__Original Research Article__

Population dynamics and exploitation level of *Stolothrissa tanganicae* Regan, 1917 **and *Limnothrissa miodon* (Boulenger, 1906), two clupeid fish species of commercial interest of Burundian waters northeast of Lake Tanganyika.**

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ABSTRACT

Aims: Show exploitation level and propose rational management measures of the two clupeid-fish species of commercial interest, *Stolothrissa tanganicae* and *Limnothrissa miodon*

Study design: Modeling the demography of clupeid fishes of Lake Tanganyika.

Place and Duration of Study: Two stations (Kajaga and Nyamugari) situated in the northern part of Lake Tanganyika on the Burundian coast from December 2019 to April 2020.

Methodology: Monthly fish sampling was done withlocal fishermen Demographic parameters were determined according to the Von Bertalanffy growth model using size frequency distributions based on total length. Excel 2013 and FAO-ICLARM. Stock Assessment Tools (FiSAT II version 1.2.2 software.)

Results: The values of the growth parameters obtained for each of the two species are close at the level of the two stations. For *S. tanganicae*, we have L∞= 135 mm and 118 m and K=0.94 yr-1 and 0.99 yr-1 respectively at Kajaga and Nyamugari. For *L. miodon*, we have L∞= 148 mm and 132 m and K=1.04 yr-1 and 0.92 yr-1 respectively at Kajaga and Nyamugari. The Ø' values obtained are high and vary from 4.14 to 4.58 depending on the species and the stations: For *S. tanganicae*, higher Ø' was recorded at Kajaga (Ø'= 4.23). In *L. miodon*, it was observed at Nyamugari (Ø'=4.58). M oscillate around 1 (M varies from 1.08 to 1.17 year-1) for the two species at two stations. F is high everywhere and varies from 3.03 to 6.49 yr-1 depending on the species and the stations. Both species are overexploited : 0.73<E<0.86, so E is close to 1. Small-sized individuals dominate catches: minimum sizes are between 24 and 30 and 42 and 54 mm respectively in *L. miodon* and in *S. tanganicae*

Both the fish species adapt well to their environments (the values of Ø' are very high).

Conclusion: Both species of fish adapt well to their environments (the values of Ø' are very high). Given their overexploitation, the existing rational management measures must be strengthened and rigorously applied.

Keywords:*Stock management, commercial fishing*, *Lake Tanganyika*

1. INTRODUCTION

Lake Tanganyika is a large, deep lake located in East Africa, shared by four countries namely Burundi, Tanzania, the Democratic Republic of the Congo (DRC), and Zambia. It is the second-oldest and second-deepest lake in the world, with a maximum depth of 1,470 meters and an average depth of 570 meters. It is known for its unique biodiversity, freshwater source, and economic and cultural resource. Associated with a Latidae *Lates stappersii*, the production of the clupeids *S. tanganicae* and *L. miodon* are main fish species exploited by commercial fisheries on lake Tanganyika(Aro & Mannini, 1995; Coulter, 1991; Mannini, 1993; Mannini et al., 1996; Mulimbwa, 2006; Plisnier et al., 2018). They plays crucial economic and nutritional role for the riparian populations of Lake Tanganyika (Plisnier & Marijnissen, 2010).

Aside from the research conducted in the 1990s under the FAO's FINNIDA project, the majority of Lake Tanganyika-related studies have concentrated on biodiversity and its utilization, fish conservation, processing, packaging, and marketing, and the development of fishing statistics (Allison et al., 2000; Bellemans, 2012; Devos & Snoeks, 1994; Evert, 1980; Hanek, 1994; Ntakimazi, 1995; Patterson & Makin, 1998). It is challenging to develop a model for estimating stocks of populations of clupeids while little is known about the structure and dynamics of populations and, consequently, their demographic aspects (de Merona et al., 1988; de Pontual et al., 2002) with a commercial interest in Lake Tanganyika. The capture per unit effort was the lowest and the proportion of juvenile fish in catches was highest in the northern region of Lake Tanganyika some years ago (Aro & Mannini, 1995; Coenen, 1995; Mannini et al., 1996; Ntakimazi, 2013). We conducted the current study within this framework, allowing us to understand the current structure of the captures in this lake's region. This study aims to estimate the population dynamic parameters and stock status indicators for *L. miodon* and *S. tanganicae* in the northeastern part of Lake Tanganyika. The findings of this study provide knowledge that will aid in the management of Lake Tanganyika's fisheries.

2. MATERIAL AND METHODS

2.1. Study location

This research has been conducted in the northeastern part of Lake Tanganyika from the fishing landing beaches of Kajaga and Nyamugari (Figure1). Kajaga Beach is located far north of the lake, in the Mutimbuzi commune of Bujumbura province, not far from the mouth of the Rusizi River, not far from the border between Burundi and the DRC. Nyamugari beach is located just south of the city of Bujumbura, in the Kabezi commune of the same province.

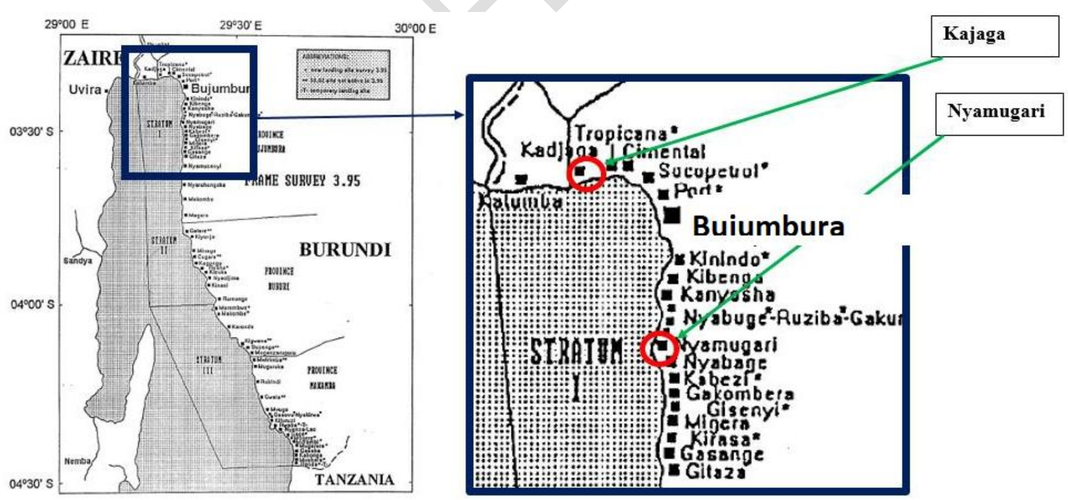


Figure 1: Location of Kajaga and Nyamugari beaches (adapted from Bambara, 1995

2.2. Sampling

Our model was the sampling process outlined by (Aro, 1993). The two clupeids were sampled from December 2019 to April 2020, focusing on artisanal fishing harvests. The samples were taken from the fishermen's unsorted catches. The total length (TL, mm) of every individual in the sample was measured using an ichthyometer.

2.2. Data treatment

The fish total length, which is most frequently used (Aprila et al., 2020; Boungou et al., 2020; López-Martínez et al., 2020; Niyonkuru et al., 2015; Pauly, 1985; Sparre & Venema, 1998), was used to study the following parameters: size frequency, growth parameters, mortality, and recruitment pattern. Data processing was carried out using FiSAT II, the FAO software (Gayanilo et al., 2005).

2.2.1. Growth parameters

The study of growth was made using the model of Von Bertalanffy (1957) cited by Niyonkuru (2007) which is the most used in studies of fish growth and which made it possible to describe in a satisfactory manner the growth of many species of fish (Sparre et al., 1989).This model shows the relationship between the growth parameters and expresses the total length (Lt) of the fish as a function of its age t, according to the following expression:Lt= L∞(1- exp-K (t-t0)) where: Lt = total fish length; L∞= asymptotic length (average length that a fish would reach that could live and grow indefinitely); K = growth coefficient, indicating the speed at which the curve approaches the asymptote; t0 is the age for which Lt =0 (i.e. the abscissa of the point of intersection of the curve with the age axis).In the present work, the K and L∞ parameters were estimated using the ELEFAN I (Electronic Length Frequency Analysis) program incorporated in the FISAT (FAO-ICLARM. Stock Assessment Tools) II software (Gayanilo et al., 2005). Indeed, L∞ corresponds to a size that the fish cannot really reach; the theoretical age, to, corresponding to a zero length which does not really exist since growth begins when the fish hatches. These parameters are only used for a better adjustment of the curve (Morize, pers. comm.). FiSAT has a subroutine allowing to associate the fixed values of L∞ to ranges of valuesof K (K-scan procedure). The retained value corresponding to the highest normalized adjustment value Rn. Rn=10ESP/ASP/10. A preliminary estimate of L∞ was obtained by the method of Wetherall (1986).

The Growth index Ø' is used to compare the growth performance of the species of fish studied and takes into account the parameters L∞ (or W∞) and K has been defined. It is given by the equation of Munro & Pauly (1983) cited by Niyonkuru (2007): Φ'= log K + 2log L∞. According to these authors, the value of Ø' is between 0.3 and 3.2. It makes it possible to test the reliability of the sampling carried out. The FiSAT software makes it possible to quickly calculate this index when we have the growth parameters L∞ and K.

2.2.2. Mortality parameters and exploitation rate

Growth parameters (L∞, K) obtained, were used to analyze catch curves converted to length to obtain estimates of total mortality (Z) (Pauly, 1983). Natural mortality (M) was estimated using the empirical formula of Pauly (1980) cited by Niyonkuru (2007): log M = 0.0066 log K + 0.279 log LT + 0.4634 log T where T is the environmental temperature annual average (°C), it is about 25°C in the Lake Tanganyika region. The fishing mortality rate, F, was calculated as Z-M: F=Z-M. The exploitation rate (E) is defined by the ratio of fishing mortality to total mortality: E = F/Z. It is between 0 and 1. When the exploitation rate is less than 0.5, the stock is underexploited. On the other hand, when it is greater than 0.5; the stock is overexploited. Yield is optimal when total mortality equals fishing mortality (Gulland, 1971) cited by (Niyonkuru, 2007)

2.2.3. Potential longevity, t_{max}

It was calculated by the formula: tmax ≈ 3/K (Taylor, 1962; Pauly, 1980 cited by Niyonkuru (2007)). For populations with low longevity, the M/K ratio is often very high (more than 2). In such a case, the yield per recruit has a maximum for a high value of E (= F/Z) (greater than 0.5) usually linked to a value of F itself very high.

2.2.4. Recruitment pattern

It is the process by which the young are first integrated into the adult stock and therefore become accessible to fishermen. The normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy 1985 cited by Niyonkuru (2007)) in FiSAT II.

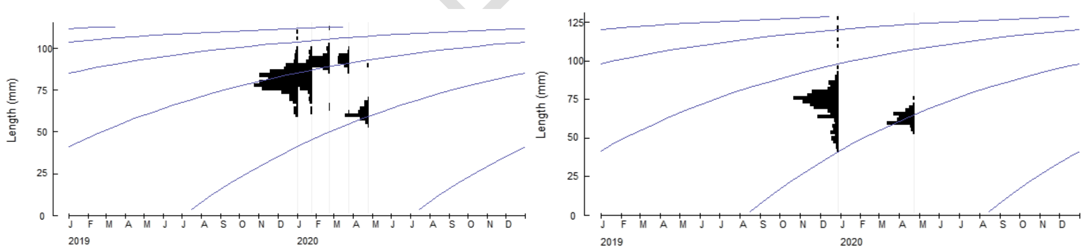
3. RESULTS AND DISCUSSION

3.1. Growth parameters

The synthesis of growth parameters of *S. tanganicae* and *L. miodon* is presented in Table 1 and the von Bertalanffy growth curves are presented in Figures 2 and 3. Values retained correspond to the highest normalized adjustment value (Rn). In *S. tanganicae*, values of Lt $_{max}$ obs, L∞(mm), Ø' and T_{max} are higher in Kajaga station than in Nyamugari station. K-values are very close for the two stations: K=0.99 year-1 and K= 0.94 year-1 for the Nyamugari and Kajaga stations respectively. In *L. miodon*, the same observation is made for values of Lt max obs, L∞(mm) and K which are higher in the Kajaga station than in the Nyamugari station. Ø'-values and T_{max} are higher at Kajaga in *S. tanganicae* whereas they are at Nyamugari in L. miodon. Those different values show that values of various parameters cannot be generalized over Lake Tanganyika as a whole. The average values on several sites could then be considered for the same species.

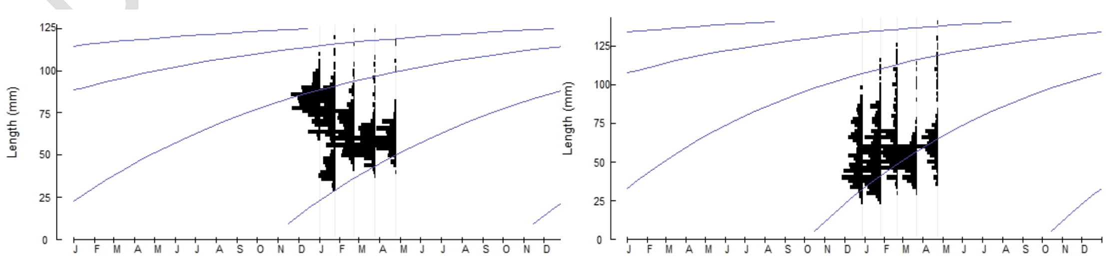
Table 1: *Synthesis of the growth parameters obtained for S. tanganicae and L. miodon in the two study stations*

	S. tanganicae		***L. miodon***	
Parameters	**Nyamugari beach**	**Kajaga beach**	**Nyamugari beach**	**Kajaga beach**
Lt max obs. (mm)	112	128	124	140
L∞(mm)	118	138	132	148
K (year^{-1})	0.99	0.94	0,92	1.04
Ø'	4.14	4.23	4.58	4.36
Rn	0.155	0.158	0,128	0,12
T max (years)	3.03	3.19	3.26	2.88



(a) (b)

***Figure 2**: Von Bertallanffy growth curves for S. tanganicae: (a) Nyamugari Beach and (b) Kajaga Beach*



(a) (b)

***Figure 3**: Von Bertallanffy growth curves for L.miodon: (a) Nyamugari Beach and (b) Kajaga Beach*

In *L. miodon*, L∞ obtained in the present study is lower than that estimated by Aro & Mannini (1995) in the years 1993-1994. It was 176 mm, 175 mm, 178 mm respectively in Bujumbura, Kipili and Mpulungu and 179 mm in Uvira by Mulimbwa (2006). These low L∞ values may be attributable to fishing pressure (see F and E values later in other sections). The K-values obtained in this study are close to those of previous studies : K = 0.86/year, 1.16/year and 0.84/year respectively in Bujumbura, Kipili and Mpulungu respectively) (Aro & Mannini, 1995). Ø'-values are close to those obtained previously in Bujumbura, Kipili and Mpulungu, i.e. Ø' = 4.43, 4.55 and 4.42 respectively (Aro & Mannini, 1995). Unlike *L. miodon*, L∞ of *S. tanganyicae* obtained is higher than that obtained in previous studies by Aro & Mannini (1995), i.e. K=110 mm in Uvira and Mpulungu, 114 mm in Bujumbura, 111 mm in Karonda and 100mm in Kigoma. K obtained is lower than that found by Aro & Mannini (1995). The latter found values of K>2/year. Ø'-values obtained in the present study are very high and also close to those found by Aro & Mannini (1995), i.e. Ø' = 4.44; 4.37 and 4.27 respectively in Bujumbura, Karonda, 4.27 and Kigoma.

3.2. Mortality parameters and exploitation rate

Instantaneous mortality rates M, Z, F; exploitation rate, E as well as the M/K and Z/K ratios are shown in Table 2. Instantaneous mortality rates M for the two species are very close at the two stations and oscillate around 1. For the two species, we have M/K<2, which means that the two fish species have a high longevity (Beverton & Holt (1966) cited by Niyonkuru (2007). The Z/K>1 ratio for both species (varying from 4.02 to 6.6 depending on the species and the stations indicates that in the latter, mortality dominates growth (Beverton & Holt (1966) cited by Niyonkuru(2007). Fishing mortality values are very high and vary from 3.03 to 6.49 depending on species and stations. Consequently, exploitation rate E is very high: we have 0.73≤E≤0.86 depending on species and stations: E>0.5, meaning both species are overexploited E in *S. tanganicae* is greater than E in *L. miodon*.

Table 2: Mortality parameters and exploitation level in *S. tanganicae* and *L. miodon* in the two stations

	S. tanganicae		***L. miodon***	
Parameters	Nyamugari beach	Kajaga beach	Nyamugari beach	Kajaga beach
M ($year^{-1}$)	1.17	1.09	1.08	1.13
Z ($year^{-1}$)	6.57	7.58	4.11	4.18
F ($year^{-1}$	5.40	6.49	3.03	3.05
E	0.82	0.86	0.74	0.73
M/K	1.19	1.16	1,18	1.1
Z/K	6.64	8.1	4.46	4.02

Unfortunately, the use of prohibited fishing gear and techniques such as mosquito nets, fine mesh nets, strike fishing, etc.; continues to be practiced despite the constraining measures aimed at their use. Thus, in *S. tanganicae,* the minimum lengths observed during the present study are 42 mm and that of 54 mm in Kajaga and Nyamugari respectively.The most frequent size is 76 mm in Kajaga and 84 mm in Nyamugari. The most strongly captured individuals are found in the 60 to 66 mm length bands. In 1993, Aro and Mannini (1995) had observed a minimum size varying from 20 to 29mm in Bujumbura, it was 30 mm in 2011 in

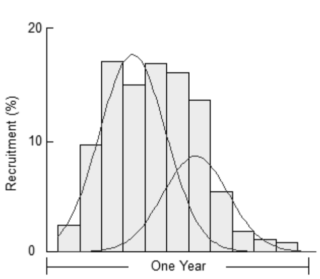
Uvira (Mulimbwa, 2006) and 40 mm in 2013 in Kajaga (Ntakimazi, 2013). A minimum size observed in 1994-1995 in Uvira varied from 24 to 29 mm, against the maximum length varying from 105 to 110mm (Mulimbwa, 2006). In *L. miodon*, the minimum length observed at Kajaga is 24 mm and 30 mm at Nyamugari. The most frequent size is 54 mm at Kajaga and 56 mm at Nyamugari By combining the samples from the two sites, we see that the greatest frequency is between 34 and 90 mm in size. It was between 40 and 99 in 1993 (Aro & Mannini, 1995) and between 56 and 96 mm in Kajaga in 2013 (Ntakimazi, 2013). Faced with this overexploitation, the Government of Burundi has implemented, for several years, measures to close and open Lake Tanganyika for a period of 2 weeks for each of these two periods. This period of closure of the lake was introduced to allow the various poisons in the advanced sexual maturity period to reproduce.

3.3. Potential longevity, t_{max}

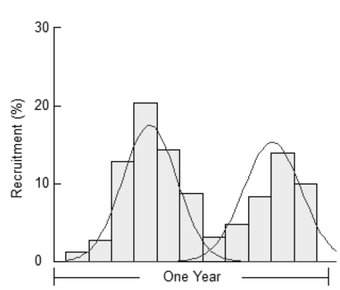
The potential longevity of the two species of clupeids oscillates around 3 years, either 3.03 and 3.19 years in *S. tanganicae* respectively in Nyamugari and Kajaga; 3.26 and 2.88 years in *L. miodon* respectively in Nyamugari and Kajaga. As mentioned above, we have M/K<2 for both species of fish, this means that these species have a high longevity according to Beverton & Holt (1966) cited by Niyonkuru (2007)

3.4. Recruitment pattern

Recruitment curves obtained at the two sites and for the two species are shown in Figures 4 and 5. Analysis of these figures shows continuous recruitment for the two species with one or two peaks depending on the species and the environment. Thus in *S. tanganicae*, we observed, at Kajaga station, 2 peaks with a large peak between April and May (corresponding to the long rainy season) and a small peak between October and November corresponding to the short rainy season. In all other cases, there is a single peak. In *S. Tanganicae* from the Nyamugari station, continuous recruitment is observed with the maximum between March and August: months of March to May corresponding to the rainy season and months of June to August corresponding to the dry season. In *L. miodon*, there is a peak from June to August, corresponding to the great dry season at the Nyamugari station) and a peak from July to September corresponding to the great rainy season (July and August) and the beginning of the short season dry (September). The results that recruitment period takes place during dry season are the same as those found by Mannini et al. (1996); Mulimbwa & Shirakihara (1994) in the same species. Knowledge of these recruitment periods is of great importance in the management of halieutic resources because they make it possible to organize fishing periods allowing rational exploitation of fish stocks.

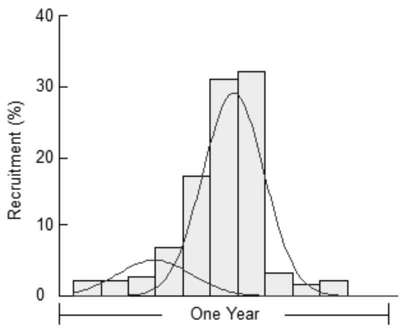


(a)



(b)

Figure 4: Illustration of recruitment curves and their peaks in chez *S. tanganicae* at at Nyamugari (a) and Kajaga (b) beaches



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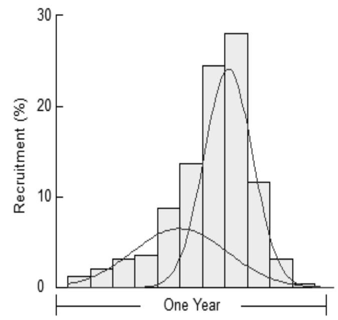

(b)

Figure 5: Illustration of recruitment curves and their peaks in *L. miodon* at at Nyamugari (a) and Kajaga (b) beaches

4. CONCLUSION

This study revealed that in the study area, fish species studied are overexploited. Fishing mortalities are high and predominate over natural mortalities. Measures aimed at rational exploitation should be reinforced by alternative solutions as income-generating activities for fishermen and fishmongers who live daily from this lake. There is a sub-regional organization, the Lake Tanganyika Authority, encompassing countries bordering the lake. This authority should adopt and apply common effective measures for the management of the Lake.

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