zambian waters of lake Tanganyika. All models tested were significant for $p < 0.05$. The heaviest female fish while testing the linear. power and exponential regression models for the partial fecundity weight relationship brought about suspicions. The concern was therefore how to make a choice of model which fits better the observed data by checking whether the heaviest data point was an outlier. In addition to the larger value of R^2 as criterion of goodness of fit. the residual plots of partial fecundity against the body weight were examined (Fig. 4.5.1). All these plots exhibit a "megaphone" trend which is indicative of the non constancy of error variance. whatever the number of observations used (either 77 or 76). Moreover. the visual inspection of these plots show that the magnitude of departure from the line e_{Pfec} =

0 (which normally may be the mean of residuals) is smaller for exponential relationships apart from the heaviest data point that proved to be an outlier (Fig. 4.5.1 e and f) than for linear (Fig. 4.5.1 a and b) and power (Fig. 4.5.1. b and c) relationships. All these observations lead to choosing the exponential model with n = 76.

Finally, the highest value of R^2 as criterion of goodness of fit in conjunction with the examination of residual plots for partial fecundity – body weight relationship lead to retaining the following relationships:

- Exponential relationship between total length and partial fecundity (Fig. 4.5.2 a) and body weight – partial fecundity (Fig. 4.5.2 b).
- A linear association between gonad weight and partial fecundity (Fig. 4.5.3).

Table 4.5.1. Parameters of the partial fecundity- body size and gonad weight relationships of *L. stappersii* in the Zambian waters of Lake Tanganyika.

(a) TL- partial fecundity relationship.

Relationships	Parameters				
	a	b	R^2	n	t test (P<0.005
Power	12.537	2.795	0.836	77	*
Exponential	**$1.0270 * 10^4$**	**$9.07 * 10^{-2}$**	**0.861**	**77**	*

(b) W-partial fecundity relationships.

Relationships	Parameters				
	a	b	R^2	n	t test (P<0.005
Linear	$1.0275 * 10^3$	$-3.2247 * 10^4$	0.790	76	*
Linear	$9.591 * 10^2$	$-1.4497 * 10^4$	0.801	77	*
Power	$1.1213 * 10^3$	$9.5565 * 10^{-1}$	0.839	76	*
Power	$1.1313 * 10^3$	$9.5394 * 10^{-1}$	0.847	77	*
Exponential	**$6.4308 * 10^4$**	**$4.0824*10^{-3}$**	**0.857**	**76**	*
Exponential	$7.4224 * 10^4$	$3.5 * 10^{-3}$	0.802	77	*

(c) Gonad weight (w) – partial fecundity relationship

Relationship	Parameters				
	a	b	R^2	n	t test (P<0.005
Linear	**$5.6005*10^3$**	**$3.6976*10^4$**	**0.993**	**77**	*

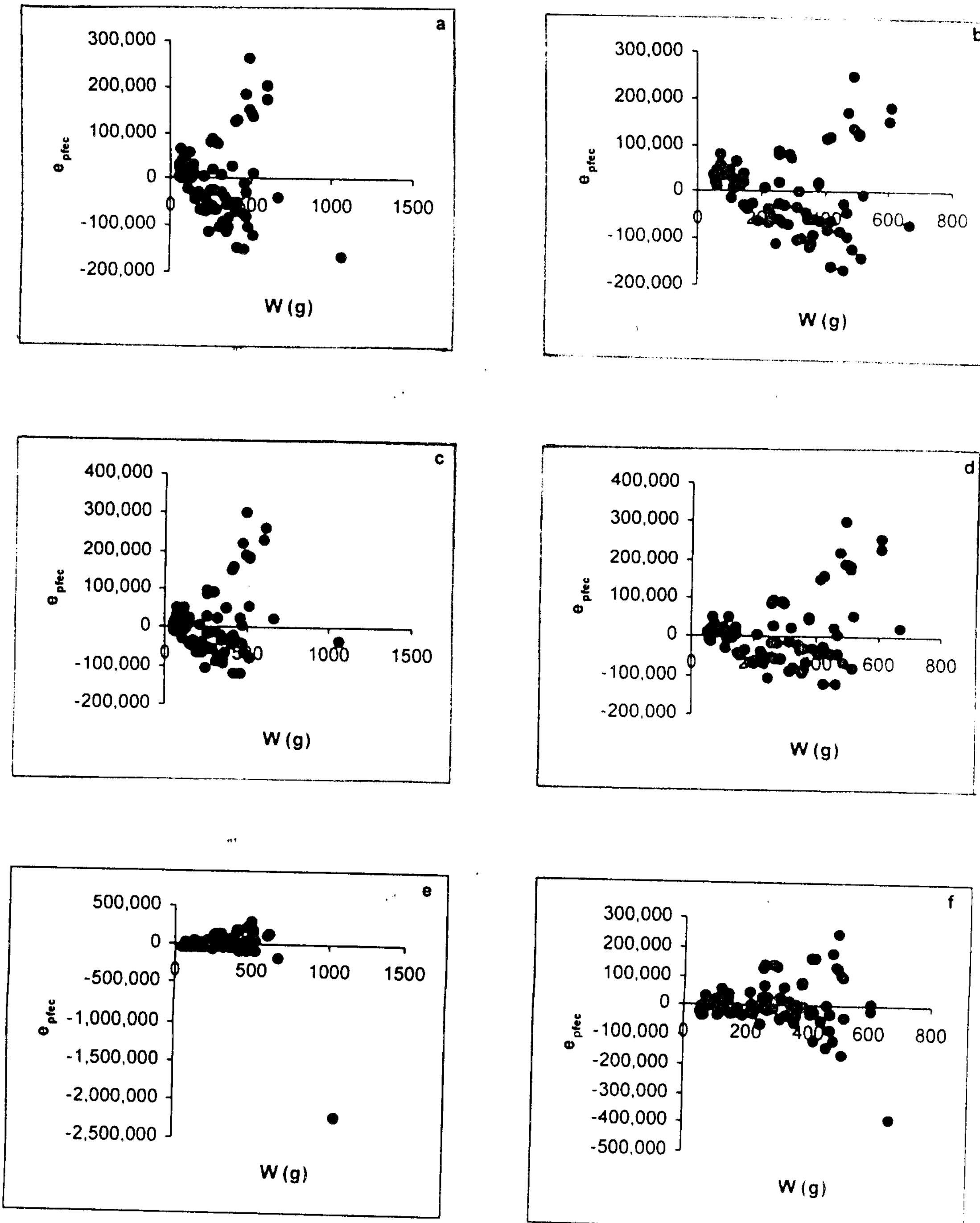


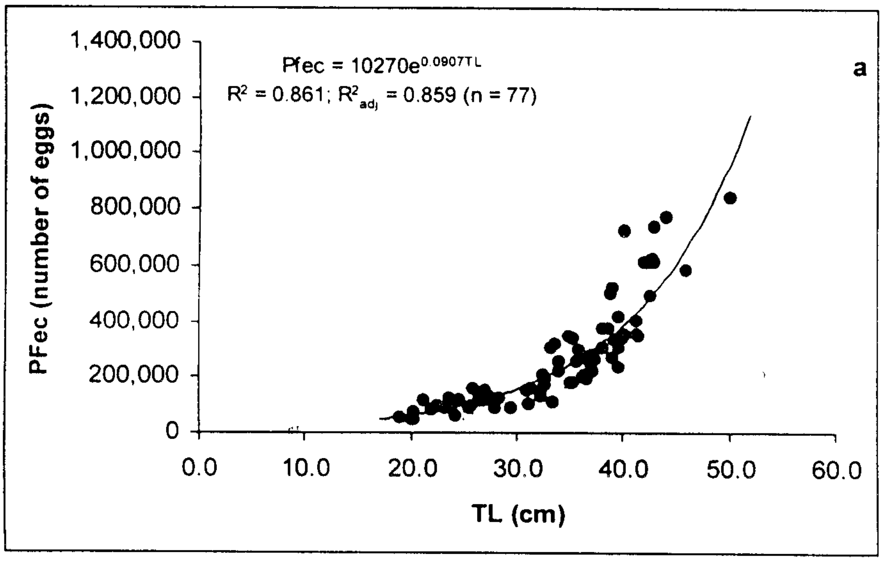
Figure 4.5.1 Residual plots of partial fecundity against body weight related to:

a – b: linear weight – partial fecundity relationship

c – d: power weight – partial fecundity relationship

e – f: exponential weight - partial fecundity relationship

left graphs for n = 77; right graphs for n = 76



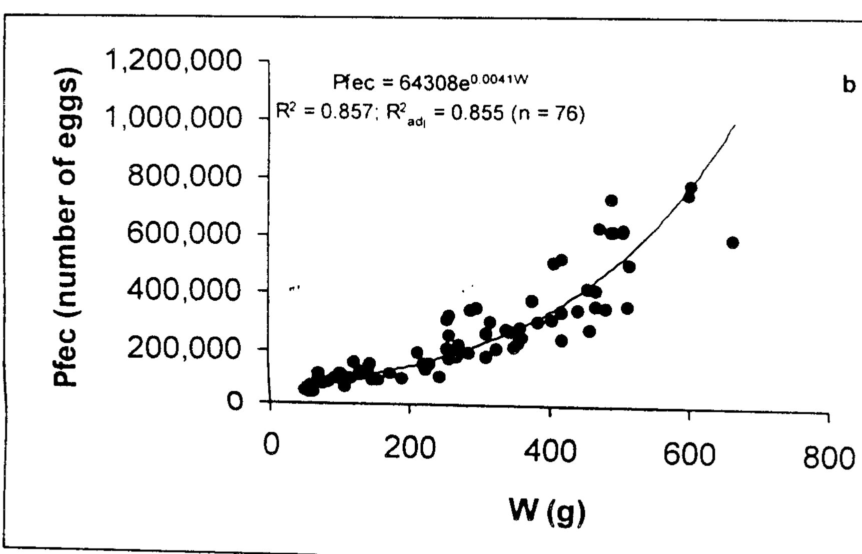


Figure 4.5.2 - Relationship between (a) total length (TL) and patial fecundity; (b) body weight (W) and partial fecundity of *L. stappersii* in the Zambian waters of lake Tanganyika.

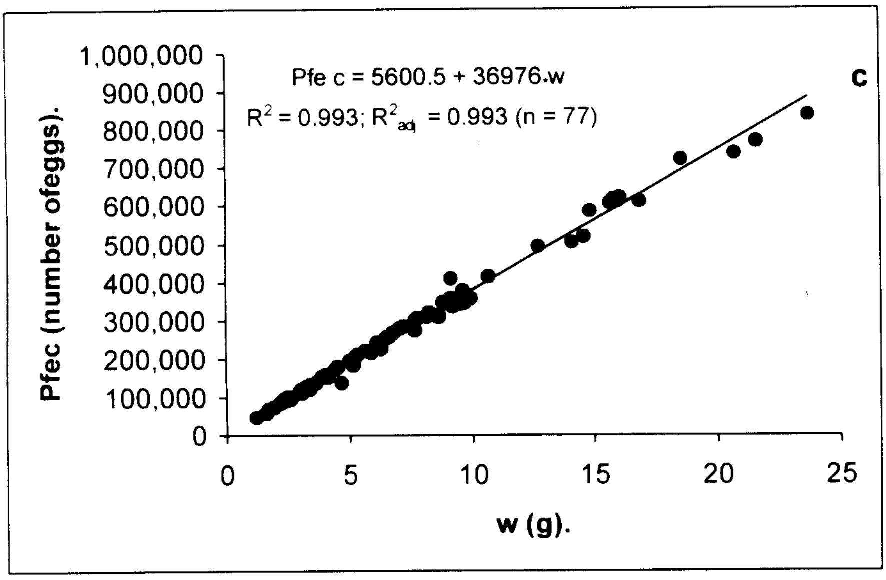
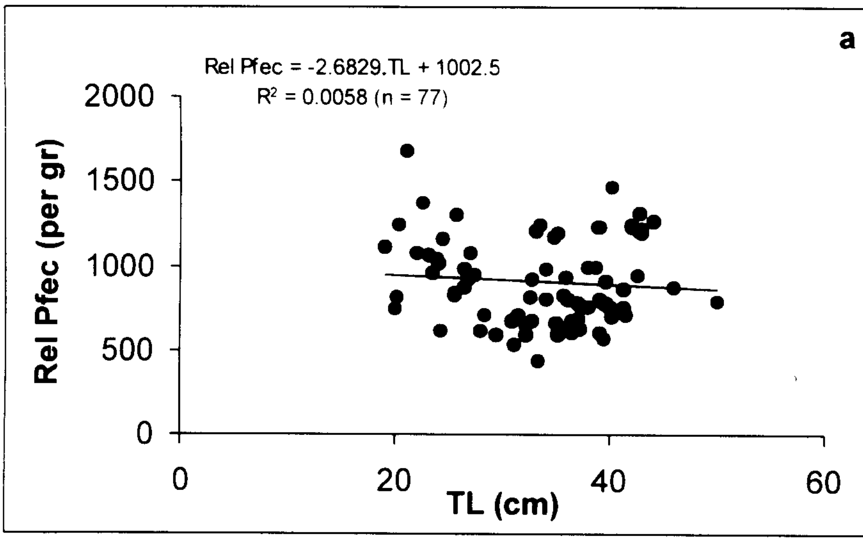


Figure 4.5.3 - Relationship between gonad weight (w) and partial fecundity of *L. stappersii* in the Zambian waters of Lake Tanganyika.

Results on relationships between TL and relative partial fecundity and between body weight and relative partial fecundity indicate that there are no linear associations between these variables (Fig. 4.5.4a and Fig. 4.5.4b). In both cases, the coefficient of correlation is not significantly different from zero ($p = 0.05$). In contrast, a linear relationship exists between the gonad weight and the relative partial fecundity ($R = 0.374$; $p < 0.05$; Fig. 4.5.5).



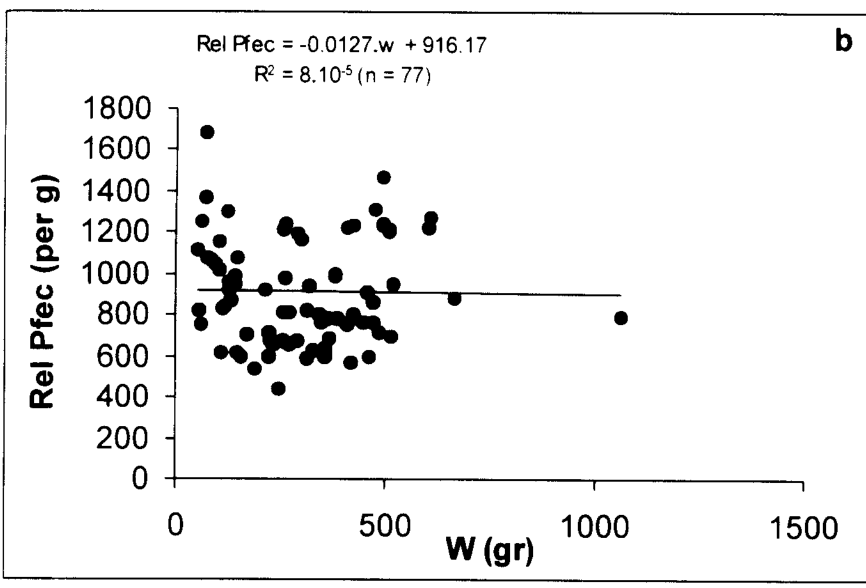


Figure 4.5.4 - Relationship between (a) total length (TL) and relative partial fecundity: (b) body weight (W) and partial fecundity of *L. stappersii* in the Zambian waters of Lake Tanganyika.

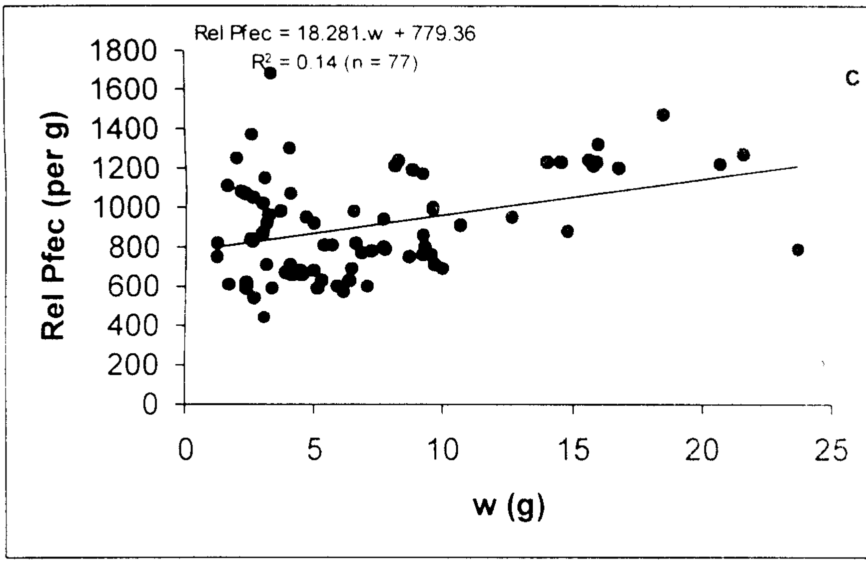


Figure 4.5.5 - Relationship between gonad weight (w) and partial fecundity of *L. stappersii* in the Zambian waters of Lake Tanganyika.

5.0. DISCUSSION

For stages of maturity, the macroscopic observations are enough for routine work in the field conditions. However, there is often a need to know more about the characteristics of stages of maturity. In this regard the quantitative information brought by the mean gonado somatic index is helpful. Further analyses are required as well such as the observations and measurement in vivo of ovocytes and the histological study.

Confined to the period and sector under study, the spawning of *L. stappersii* was likely taking place between December and February. This period falls into the *L. stappersii* spawning season reported by Aro and Mannini (1995) in the same water (i.e. from December to April), Ellis (1978) in the Burundian waters (i.e. from December to March), and Chapman and Van Well (1978) in the Tanzanian sector (i.e. from November to January in particular). Despite the uncertainties surrounding the spawning peaks for *L. stappersii* observed by Kinoshita (1997) using larva abundance criterion, monthly observations of maturity stages supplemented by GSI yielded some reliable information in the current study. An increase in the number of fish at stage IV and in mean GSI indicate spawning season. This is generally in agreement with the findings of Pearce (1991) in the same waters. However, in this study, the simultaneous low GSI and a high K in the month of December 1999 remain unexplained.

The sizes at maturity (L_{50}) and related dimensions (L_{25} and L_{75}) are generally comparable with those reported by Mannini *et al.* (1996) for the same species in the Zambian waters of Lake Tanganyika. However, the values of L_{50} estimated in this study disagree with those recorded by these authors in that, under the hypothesis of similar rates of growth for both sexes, males reach maturity younger than females. However, these contrasting findings for the same population in the same area may stem from different studying methods or the inter-annual variability in the sizes at maturity. The latter aspect needs to be further investigated.

The overall sex ratio of 53% females: 47% males obtained in this study generally agrees with values estimated by Pearce (1985) and Mannini *et al.* (1996) in the same study area for the same species. It is not significantly different from the theoretical one (1 female: 1 male), and this corroborate with the results obtained by Coulter (1976 and 1991), Nyakageni (1995) and Mannini *et al.* (1996). However, a close analysis proved that this global trend does not remain valid from month to month (Fig. 4.3.1: Table 4.3.1) and for various length classes (Fig.4.3.2: Table 4.3.2.). The former observation agrees with that of Mannini *et al.* (1996) in which the sex ratios in *L. stappersii* varied seasonally. The latter contrasts with that of Ellis (1978) in Burundian waters of Lake Tanganyika, where it was found that neither sex dominates a particular length class, but confirms that of Pearce (1991) in the Zambian sector of the lake.

In the Zambian sector of Lake Tanganyika, the predominance of females *L. stappersii* in fishing grounds during the spawning season suggest a differential availability of both sexes to the fishery which could be synchronized with their differences in reproductive behaviour. Similarly, the predominance in these waters of females *L. stappersii* in larger classes (>32 cm TL) would be related to a number of factors, including the following: a differential vulnerability against females: an abnormal distribution of large individuals of both sexes within schools, itself related to differential behaviour: a short life span and high vulnerability of males, preventing them to reach large sizes etc. These attempts of explanations are somewhat hypothetical and need to be demonstrated.

Fecundity for *L. stappersii* is expected to be high because of small eggs. This suggests the absence of parental care and high mortality of eggs and juveniles. Since at least three modal groups of eggs were observed in nearly all mature ovaries (see also Pearce, 1985a), probably *L. stappersii* is a multiple spawner. Moreover, the presence each month of ripe adults of *L. stappersii* (Coulter, 1976; Ellis, 1978; Pearce, 1985; Chapman and Van Well, 1978; Mannini *et al.*, 1996), and larvae (Kinoshita, 1997) suggest that the species reproduce throughout the year. These considerations suggest that the annual total fecundity of *L. stappersii* is likely to be higher than that estimated by Pearce (1985a) (i.e. between 100 000 to 2 million eggs per fish per year).

The partial fecundity of *L. stappersii* was positively correlated to length, weight and gonad weight. This is true for many fish species (Lowe- Mc Conwell, 1975; King, 1997). There was no information on fecundity body size relationship and fecundity – gonad weight for *L. stappersii* previously in the literature. The partial fecundity-gonad weight relationship is more precise in evaluating the partial fecundity in *L. stappersii* because of the higher value of coefficient of determination. However as the gonad weight is difficult to evaluate in routine work, this relationship is generally without practical interest for a fish population. The partial fecundity-length relationship is therefore preferable to other relationships calculated in fecundity studies. This is because length has an advantage over weight as a measure of size in that a fish will not shrink significantly but can lose weight (Bagenal, 1967).

Many authors have plotted fecundity length relationship using the power function, the fecundity and weight employing the linear function (Bagenal, 1967 and 1978b). For this study, the exponential model proved to be the best relationship between total length and partial fecundity on one hand, and body weight and partial fecundity on the other, for *L. stappersii* from the Zambian waters of lake Tanganyika. This model is suitable for data at hand, as long as the goodness of fit is evaluated by the largest value of R^2. However, the relationship retained may be used with caution and is worth validating. In fact a large value of R^2 does necessarily imply that the fitted model is a useful one. and other alternative models. including the classical ones. are significant as well. This is particularly the case of the power relationship between total length and partial fecundity (Table 4.5.1) which is generally flexible when incorporating it in analytical models (e.g. the Beverton and Holt model).

This work is the first comprehensive contribution to the study of fecundity in *L. stappersii*. The absence of comparable studies limits the discussion of the partial fecundity and partial fecundity body size relationships. However the partial fecundity obtained in this study are slightly higher than those observed by Pearce (1985a). The fitted models of partial fecundity body size relationships are highly significant too.

The study could be improved if sampling is done over a long period of time (e.g. one year) to capture the spawning peaks. At the same time more information on fecundity of *L. stappersii* is also needed (i.e. morphometric measurements of eggs to assess the modal distribution of eggs in the ovaries). This can be made possible if eggs were observed measured and counted under the dissecting microscope fitted with a micrometer.

6. CONCLUSION

The study revealed that the mean GSI increases from stage I to stage IV in both sexes. It drops in stage V for females because of release of sexual products. The GSI indicated that sampling probably coincided with a part of spawning activity. as observed between December and February. The size (TL at maturity L_{50}) for both sexes was 24.89 cm for females and 21.68 cm for males. The overall sex ratio was 53% females : 47% males: it was statistically insignificant from the theoretical sex ratio (i.e 50% females : 50% males). The average fecundity of *Lates stappersii* was 273 000 eggs per fish. ranging from 46 000 to 839 000 eggs. The average estimate of relative partial fecundity was 914 eggs * g^{-1} of fresh fish. The results showed better exponential fit between TL and fecundity and body weight and gonad weight. A linear relation was found between partial fecundity and gonad weight.

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APPENDIX A: Monthly input data for stages of maturity. size at maturity. and sex ratios for *L. stappersii* in the Zambian waters of Lake Tanganyika.

FEMALES (September, 1999) **MALES (September, 1999)**

TL cm	Stages (Females)					Total		Stages (Males)					Total
	(I)	(II)	(III)	(IV)	(V)			(I)	(II)	(III)	(IV)	(V)	
15	1					1							
16													
17	2					2		1					1
18	2	1				3				1			1
19	2	4				6			3	2			5
20	4	3				7		1	5	8	1		15
21	5	8	11			24		1	7	18	1		27
22	7	4	5	1		17			4	21	1		26
23	7	10	3	4	1	25		1	11	21	2		35
24	4	3	4	3		14			3	14	1		18
25	3	1	3	2		9			2	8	1		11
26		1	1	1		3			1	2			3
27	1	1	1	1		4			1	4			5
28				2		2				2			2
29					1	1							
30				1		1				1			1
31									1	1	1		3
32				1		1					1		1
33													
34													
35													
36													
37													
38													
39													
40													
41													
42													
43													
44													
Total	**38**	**36**	**28**	**16**	**2**	**120**		**4**	**38**	**103**	**9**		**154**

FEMALES (October, 1999) **MALES (October, 1999)**

Length TL(cm)	Stages (Females)					Total		Stages (Males)					Total
	I	II	III	IV	V			I	II	III	IV	V	
15													
16	2					2		1					1
17	3					3		4	1	1			6
18	3					3		9	1	2			12
19	7	1	6			14		6	16	5	1		28
20	8	2	6	5		21		7	21	14	8		50
21	11	5	10	5		31		5	17	17	7		46
22	4	5	14	2		25			14	22	9		45
23	5	2	8	7		22		2	9	7	1		19
24	6	2	3	2		13		1	2	10	9		22
25	2		1	3		6		2	3	5	6		16
26	2	2	1	1		6		1		1			2
27	1		1			2		1		2	1		4
28										2	1		3
29											1		1
30		1		1		2					2		2
31											4		4
32			1	1		2				2	1		3
33				1		1					1		1
34			1			1					3		3
35			2	5		7					2		2
36			2	3		5							
37			5	3		8					2		2
38				1		1							
39			2	4		6				1	3		4
40			2	3		5					1		1
41				2		2					1		1
42				2		2					1		1
43				1		1							
44					1	1							
Total	**54**	**20**	**65**	**52**	**1**	**192**		**39**	**84**	**91**	**65**		**279**

FEMALES (November, 1999) **MALES (November, 1999)**

Length TL(cm)	Stages					Total		Stages					Total
	I	II	III	IV	V			I	II	III	IV	V	
15													
16													
17													
18								1					1
19									1				1
20			1			1			2				2
21	1					1			1				1
22	2	1	2	1		6			6	2			8
23			3			3		1	1	2	2		6
24			1	3		4			1	3			4
25	2		2	1		5				2	1		3
26			1			1			1	3	1		5
27	1	1				2							
28										1	1		2
39		1				1					1		1
30			1			1							
31													
32				2		2							
33			1	2	1	4				1	1		2
34				2	1	3					1		1
35				3		3					2		2
36			1	2		3					2		2
37				3		3					2		2
38			1	2		3					3		3
39			1	4		5					5		5
40				3		3				1	1		2
41				4		4					1		1
42													
43													
44													
50				1		1							
Total	**6**	**3**	**15**	**32**	**2**	**58**		**2**	**13**	**15**	**24**		**54**

FEMALES (December, 1999) **MALES (December, 1999)**

Length TL(cm)	Stages					Total		Stages					Total
	I	II	III	IV	V			I	II	III	IV	V	
15													
16													
17	1					1							
18	1					1							
19													
20	2					2				1			1
21	2	1		1		4			1	2			3
22	5	4	1	1		11			4	3	4		11
23	4	6	3	2		15			5	4	6		15
24	4	3	5	5		17			2	5	10		17
25	5	2	0	6		13			2	5	9		16
26	1	1	0	2		4			3	2	9		14
27		1	0	3		4			2	1	12		15
28	1	2	1	1		5				3	3		6
29	2	1	1			4					4		4
30		1	1			2					3		3
31				1		1					2		2
32				2		2					2		2
33													
34				4		4					1		1
35		1				1					1		1
36				2		2							
37				2		2					1		1
38											2		2
39													
40													
41				1		1							
42				1		1							
43													
44													
Total	**28**	**23**	**12**	**34**		**97**			**19**	**26**	**69**		**114**

FEMALES (January, 2000) **MALES (January, 2000)**

LENGTH TL (cm)	Stages					Total		Stages					Total
	I	II	III	IV	V			I	II	III	IV	V	
15													
16													
17													
18													
19													
20	2					2							
21	2					2			1	1			2
22	2					2			2	2			4
23	5			2		7		1	2	2			5
24	4			3		7			3		1		3
25	1		2	2		5			2	3	1		6
26	3	1		2		6			1	2	3		4
27	2	1	3	1		7			2	3	6		8
28	2	4		3		9			6		1		12
29		1		2		3					1		1
30		2		1		3					2		1
31		2		1		3				1	2		3
32			3	2		5					2		2
33		1	2	3		6					2		2
34			2	9		11					2		2
35			4	11		15					3		2
36			1	11		12				1	1		4
37			2	10		12					1		1
38			1	12		13					3		1
39			1	9		10							3
40				7		7					1		
41				4		4							1
42													
43				1		1							
44				1		1							
Total	**23**	**12**	**21**	**97**		**153**		**1**	**19**	**15**	**32**		**67**

FEMALES (February, 2000) **MALES (February, 2000)**

Length TL (cm)	Stages					Total		Stages					Total
	I	II	III	IV	V			I	II	III	IV	V	
16													
17						0							0
18						0							0
19						0							0
20						0		1					1
21	2					2		1	2	1			4
22	2					2		1	2				3
23	4		1	1		6		1	3				4
24	2		2			4		1	1				2
25	2		1	2		5			2	1	1		4
26	2	2	1			5							
27	1	1	1	1		4			2				2
28	4	2	4			10							0
29			2	5		7				1	1		2
30		2	1	2		5							0
31			3	3		6					2		2
32	1		3	10		14					4		4
33		1	3	11		15					4		4
34		0	1	12	1	14					5		5
35			3	20		23					6		6
36			4	16		20					5		5
37			3	15		18					2		2
38				7		7							0
39				10		10					3		3
40				8		8					1		1
41				3		3					0		0
42				6		6					0		0
43				3		3					0		0
44													
45													
46													
Total	**20**	**8**	**33**	**135**	**1**	**197**		**5**	**12**	**3**	**34**		**54**

APPENDIX B: Partial and relative partial fecundity data of *L. stappersii* in the Zambian waters of Lake Tanganyika

N_0	TL (cm)	W (g)	w (g)	Pfec	Rel Pfec
1	38	408	8.69	307,734	754 25
2	37.2	358	6.34	226,338	632.2291
3	40.0	445	9.5	339,150	762 1348
4	46.0	666	14.78	583,810	876.5916
5	24.2	107	1.72	65,704	614.0561
6	33.4	246	3.04	108,528	441.1707
7	50.0	1064	23.72	839,664	789.1579
8	25.5	112	2.61	93,177	831.9375
9	40.1	514	9.97	355,929	692.4689
10	35.2	312	5.14	183,498	588.1346
11	43.0	604	20.69	738,633	1222.902
12	19.0	51	1.59	56,763	1113
13	39.1	421	9.25	337,625	801.9596
14	36.4	354	5.94	212,058	599.0339
15	44.0	607	21.59	770,763	1269.791
16	41.5	485	9.70	346,290	714
17	43.0	510	16.8	611,520	1199.059
18	33.2	255	8.14	308,506	1209.827
19	41.3	471	9.17	407,148	864.4331
20	34.9	299	9.21	349,059	1167.421
21	38.0	378	9.60	376,712	996.5926
22	36.1	341	7.66	273,462	801.9413
23	42.0	495	15.95	610,885	1234.111
24	38.7	379	9.61	374,790	988.8918
25	37.3	347	6.81	265,590	765.389
26	39.6	458	10.65	415,350	906.8777
27	42.1	492	15.63	609,570	1238.963
28	36.5	288	5.02	195,780	679.7917
29	35.0	270	4.56	177,840	658.6667
30	31.4	221	4.03	157,170	711.1765
31	35.7	313	6.62	258,180	824.8562
32	37.0	361	7.23	281970	781.0803
33	40.1	493	18.53	722,670	1465.862
34	26.5	132	2.96	115440	874.5455
35	25.6	117	2.52	98280	840
36	23.2	84	2.30	89,700	1067.857
37	35.2	289	8.83	344,370	1191.592
38	28.4	173	3.13	122,070	705.6069
39	27.4	143	4.68	135720	949.0909
40	34.0	272	5.70	220,020	808.8971
41	25.8	122	4.08	159,120	1304.262
42	23.6	130	3.24	124,740	959.5385
43	24.5	103	3.05	118,950	1154.854
44	21.2	70	3.37	117,950	1685
45	37.0	364	6.48	249,600	685.7143

46	32.3	232	4.14	152,352	656.6897
47	36.2	326	5.26	205,140	629.2638
48	32.5	256	5.33	207,870	811.9922
49	24.0	106	3.01	108,360	1022.264
50	32.2	224	3.40	132,600	591.9643
51	31.2	190	2.68	101,840	536
52	22.0	76	2.16	81,864	1077.158
53	26.5	141	3.65	138,700	983.6879
54	20.3	60	1.97	74,860	1247.667
55	20.2	57	1.23	46,740	820
56	23.8	94	2.59	98,420	1047.021
57	22.5	72	2.60	98,800	1372.222
58	20.0	64	1.23	47,970	749.5313
59	42.6	519	12.67	494,130	952.0809
60	42.8	509	15.80	616,200	1210.609
61	38.8	409	14.05	501,585	1226.369
62	39.0	421	14.54	519,078	1232.964
63	41.3	471	9.17	357,630	759.2994
64	39.5	420	6.15	239,850	571.0714
65	31.0	227	3.92	152,880	673.4802
66	27.0	145	4.10	155,800	1074.483
67	26.8	130	3.16	120,080	923.6923
68	39.0	460	7.05	274,950	597.7174
69	42.7	475	16.02	624,780	1315.326
70	33.5	260	8.25	321,750	1237.5
71	32.7	258	4.48	174,720	677.2093
72	29.5	156	2.38	92,820	595
73	28.0	148	2.34	91,260	616.6216
74	32.7	213	5.01	195,390	917.3239
75	34.0	260	6.52	254,280	978
76	35.9	320	7.68	299,520	936
77	39.6	386	7.78	303,420	786.0622