Breeding Strategy of Nannothrissa stewarti POLL and ROBERTS 1976 (Clupeidae) in Lake Mai-Ndombe, Democratic Republic of Congo

Lingopa, Norbert Zanga; Pwema, Victor Kianfu; Mbomba, Nseu Bekeli; Mutambwe, Shango; Musibono, Dieudonné Eyul'Anki; Mbadu, Victorine Zebe; Tembeni, John Makiadi; Wilander, Anders; Ntalakwa, Théophane; Mondzoi, Adrien Boika; Micha, Jean Claude

Published in:
Egyptian Journal of Aquatic Biology and Fisheries

DOI:
10.21608/ejabf.2023.280234

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(1): 27 – 45 (2023)
www.ejabf.journals.ekb.eg

Breeding Strategy of *Nannothrissa stewarti* POLL and ROBERTS 1976 (Clupeidae) in Lake Mai-Ndombe, Democratic Republic of Congo

Norbert Zanga Lingopa[1,2], Victor Kianfu Pwema[2], Nseu Bekeli Mbomba[2], Shango Mutambwe[3], Dieudonné Eyul'anki Musibono[3], Victorine Zebe Mbadu[2,4], John Makiadi Tembeni[2], Anders Wilander[7], Théophane Ntalakwa[3], Adrien Boika Mondzoi[9], Jean Claude Micha[5,6]

[1] Institut Supérieur de Pêche (ISPê), Mbandaka, RD Congo
[2] Laboratory of Limnology, Hydrobiology and Aquaculture, Department of Biology, Faculty of Sciences, University of Kinshasa, B.P. 190 Kinshasa XI, DR Congo
[3] Department of Environmental Sciences, Faculty of Sciences, University of Kinshasa, Congo
[4] Institut Supérieur des Techniques Médicales (ISTM) Kinshasa, RD Congo
[5] École régionale postuniversitaire d'Aménagement et de Gestion intégrés des Forêts tropicales et Territoires tropicaux (ERAIFT), Kinshasa, RD Congo
[6] University of Namur (UNamur), Research Unit in Environmental Biology (URBE), Namur, Belgium
[7] Aquatic Sciences and Environmental Assessment Laboratory, Faculty of Natural Resources Management, Department of Aquatic Sciences and Environmental Assessment, Swedish University of Agri. Sciences
[8] Laboratory of systemic biodiversity conservation of nature and endogen knowledge Faculty of Sciences, University of Kinshasa
[9] Institut Supérieur Pédagogique de Mbandaka RD Congo

[*]**Corresponding Author: zanganorbert@gmail.com**

ARTICLE INFO

Article History:
Received: Oct. 11, 2022
Accepted: Nov. 27, 2022
Online: Jan. 13, 2023

Keywords:
Fecundity,
First sexual maturity size,
Lake Mai-Ndombe,
Gonado-somatic index,
Maturity stage,
Oocyte diameter,
Sex ratio

ABSTRACT

The clupeid, *Nannothrissa stewarti* (Poll and Roberts 1976), endemic to Lake Mai-Ndombe, is one of the most heavily fished fish species using practices and nets not allowed by the country's legislation. The objective of this study was to determine some aspects of the reproductive biology of *N. stewarti* in Lake Mai-Ndombe. Fish were monthly sampled from November 2020 to October 2021. Breeding parameters were determined: gonado-somatic index (GSI), size at first sexual maturity, absolute fecundity and the relationship between total weight (TW) and total length (TL). Results obtained showed that the sex ratio was in favor of females (1: 0.8). Estimated absolute fecundity was between 227 and 4080 oocytes for females of total length between 23 and 35mm, with an average of 923 ± 664g oocytes and a relative fecundity varying between 25120 and 155460 oocytes kg-1. The average oocyte diameter was 0.20 ± 0.14mm. Distribution of oocyte diameters observed in the population as well as monthly variations of the Somatic Gonado Index (SGI) indicates that the species has two main clutches during the year. LT_{50} size at first sexual maturity is 27.6mm for males and 25.5mm for females. *N. stewarti* from Lake Mai-Ndombe has multiple reproductions throughout the year, with two maximum peaks at the beginning of the peak rainfall (February-March and September-October).

INTRODUCTION

Fish reproduction is one of the most complex aspects of their biology. As in most vertebrates, it is a cyclical phenomenon whose annual periodicity is often influenced by environmental and endocrine conditions that affect gonadal maturation, development of primary, secondary sexual characters and reproductive behavior **(Bouhali *et al.*, 2015)**.

Clupeidae are small to moderately sized fishes with much variation in body shape and depth, from rounded to compressed **(Whitehead, 1985; Whitehead & Wongratana, 1986a as cited in Musschoot *et al.*, 2021).**

Nannothrissa stewarti (Poll & Robert 1976) has distinct and keeled prepelvic scutes, deep maxillary blade without ridge, diamond-shaped posterior supramaxilla and toothless dentary and premaxilla **(Whitehead 1985 as cited in Musschoot *et al.*, 2021)**.

Moreover, its body is slender or moderate, with a depth of about 25% SL; scutes a little behind isthmus, very trongly keeled, 9-10 prepelvic and 7-9 postpelvic scutes; lower jaw is very slightly projecting, toothless; no teeth are found on premaxilla or maxilla; posterior supramaxilla as deep as maxilla blade and with long slender anterior shaft; 20-23 lower gill rakers; pelvic fin with 1 unbranched and 6-7 branched rays, inserted just below dorsal-fin origin; 17-19 anal-fin rays; 34-35 scales in lateral series **(Poll & Roberts, 1976; Whitehead, 1985** as **cited in Musschoot *et al.*, 2021)**.

N. stewarti is sold at various ports in the town of Inongo and throughout the settlements around the lake for the sake of earning money to cover the social and economic needs **(Béné *et al.*, 2009)**. This fish species is prized by the local populations **(Zanga *et al.*, 2022)**. In addition to its direct use for human consumption, it serves as a source of animal feed and play an important role in ecosystems as prey for all kinds of food web predators **(FAO, 2020)**.

Unfortunately, to our knowledge, few studies based on the fishery resources of Lake Mai-Ndombe have been undertaken except the work of **Luhusu and Micha (2013)**; while, information on the reproductive biology of *N. stewarti* is almost non-existent. It is worth noting that, information on the reproduction of *N. stewarti* in Lake Mai-Ndombe can be used to consider stock assessment models on the one hand and management decisions to plan the rational use and protection of fishery resources on the other **(Heins *et al.*, 2004)**. Determining the size at first sexual maturity and the periods of peak reproduction would allow the fishermen to be advised with the types of gears and period of the year when fishing of specific species can be achieved to avoid the depletion of stock, especially that the species is endemic **(Olayinka, 2018)**.

The objective of this study was to determine some aspects of the reproductive biology as well single variable of croissance of *N. stewarti* in Lake Mai-Ndombe in the Democratic Republic of the Congo. More specifically, it aimed to specify sex ratio, gonado-somatic index (GSI), fertility, oocyte diameter and size of first sexual maturity in addition to the relationship between total weight (WT) and total length.

MATERIALS AND METHODS

Environmental studies

This study was conducted in Lake Mai-Ndombe (Fig. 1) located at 18°14'E and 1°53'S. This lake is 146km long, 18km wide and covers an area of 2300km^2.

Fig. (1) shows the sampling area illustrated by four sites.

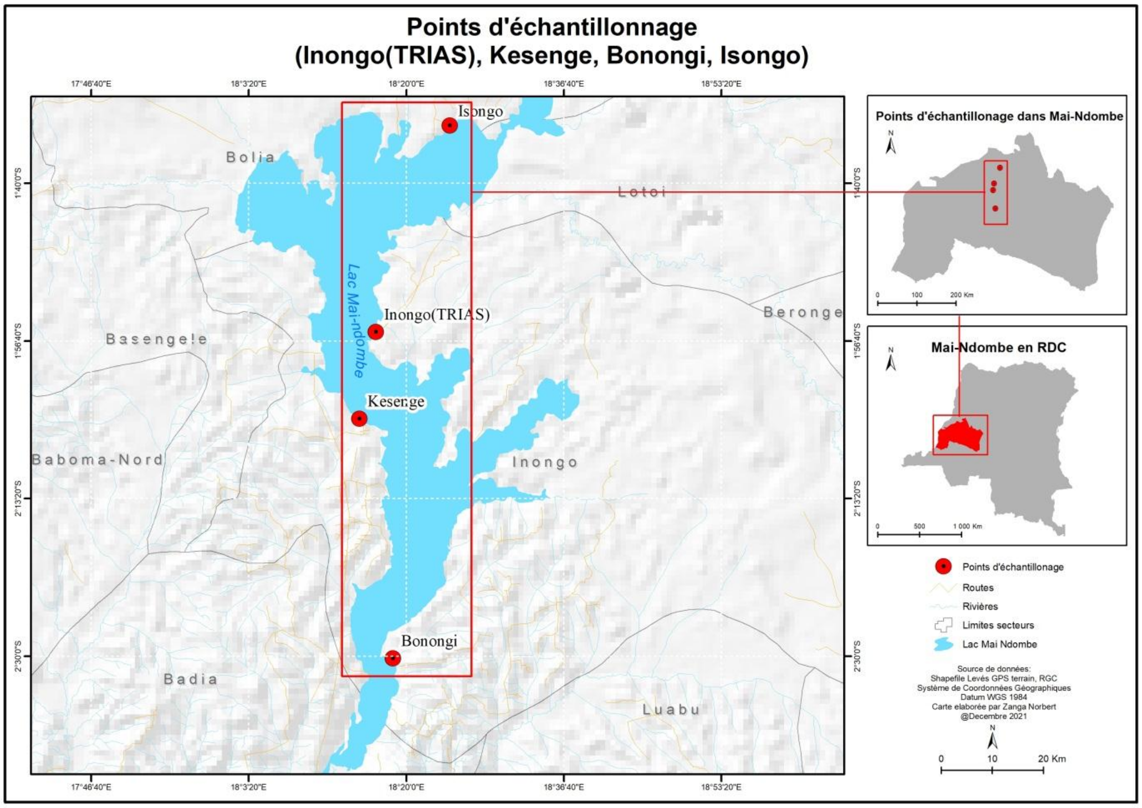


Fig. 1. Map of Lake Mai-Ndombe showing the four study sites (red dots)

The Lake Mai-Ndombe is in a region with an Af-type climate according to the Köppen classification **(Bultot & Griffits, 1971)**. The monthly diurnal air temperature ranges from 26 to 27.3°C, with an average of 26.4 ± 0.49°C. Monthly rainfall fluctuates from 69.9 to 153.6mm, with an average of 115.4 ± 28.2mm. While, the annual precipitation ranges from 1000.9 to 1740.7mm. Fig. (2) illustrates two weather variables: temperature and precipitation, desrcibing the season in the study area.

It indicates that the region of Lake Mai-Ndombe does not experience a marked dry season although there is a decrease in rainfall in June and July.

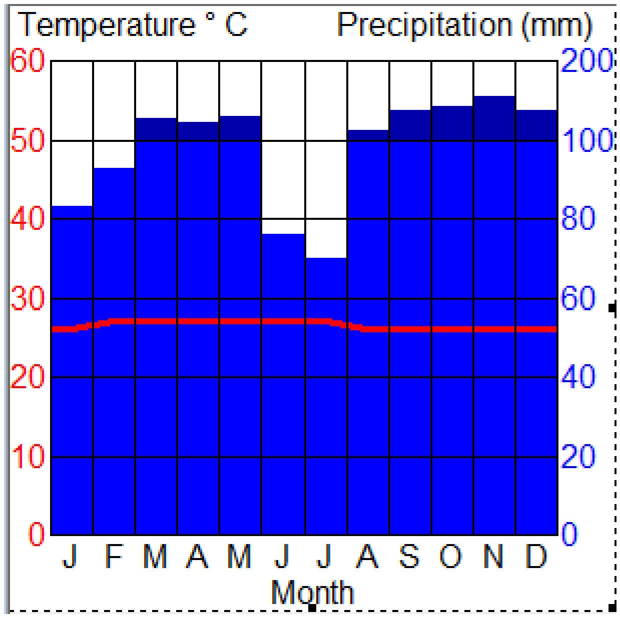


Fig. 2. Umbrothermal diagram of the Lake Mai-Ndombe region data provided for 10 years from 2010 to 2019 by ELAYA technician collector in Lake Mai-Ndombe meteorological station

The water of Lake Mai-Ndombe has an acidic pH between 3.94 and 4.05, with a low transparency of 0.5 and 0.8m and potassium ion (K^+) concentrations fluctuating between 0.006 and 0.010 $meq{\cdot}L^{-1}$ (milliequivalents per liter). Phosphate ion (PO_4^{-3}) concentration was recorded less than $4\mu g{\cdot}L^{-1}$, while silica (Si) concentration was around $1.2mg{\cdot}L^{-1}$. The ammonium nitrogen (NH_4^+) concentration was around $21\mu g{\cdot}L^{-1}$ **(Micha *et al.*, 2020)**.

According to **Belesi (2016)**, macrophytic vegetation of Lake Maï-Ndombe is characterized by *Loudetia phragmitoides* - *Andropogon schirensis* and *Fimbristylis dichotoma* - *Solenostemon monostachyus* groupings. In the flooded forest vegetation, species such as *Zeyherella longipedicellata* dominates the vegetation cover. The phytoplankton was dominated by chrysomonales, chlorophyceae (green algae), diatoms, flagellates and cyanophyceae **(Micha *et al.*, 2020)**. Whereas, zooplankton contained copepods, cladocerans and rotifers.

For fishes, about fifty species have been detected **(Micha *et al.*, 2020)**. The emblematic families recorded are Clariidae, Channidae, Clupeidae, Mormyridae, Claroteidae, Cichlidae and Alestidae.

Biological materials

Thus, 688 specimens of *N. stewarti* were caught between November 2020 and October 2021.

Biological sampling

The fish were caught by using a battery net (where two types of monofilament nets of 0.1cm and 2.5cm knots, 500m long and 2m drop) was an active technique hauling for 3 hours in a single haul per day once a month at each site. The fishing started at 5 o'clock in the morning. The fishing was done at the same time for each sampling site. The sampling points were determined in a random way at the four sites.

Measurements and calculations

Fish species identification was performed using the identification key proposed by **Whitehead (1985)** and **Musschoot *et al.* (2021)**. Species validation was confirmed with FishBase **(Froese & Pauly, 2022)**. Each specimen was measured to the nearest 0.1mm (total length, TL) and weighed to the nearest 0.1g (W) at the same time.

The relationship between total weight (WT) and total length (TL) is represented by the following mathematical formula:

$$TW = a\ TL^{b}$$

Where, TW= total weight (g); TL= total length (mm); a the intercept and b are the allometric coefficient/slope.

The equation was linearized by a log-transformation. The 95% confidence interval (CI) for parameters a and b and the coefficients of determination (R^2) were also determined **(Keys, 1928; Froese, 2006; Zhang *et al.*, 2022)**.

Sex ratio (SR) was determined as the quotient number of males caught/number of females caught.

GSI was calculated from the following formula **(Koné *et al.*, 2016):**

$$GSI = \frac{Wgo}{TW} * 100$$

Where, GSI= Gonado Somatic Index; Wgo= gonad weight (g), and TW= total fish weight (g).

Gonads were classified into different stages of sexual maturity according to the conventional maturity scale **(Berchie *et al.*, 2020)**. Only fish in maturity stages III, IV and V were considered for this study. The size of first sexual maturity was defined as the size (L_{50}) at which 50% of individuals of both sexes in the study population have reached sexual maturity. The L_{50} was determined by the equation of the sigmoid curve of the evolution of the percentages (P) of sexual maturity as a function of the size classes (TL). This curve is obtained by logistic transformation according to **Dagnelie (1973)** and is given by the succeeding formula:

$$P = \frac{X}{(1+X)}$$

with $X = e^{(a+bTL)}$

P= Percentages of sexual maturity; TL = Total length, and a and b are coefficients. The logarithmic transformation of the equation facilitates putting it in the following form:

$\ln (P/1-P) = a+bTL$

Where, L_{50} is obtained by the formula L_{50} via inserting P= 0.5 (50 %). Origin 6.1 software was used for this purpose.

The number of mature eggs in the gonads was determined by counting oocytes in an ovary fraction under a Wild Heerbrugg 113099 binocular loupe at 10X magnification and then reported to the total gonad weight **(Dadébo *et al.*, 2003)**. It was estimated according to the following formula:

$$F = (n*W_{go})/W_{sample}$$

Where, F= Individual fecundity per egg-laying act; n = Number of oocytes contained in the ovary sample; W_{go} = Total ovary weight (g), and W_{sample} = Ovary sample weight (g).
Relative fecundity was calculated using the following expression:

$$F_r = F/W$$

Where, F_r is relative fecundity; F is absolute fecundity, and W= somatic weight (g) **(Berchie *et al.*, 2020)**.

For the determination of the oocyte diameter (mm), 30 oocytes in stage IV were measured under a binocular loupe equipped with a micrometer (model MG 10085-1). The collected gonad fragments were weighed then fixed in modified Gilson's liquid (100ml of 60% alcohol + 800ml distilled water and 15ml of 80 % nitric acid + 18ml of glacial acetic acid + 20g of mercuric chloride) for 24 hours. This operation promotes the dissociation of oocytes and thus allows them to be isolated from each other in order to count them. The average diameter was determined from the arithmetic mean of the measurements.

The absolute fecundity-gonad weight relationship was determined from the relationship using the following absolute fecundity-gonad weight linear regression equation. **Pwema *et al.* (2013)** established the fecundity-length relation to *Labeo* sp., which describes the relation between fecundity and length in a satisfactory way:

$$F = a*W^b$$

Where, F = absolute fecundity; a and b = coefficients; L = length (mm), and W= weight (g).
After logarithm transformation, the constants were calculated by linear regression (the least squares method) to give the values for the coefficients a and b.

The computer software Statistix version 10, Origin version 6.1, Past 4.03 and Excel were used to analyze and process the data.

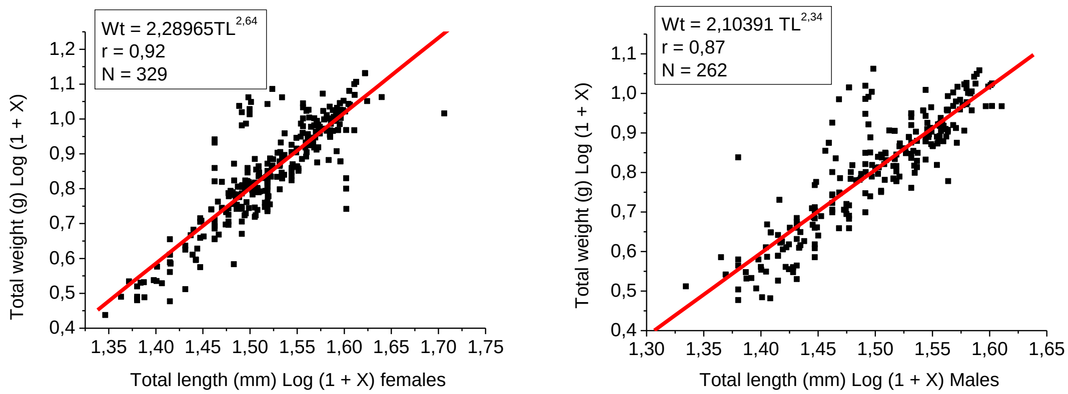
RESULTS

Measurements

The total length of the males varied from 20.6 to 38.5mm, with an average value of 28.8 ± 4.6 mm and weight varying between 2.0 and 10.54g, with an average value of 5.02 ± 2.06 g. For females, the length was between 20.6 and 49.84, with an average value of

32.4 ± 4.5mm. While, the weight was between 1.74 and 12.52, with an average value of 6.36 ± 2.25g.

The relationship between total weight (g) and total length (mm) of males and females of *N. stewarti* is presented in Fig. (3a, b).



3. a 3. b

Fig. 3. A, B. Total weight - total length relationship after log transformation in females and males of *N. stewarti*, respectively, in Lake Mai-Ndombe

Reproductive features

The determination of the sex ratio involved 591 specimens of *N stewarti* of which 262 were males and 329 were females. The sex ratio was 1: 0.8; that is 1 female for 0.8 males. The evolution of the Somatic Gonado Index of *N stewarti* specimens showed several peaks (Fig. 4).

The GSI varied from month to month. In females, two peaks were observed; in April 2021 (9.77 ± 2.19) and August 2021 (10.55 ± 2.19). Low values of IGS were observed in February 2021 (4.07 ± 2.19) and December 2020 (4.41 ± 2.19). In males, two peaks were also observed; in June 2021 (6.37 ± 1.41) and October 2021 (4.83 ± 1.41), and the lowest values were recorded in March 2021 (1.54 ± 1.41) and December 2020 (1.86 ± 1.41).

The evolution of the maturity stages of *N. stewarti* specimens sampled in Lake Mai Ndombe is visualized in Figs. (5, 6).

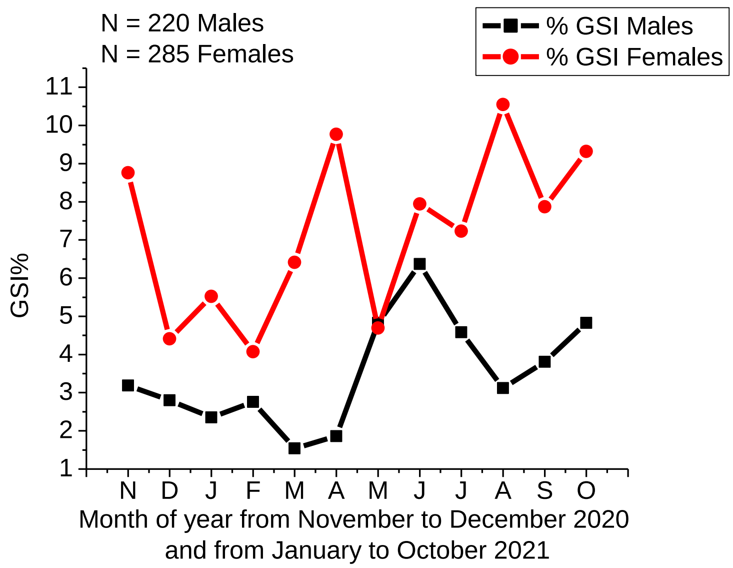


Fig. 4. Monthly evolution of the average Gonado-Somatic Index of male and female *N. stewarti* from November 2020 to October 2021 in Lake Mai-Ndombe

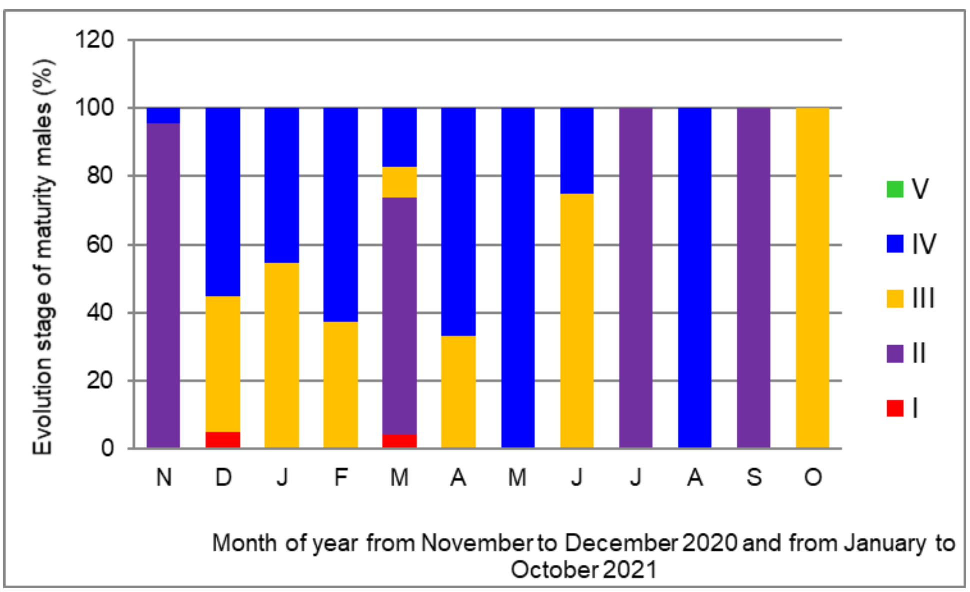


Fig. 5. Monthly evolution of sexual maturity stages of males *N. stewarti* between November 2020 and October 2021

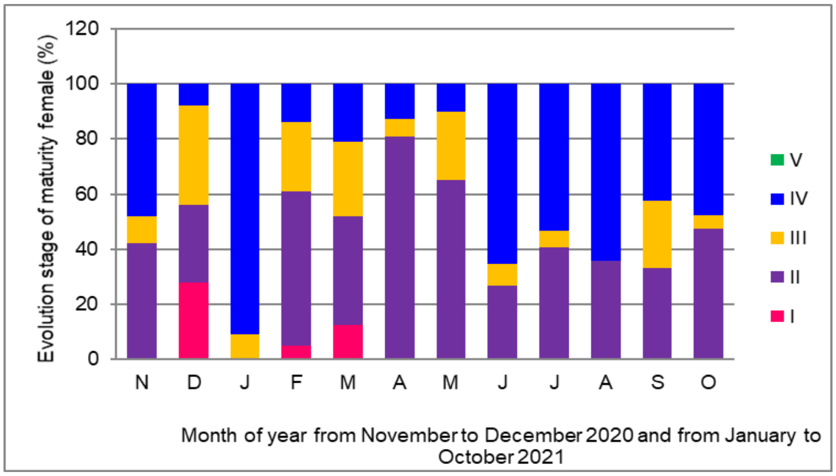
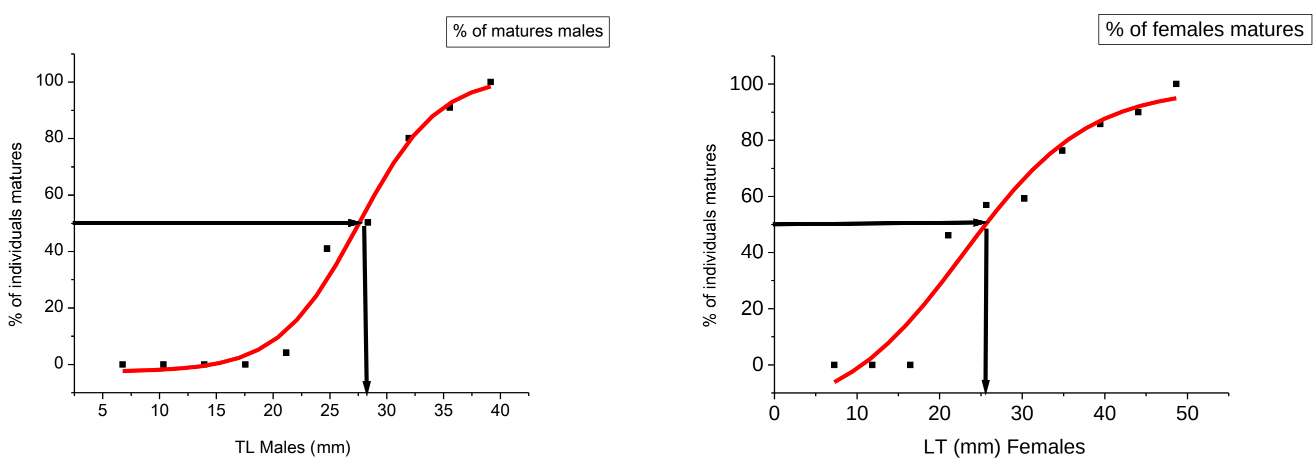


Fig. 6. Monthly evolution of sexual maturity stages of females *N. stewarti* between November and December 2020 and from January to October 2021

Male gonads began to develop in March and December; maturity was then observed every month except July, September and October (Fig. 5). Female gonads started to develop in December, February and March (stage I). Stage II evolved from February to December. Stage III, the beginning of maturity, was encountered during most of the year, except for the months of May, August and September. Stage IV, maturation and expulsion of the gametes, was observed all the months of the year. Stage V, which corresponds to the resting stage, was not so visible **(Fig. 6).**

The size of first maturity (L_{50}) for males and females of *N. stewarti* is presented in **(Fig. 7).**



a *N. stewarti* males b. *N. stewarti* femalles

Fig. 7. Determination of the size of first sexual maturity (L_{50}) in male (a) and female (b) *N. stewarti*.

In females of *N. stewarti* the size of first sexual maturity (L_{50}) was reached at 25.5 mm (Total length) and at 27.6 mm in males.

The estimated absolute fecundity for *N. stewarti* varied from 227 to 4080 oocytes for females with total length between 23 and 35 mm with an average absolute fecundity of 923 ± 664 oocytes.

Estimated relative fecundity was ranged from 25,120 to 155,460 oocytes kg^{-1} of total body weight with a mean of 161,500 ± 87,890 kg^{-1}. The diameter of the oocytes in stage III and IV found in the fish ranged from 0.1 to 0.5 mm with a mean of 0.2 ± 0.14 mm. **Fig. 8** visualizes the annual oocyte diameter distribution.

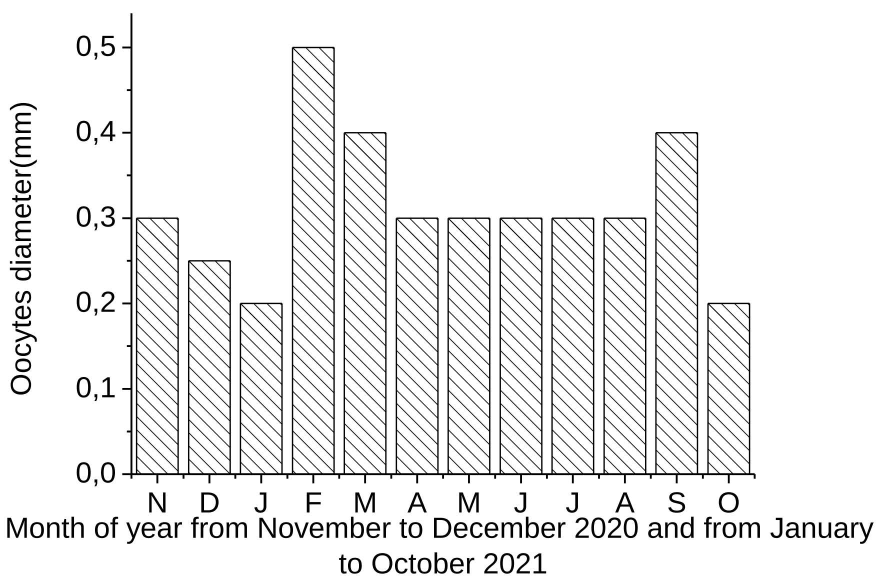


Fig. 8. Oocyte diameters of *N. stewarti* sampled from November to Décemebr 2020 and from January to October 2021 in Lake Mai-Ndombe.

It shows two peaks in oocyte diameter, suggesting two main oviposition events during the year for *N. stewarti* in Lake Mai-Ndombe.

The relationship between absolute fecundity and total length of *N. stewarti* is shown in **(Fig. 9)**.

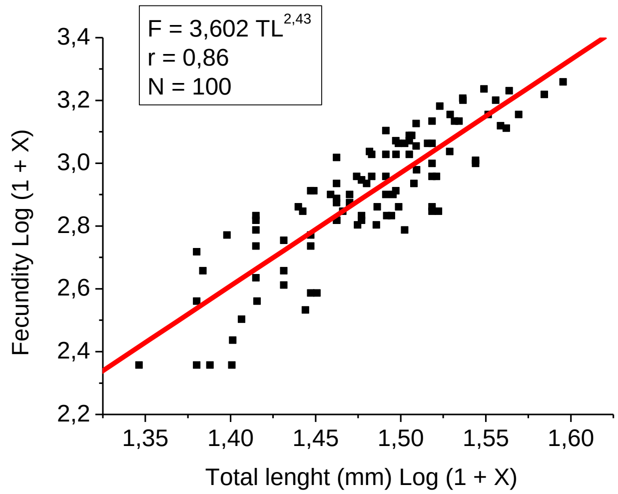


Fig. 9. Relationship between absolute fecundity and total length after logarithmic transformation in *N. stewarti* females caught in Lake Mai-Ndombe.

After log transformation is the equation relating absolute fecundity and total length linear with a highly significant relationship between the two parameters (r = .86) (*p* at the 0.05 < .0001 significance level).

The relationship between absolute fecundity and total weight (g) of *N. stewarti* is visualized in **(Fig. 10)**.

The absolute fecundity - total weight relationship, after log transformation, was linear with a high regression coefficient (r = .85) and highly significant (p at the 0.05 < .0001 significance level).

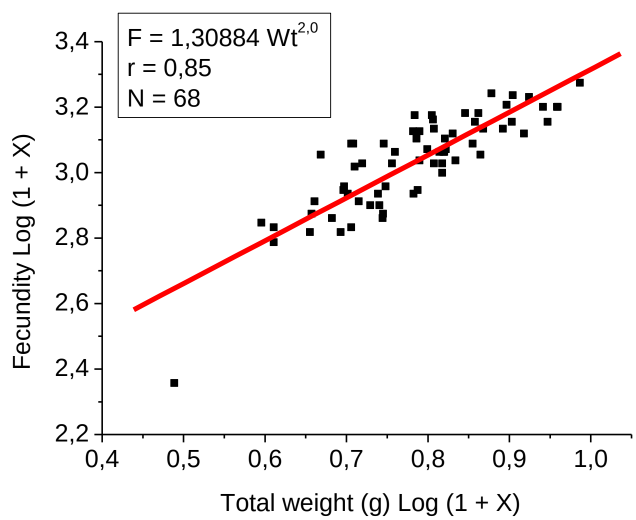


Fig. 10. Absolute fecundity - total weight relationship in *N. stewarti* females caught in Lake Mai-Ndombe.

DISCUSSION

Length and weight.

The relationship between total weight and total length of the fish **(Fig. 3)** shows a very high and highly significant correlation coefficient (*p*-value < .0001): r = .87 for both females and males).

Specimens of *N. stewarti* studied in Lake Mai-Ndombe measured between 23.0 and 49.84 mm in total length and weighed between 2.0 and 12.52 g. These sizes are close to those obtained by **Kolding *et al*. (2019)** for *Microthrissa moeruensis* Poll, 1948, endemic to Lake Mweru in eastern DRC and that of *Pellonula leonensis* Boulenger, 1916 (Fishbase TL12.1 cm, TW 13.5 g) and *Sierrathrissa leonensis* Thys van den Audenaerde 1969, a small West-African clupeidae known as a pygmy herring (Fishbase max SL 3.0 cm). Different sizes of these could be a result from long time adaptation or evolution in these various environments but may also result from their levels of exploitation and the mesh size of the fishing nets used. In additional the length and weighed relationship are influenced by different growth size, gender, fishing, and environmental factors, such as season, temperature, and food **(Rekha *et al.*, 2021; Ni *et al.*, 2022; Zhang *et al.*, 2022).**

Our results provided the new data for FishBase, allow for the convenience of fish stock assessment, and are expected to provide a useful baseline for further studies of population parameters to improve management decisions in Lake Mai-Ndombe.

Sex ratio.

The sex ratio of *N. stewarti* fish (262 males and 329 females) is in favor of females, i.e. 1 female for 0.8 males. Females were slightly numerous than males. Predominance of one sex is a relatively common phenomenon in many teleost fish species **(Osei *et al.*, 2020).** Variations of the sex ratio according to size have a considerable impact on the fertility of stocks according to whether the adult individual majority captured is female or male. The sex ratio is influenced by many factors such as movement for foraging and spawning, differential growth, and sex-specific mortality rates also influence the sex ratio in fishes. High catchability of females, higher natural mortality in males, or simply differential growth of individuals may also explain this sex ratio. However, our results show that this is not a sexual difference in growth, as the weight-length relationships are quite similar **(Osei *et al.*, 2020).** Our observations are similar to those made on *Pellonula Leonensis* **(Boulenger, 1916)** in the Kossou dam lake in Benin and Côte d'Ivoire where **Sossoukpe *et al.* (2016)** noted that the overall catch of *Sardinella maderensis* Lowe, 1838 and *P. leonensis* was dominated by females. The difficulties of determining the sex of immature and hermaphrodite individuals could greatly affect the proportion of males and females obtained. But a reverse result was recorded with a sex ratio of 1.3:1 in favour of males by **Berchie *et al.* (2020)** in the studies of *Ilisha africana* Bloch, 1795 from the coast of Ghana West Africa.

Fecundity.

The absolute fecundity value calculated for *N. stewarti* ranged from 227 to 4080 oocytes for females with total length between 23 and 35 mm. The estimated relative fecundity in *N. stewarti* ranges from 25,115 to 155,457 oocytes kg^{-1}. These relatively high fecundity values place *N. stewarti* in the rank of prolific species with high fecundity, which produce many small eggs and invest several times per year in ovarian production (high IGS). In addition, **Kolding *et al.* (2019)** obtained similar results to ours in Nigeria in the study conducted on *Pseudotolithus elongatus* (Bowdich, 1825)**.** This high fecundity also places this fish in the group of individuals with a reproductive strategy (r), which allows it to take advantage of food source any momentarily abundant sources in the lake (zooplankton boom) **(Sylla *et al.*, 2009).** This fecundity could be attributed to a number of factors including availability of food resources, sizes and age of specimens examined, season and specific environmental conditions noted the disparity in fecundity among populations of a given fish species as adaption to different environmental conditions that produce higher or lower survival opportunities for the species intense, fishing pressure, strong water acidity and other human perturbations **(Okun *et al.*, 2020).**

Gonadal development.

Information about gonadal development and the spawning season of a species plays a significant role in determining the spawning frequency of its population, which is critical for its management **(Hasan *et al.*, 2018; Adaba and Lilian, 2018).** During the year, the GSI of females and males show a sawtooth variation. In any case, the energy allocation attributed to the constitution of genitalia appears to be less important for males than for females. These results are consistent with those obtained by **Abekan *et al.* (2017)** on the study of *Auxis thazard* Lacepède, 1800 caught in the Gulf of Guinea by the Ivorian artisanal fleet. Two peaks are evident for the females, the first in April and the second in August. However, males show them in June and October. These variations in females are synchronized with the high hydrology related to the two peaks. Variation in spawning periods with regards to other studies may be due to regional variation as well as other environmental factors such as season fluctuation and flood change **(Hasan *et al.*, 2018).**

Spawning seasons.

The major spawning seasons of male and females observed from the current study was found to have occurred in the period for the high increase in zooplankton and phytoplankton. As a result, the increase in phytoplankton biomass may be viewed as one of the environmental drivers for an approaching favourable season for better growth and survival of fish. In males the first peak occurs during the June rainfall decrease, when the hydrological level is low. In addition, sexual maturity stages and oocyte diameters follow the same variations, especially since they are linked to the evolution of the GSI. The maturity scales characterize the different states presented by the ovaries and testes during their evolution corresponding to that of the GSI. Oocytes of different sizes corresponding to the different stages of development. Oviposition is probably performed throughout the year but with two more important peaks corresponding to the observed bimodal distribution. These results are consistent with those obtained by **Ezenwaji and Offiah (2003)** in the Anambra River in Nigeria. This situation is observed in the area near the Equator, where it rains almost all year round. **Mulimbwa *et al.* (2022)**, determined in their studies at Lake Tanganyika the breeding peaks for *Limnothrissa miodon* Boulanger, 1906 in the months of January, April and October. Whereas *Stolothrissa tanganicae*, also endemic to Lake Tanganyika, has a small peak in January and March and then another peak in June-July. These similarities and differences may be due to the physic-chemical variations of the waters (hydrology, transparency, temperature, and concentration of mineral salts), the level of production of plankton, the genetics of the species and the synchronization of the climate with the reproductive cycle of the fish species **(Koné *et al.*, 2016).**

Environmental conditions in February, March, April, September, October and November are dominated by strong winds that cause water mixing, bringing nutrients to the surface, allowing primary and then zooplanktonic production, probably favorable to Clupeidae larvae. Rainfall also brings additional nutrients from the watershed stream. They cause algal production which results in high biomass of zooplankton. Zooplankton is the main food of *N. stewarti*, and the larvae of Clupeidae feed on copepod nauplius. This abundance of zooplankton could contribute to the turnover of *N. stewarti* cohorts successively for several months during the year (**Encyclopedy of Limnology, 2010).** Our results show that the reproductive investment of *N. stewarti* was high during high water in February, March, April, May, August, September, October, November and December and synchronized with high rainfall and temperature periods that coincide at the same time with peak plankton abundance **Mulimbwa *et al.* (2022)**. The success of several cohorts of *N. stewarti* thus seems to be linked to higher temperature and rainfall causing the abundance of phytoplankton (diatoms) and zooplankton (cladocerans, copepods, rotifers) **Amin *et al.* (2016)**. Variables such as stage of maturity and oocyte diameters follow the same fluctuations and therefore produce the same effects **(Okon *et al.*, 2020).**

Maturity.

N. stewarti females from Lake Mai-Ndombe reach their first sexual maturity (L_{50}) at 25.5 mm (TL) while males reach it at 27.59 mm (TL). Average length of males where 28.8 ± 4.6 mm and females 32.4 ± 4.5 mm comparing these values with the length of the first capture in the present study, it appears that *N. stewarti* of Lake Mai-Ndombe black water reaches the size of first sexual maturation before its first capture. This particularity is linked to genetic factors of the species as well as to environmental and ecological factors: food, water conductivity, temperature, and predation. **Hasan *et al.* (2018)** stated that the maturity of a fish relies on its growth rate, and for this reason, a stunted fish will be sexually mature at a small size whereas a fast-growing fish will attain maturity at a much larger size. **Amin *et al.* (2016)** stated several environmental conditions might have changed and thus, affecting the sexual maturity of the fish. For the sustainability of the fish stock, **Isangedighi and Ambrose (2015)** demonstrated that larger fishes are bound to produce more eggs. To support the claim by **Isangedighi and Ambrose (2015)**, indicated that the fecundity of *N. stewarti* increased with fish length and weight. Based on this, the relatively small length at first maturity of the species (both male and female) in the current study may be viewed as a negative reproductive characteristic leading to the overfishing and decreasing of its stock fishes in Lake Mai-Ndombe. These elements push the species to develop an adaptation system to perpetuate its offspring. These results are similar to those of **Bouhali *et al.* (2015); Kolding *et al.* (2019), Mulimbwa *et al.* (2022)** on *Stolothrissa tanganicae* Regan 1917 and *Limnothrissa miodon* (Boulenger,1906), African clupeidae endemic to Lake Tanganyika. *Sierrathrissa leonensis* in Ghana and Nigeria reached its first maturity size at 24 mm. According to **Osei *et al.* (2020)** this early maturity could be justified by the capacity of the Bultot reproducers to adapt to environmental factors such as temperature, salinity and trophic resources as well as the internal conditions of the fish, its endocrine metabolism (pituitary and hypothalamus). It also contributes to promote the r strategy of *N. stewarti*, which, given its abundance and resilience to net seine fisheries, is perfectly efficient in Mai-Ndombe lake so a best management conditions should took place **(Al Jufaili, 2021).**

CONCLUSION

The aims of study was to determine reproductive biology from sex ratio, Gonado-Somatic Index (GSI), fertility, oocyte diameter and size of first sexual maturity in additional the relationship between total weight (WT) and total length of *N. stewarti* in Lake Mai-Ndombe at Democratic Republic of the Congo.

In the interest of preserving the species, information on the reproduction of *N. stewarti* in Lake Mai-Ndombe can be used to consider stock assessment models on the one hand and management decisions to plan the rational use and protection of fishery resources on the other. Determining the size at first sexual maturity and the periods of peak reproduction will allow fishermen to be advised on the types of gear and period of the year the species can be fished to avoid stock depletion, especially since the species is endemic. The size of first maturity (L_{50}) for males and females of *N. stewarti* was reached at 25.5 mm (Total length) and at 27.6 mm in males.

The political-administrative authorities of the province of Mai-Ndombe are called to adopt and apply a legislation which will have to govern the participation of the populations to observe the conservation of the aquatic resources of this ecosystem.

REFERENCES

Abekan, E.; N'guessan, DC.; Monin, AJ.; N'guessan, Y.; N'dri, AF.; Kouamé, A. and N'da Konan, JP. (2017). Variations saisonnières des paramètres de reproduction et relation taille-poids de *Auxis thazard* (Lacepède, 1800) capturé dans le Golfe De Guinée par La Flottille Artisanale Ivoirienne. European Scientific Journal edition 13(33): 1857–7881. https://doi:10.19044/esj.2017.v13n33p444

Adaba, T.I. and Lilian, C.N. (2018). Fish Assemblage of Amadi Creek, Port Harcourt, Rivers State Nigeria. American Scientific Research Journal for Engineering, Technology and Sciences 39 (1): 180–196. http://asrjetsjournal.org/

Al Jufaili, S.M. (2021). Decadal status of sardine fishery in Oman: Contribution of the Omani-Indian Oil sardine *Sardinella longiceps* Valenciennes, 1847 (Teleostei: Clupeidae). Iranian Journal of Ichthyology, *8*(4): 271–285.

Amin, A.; Madkour, F.; Abu El Regal, M. and Moustafa, A. (2016). Reproductive biology of *Mullus surmuletus* (Linnaeus, 1758) from the Egyptian Mediterranean Sea (Port Said). International Journal of Environmental Science and Engineering (IJESE) 7: 1–10.

Belesi Katula, K.H. (2016). Etude floristique, phytogeographique et phytosociologique de la vegetation du parc national de la Salonga (Bas-Kasai – RDC) (synthese). International Journal of Innovation and Applied Studies 14(3): 709–720. http://www.ijias.issr-journals.org/

Béné, C.; Steel, E.; Kambala, B.L. and Gordon, A. (2009). Fish as the ''bank in the water" – Evidence from chronic-poor communities in Congo. Food Policy 34: 108–118. https://doi:10.1016/j.foodpol.2008.07.001

Berchie, A.; Amponsah, S.K.K. and Nii, A. (2020). Commey Some aspects of the biology of West African Ilisha (*Ilisha africana*, Bloch 1795) from the coast of Ghana, West Africa. Egyptian Journal of Aquatic Biology and Fisheries 24(6): 1–14. www.ejabf.journals.ekb.eg

Bouhali, F.Z. ; Lechekhab, S.; Ladaimia, S.; Bedairia, A.; Amara, R. and Djebar , A.B. (2015). Reproduction et maturation des gonades de *Sardina pilchardus* dans le Golfe d'Annaba (Nord-Est algérien). Cybium 39(2): 143–153.

Bultot, F. And Griffits, J.F. (1971). The equatorial wet zone. In: Griffits JF (Ed) Climates of Africa, World Survey of Climatology. Elsevier Publishing Company, Amsterdam-London-New York 10: 451–456.

Dadébo, E.; Ahlgren, G. and Ahlgren, I. (2003). Aspects of reproductive biology of *Labeo horie* Heckel (Pisces: Cyprinidae) in Lake Chamo, Ethiopia. African Journal of Ecology 41: 31–38.

Dagnelie, P. 1973. Théorie et méthodes statistiques : application agronomiques. La statistique descriptive. Presses agronomiques de Gembloux, 378p.

Encyclopedy of Limnology (2010). Department of Limnology IBG, Uppsala University Sweden.

Ezenwaji, H.M.G. and Offiah, F.N. (2003). The biology of *Pellonula leonensis* Boulanger, 1916 in Anambra River, Nigeria. Bioresearch 1(2): 33–50. https://doi.10.4314/br.v1i2.28527

FAO (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in Action. Rome: Food and Agriculture Organization of the United Nations, 244 p. DOI: https://doi.org/10.4060/ca9229en

Froese, R. (2006). Cube law, condition factor and weight–length relationships: History, meta- analysis and recommendations. Journal of Applied Ichthyology 22(4): 241–253. https://doi.org/10.1111/j.1439- 0426.2006.00805.x

Froese, R. and Pauly, D (2022) FishBase. [Version 02/2022] http://www.fishbase.org

Hasan, T.; Hossain, M.D.; Mamun, M.; Alam, J.; Salam, M.A. and Rafiquzzaman, S.M. (2018). Reproductive Biology of *Puntius sophore* in Bangladesh. Fishes 3(2): 22.

Heins, D.C.; Baker, J.A. and Guill, J.M. (2004). Seasonal and interannual components of intra population variation in clutch size and egg size of a darter. Ecology of Freshwater Fish 13(4): 258-265. https://doi.org/10.1111/j.1600-0633.2004.00064.x

Isangedighi, I.A. and Ambrose, E.E. (2015). Aspects of the Reproductive Strategy of *Pseudotolithus elongatus* (Teleostei: Sciaenidae) in the Cross-River Estuary, Nigeria. Int. Journal of Multidisciplinary Research and Development 2(8): 593–595.

Keys, A.B. (1928). The weight–length relationship in fishes. Proceedings of the National Academy of Sciences of the United States of America 16(12): 922–925. https://doi.org/10.1073/pnas.14.12.922

Kolding, J.; van Zwieten, P.; Marttin, F. Funge Smith, S. and Poulain, F. (2019). Freshwater small pelagic fish and fisheries in major African lakes and reservoirs in relation to food security and nutrition. FAO, Fisheries and Aquaculture Technical Paper 642. 124 pp.

Koné, T.; Irène, K.F.K.; Sylvain, K.K. and Konan, N. (2016). Biologie de la reproduction du Sciaenidae *Pseudotolithus elongatus* dans la Lagune Ebrie (Cote d'Ivoire). European Scientific Journal ESJ 12(6): 327. https://doi.org/10.19044/esj.2016.v12n6p327

Luhusu, K.F. and Micha, J.C. (2013). Analyse des modes d'exploitation des ressources halieutiques du Lac Mai-Ndombe en République Démocratique du Congo. Geo-Eco-Trop 37(2): 273–284.

Micha, J.C.; Nabwenge, B.L.B.; Ibofa, R.; Mumba, F.; Mutambwe, S.; Zanga, N.; Willem, E. Svennsson, J.E. and Wilander, A. (2020). Une ressource surexploitée, *Nannothrissa stewarti*, sardine endémique du lac Maï-Ndombe (RD Congo), résultat inattendu du Programme national de Lutte contre le Paludisme. Academie Royale des Sciences d'Outre-Mer. Bulletin des Seances 64(1): 61–91. https://doi.:10.5281/zenodo.3980731

Mulimbwa, N.T.; Milec, L.J.M.; Raeymaekers, J.A.M.; Sarvala, J.; Plisnier, P.D.; Marwa, B. and Micha, J.C. (2022). Spatial and seasonal variation in reproductive indices of the clupeids *Limnothrissa miodon* and *Stolothrissa tanganicae* in the Congolese waters of northern Lake Tanganyika. Belgian Journal of Zoology. 152: 13–31 https://doi.org/10.26496/bjz.2022.96

Musschoot, T.; Boden, G. and Snoeks, J. (2021). Identification guide to the Clupeiformes of the inland waters of Africa. Royal Museum for Central Africa, Tervuren, Belgium. 150 pp.

Ni, S.; Duan, Z.; Lin, P., Wang, C. and Gao, X. (2022). Length–length and length–weight relationships of ten fish species in Yichang reach of middle Yangtze River below Gezhouba Dam, China. Journal of Applied Ichthyology 38(3): 375–378. https://doi.org/10.1111/ jai.14320

Okon, A.O.; Ekpo, I.E.; Okon, M.A. and Akpan, A.W. (2020). Some aspects of the life-history strategy of *Pellonula leonensis* (Boulenger, 1916) (Teleostei: Clupeidae) in Qua Iboe Estuary, Nigeria. South Asian Research Journal of Agriculture and Fisheries 2: 92–98. https://doi:10.36346/sarjbm.2020.v02i04.003

Olayinka, S.O.; Keke, M.M.; Kehinde, L.S. and Toba, A.A. (2018). Fish composition and diversity assessment of Apodu reservoir, Malete, Nigeria. International Journal of Fisheries and Aquatic Studies 6(2): 89–93.

Osei, I.K.; Blay. J. and Asare, N. (2020). An update of the reproductive biology of Sardinellas (Family: Clupeidae) in the coastal waters of Ghana. Journal of Fisheries Research 5(1):01–09.

Poll, M. and Roberts, T.R. (1976). *Nannothrissa stewarti*, espèce nouvelle de Clupeidae du lac Mai-Ndombe (Zaïre) (Pisces, Clupeidae). Revue Zoologique Africaine 90(1): 235–239.

Pwema K.V., Mbomba N.B., Gafuene G.N., BIPENDU M.,and Micha J-C., 2013. Comparison of reproductive biology of two species of Labeo: a rheophilic one, Labeo sorex and a limnophilic one, *Labeo lineatus* in the Malebo Pool (Congo River. Int. J. Biol. Chem. Sci. 7(4): 1657-1667.

Rekha, M.U.; Tomy, S.; Sukumaran, K.; Vidya, R.; Kailasam, M.; Balasubramanian,CP. and Vijayan, K.K. (2021) Comparison of the reproductive biology of two stocks of Indian continental *Mugil cephalus* with special reference to reproductive isolation and philopatry. Indian Journal of Geo-Marine Sciences 50(2): 130–140.

Sossoukpe, E.; Djidohokpin, G. and Fiogbe, E.D. (2016). **Demographic** parameters and exploitation rate of *Sardinella maderensis* (Pisces: Lowe 1838) in the nearshore waters of Benin (West Africa) and their implication for management and conservation. International Journal of Fisheries and Aquatic Studies 4(1): 165–171.

Sossoukpe, E.; Wilfrid, A.S.H. and Fiogbe, E.D. (2017). Growth, Mortality Parameters and exploitation rate of West African Ilisha (*Ilisha africana* Bloch, 1795, Clupeidae) off Benin coastal waters (West Africa): Implications for management and conservation. Open Journal of Marine Science 7(3): 327–342. https://doi.10.4236/ojms.2017.73024

Sylla, S.; Atsé, B.C. and Kouassi, N.J. (2009). Régime alimentaire de *Trachinotus teraia* (Carangidae) dans la lagune Ebrié (Cote d'Ivoire). Cybium 32(1): 81–87.

Whitehead, P.J.P. 1985. FAO Species Catalogue, vol. 7: Clupeoid Fishes of the World Suborder Clupeoidei). An Annotated and Illustrated Catalogue of the Herrings, Sardines, Pilchards, Sprats, Shads, Anchovies and Wolf-Herrings. Part 1. Chirocentridae, Clupeidae and *Pristigasteridae. Rome*. Rome: United Nations Development Programme/Food and Agriculture Organization of the United Nations. N°125. P 314.

Whitehead, P.J.P. and Wongratana, T. 1986. 'Clupeidae'. In M.M. Smith & P.C. Heemstra (eds), *Smiths' Sea Fishes*. Berlin: Springer-Verlag, pp. 199-204.

Zanga, N.; Wilander, A.; Inogwabini, B.I. and Bishop, K. (2019). Fishes of Lake Tumba (Democratic Republic of Congo): Evaluation of present status and comparisons with previous studies. Acta Ichthyologica et Piscatoria 49(4): 341–354. https://doi: 10.3750/AIEP/02611

Zanga, N.L.; Pwema, V.K.; Mbomba, N.B.; Mutambwe, S. and Micha, J.C. (2022). Diet study of *Nannothrissa stewarti* (Poll & Roberts, 1976) Clupeidae in Lake Mai-Ndombe, Democratic Republic of Congo. 16(6): 252-263 African Journal of Environmental Science and Technology. DOI: 10.5897/AJEST2022.3120

Zhang, A.; Zhu, J.; Lian, Q.; Sheng, P.; Guo, A.; Luo, W.; Zhou, Z. and Yuanj. (2022). Length–weight and length–length relations of 16 freshwater fish species (Actinopterygii) caught in Jiaxing section of the Beijing–Hangzhou Grand Canal, China. Acta Ichthyologica et Piscatoria 52(3): 179–182 | DOI 10.3897/aiep.52.86955