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Research Article

Population parameters and exploitation rate of two dominant fish species in Tovè River (Southern Benin)

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ABSTRACT

Most fisheries in Africa are overexploited or are at the peak of exploitation. A key contributor to this over fishing is poor data on fisheries, inefficient management strategies and unenforced policies. This study deals with growth, mortality parameters and the exploitation rate of *Synodontis schall* and *Shilbe intermedius* collected with a range of several fishing gears between October 2015 and September 2016 from Tovè River in Benin to contribute to sustainable management of these fisheries. The von Bertalanffy growth constants for *S. schall* were $TL\infty = 21.84$ cm, $K = 0.93$ yr^{-1}, and $t_0 = -0.49$ yr with a derived growth performance index of $\varphi' = 2.64$. The corresponding estimates for *S. intermedius* were $TL\infty = 25.20$ cm, $K = 0.52$ yr^{-1}, $t_0 = -0.52$yr and $\varphi' = 2.51$. The total mortality rate, Z, for *S. schall* was estimated as 4.13 yr^{-1}, with the fishing mortality, F, being calculated as 2.31 yr^{-1}. The mortality estimates for *S. intermedius* were $Z = 1.28$ yr^{-1} and $F = 0.08$ yr^{-1}. The size at first capture was estimated at 5.35 cm and 7.20 cm for *S. schall* and *S. intermedius*, respectively. The current exploitation rates for *S. schall* (0.55) and *S. intermedius* (0.06) suggest that only the stocks of *S. schall* was slightly above the assumed optimum value (Eopt = 0.5). Rational measures must be taken to effectively manage for exploitation of these 2 stocks particularly the one of *S. schall*.

INTRODUCTION

Benin water resources are free or open-access resources and have been regarded as unlimited resources that people could exploit without care. This has led to increased exploitation of fish stocks by local people using more sophisticated fishing gears and methods, in turn leading to unsustainable harvesting of some stocks (Hounkpè 1996).

In many aquatic ecosystems in Benin, large-bodied fish have become very scarce in the fisheries (Lalèyè *et al.*, 1997). However, few studies have quantified population traits of targeted fish species. In the mean-time in that study they noted that no information is available on the population parameters some aquatic resource in Tovè River which is an affluent of the Ouémé River, the largest river in the region (Benin). This River is located in the lower valley of the Ouémé which is today considered as the second richest valley in the world after the Nile in Egypt. It was chosen as the area of current study considering its importance to the waterside population in terms of fishery and agricultural zones. Nevertheless, the species in Tovè River are usually harvested by local people using gillnets and represents a high-value food source.

Indeed, population parameters such as asymptotic length $L\infty$ and growth coefficient k, mortality (natural and fishing) rate and exploitation level E were studied with the major objective of rational management and resource conservation (Nasser, 1999; Abohweyere and Falaye, 2008; Sossoukpè *et al.*, 2013). Data on age and growth are especially important to describe the status of a population of fish and to predict the potential output of fishing (Sossoukpè *et al.*, 2016). These two parameters facilitate the evaluation of production, size of stock, recruitment and mortalities (Lowe-McConnel, 1987). Various methods have been developed for assessing the exploitation level and stock status. Among these, the ELEFAN routine implemented in the FiSAT software has been most frequently used for

estimating population parameters of finfish and shellfish, primarily because it requires only length-frequency data (Al-Barwani *et al.*, 2007; Amin *et al.*, 2008). The FiSAT method has been widely applied in growth studies, especially in tropical and subtropical countries (Ye *et al.*, 2003).

The present work is the first attempt to investigate growth rates, mortality coefficients and the exploitation rate of the main fish species in the Tovè River using monthly length frequency analyses. The species considered in this study were sampled from the Tovè ichthyofauna inventory from October 2015 to September 2016 (Djidohokpin *et al.*, 2017a). Sampled fishes were identified at species level, weighted to the nearest 0,01g and the standard and total lengths were measured to the nearest 0.1 cm. During the ichthyofaunal inventory, two fish species, *Synodontis schall* (Mochokidae) and *Shilbe intermedius* (Schilbeidae) were identified as the main species of this fishery.

The present study aims to quantify series of population traits for the two dominant species, *S. schall* and *S. intermedius*, of this ichthyofauna including: size at first capture, growth, mortality rates and exploitation, which are essential tools in the management of exploited fish stocks.

MATERIALS AND METHODS

Study area

The Tovè River is located in the Southern Benin (04°42'47" N, 07°45'2" W). Benin country is located in West Africa at 6°15' and 12°25' North latitude and 0°45' and 04°00' East longitude. It is bounded at the North by Niger and Burkina Faso, at the East by Nigeria, at the West by Togo and South by the Atlantic Ocean. Its surface area is estimated at 114 763 km^2 (along 700 Km about 125 km wide and 325 km South to North).

With an approximately length of 1 km, with an average width of 3 m, the Tovè River is located in the Ouémé Division, specifically in the Adjohoun Sub Division at about 32 Km from Porto-Novo (Capital of Benin Republic). The Sub-Division is limited at the South by the Dangbo Sub Division, at the North by the Bonou Sub-Division, at the East by the Sakété Sub-Division and at the West by the Abomey-Calavi and Zè Sub-Divisions. This river rises in the swamp of Tovè at Tovègbamè and flows into the Ouémé River, the largest river of Benin. In order to have exhaustive ichtyofauna inventory of this ecosystem, and its spatial distribution in this river, the river was divided into three main areas A, B and C respectively upstream, middle stream and downstream of the river (Fig. 1)

Fish sampling and data collection

Fishes were collected monthly from October 2015 to September 2016. Fishing was undertaken daily and by night. During the daily fishing sampling, artisanal and experimental fishery techniques were used such as gillnets (mesh size between 10 mm and 100 mm node to node); hoops designed in creels wire mesh; or with local materials, with or without bait, hook in troubled waters with simple and composed lines (long lines); dam nets, enclosure acadjas and bamboo traps. For by night fishing, gears are posed at 5 pm and withdrawn by 7am of the next day. The fish caught are preserved safely in a container with ice and transported to the laboratory where they are identified up to species level and sorted by fishing gear and by areas of investigations. Identification was made using morphometric and meristic characters provided by fish identification keys of Lévêque *et al*. (1990-1992), (FAO, 1992) and Paugy *et al.* (2003a, 2003b). *Synodontis schall* (Bloch and Schneider, 1801) and *Shilbe intermedius* (Rüppell, 1832) were identified as the most abundant fish species in catches in terms of numbers.

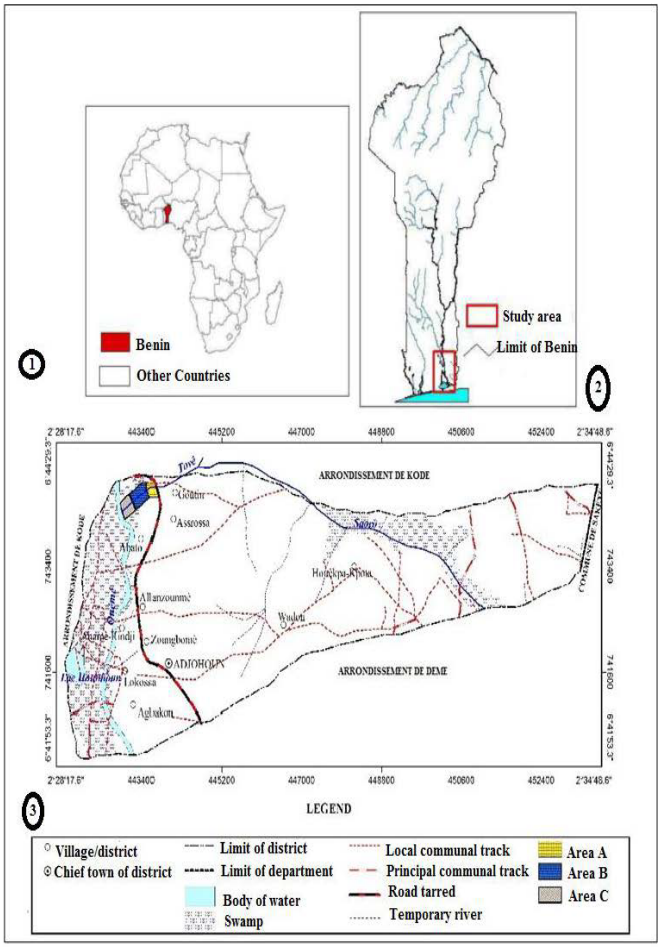

Fig. 1: Study Area of Tovè River (3) located in Southern of Benin (2), Country situated in West Africa (1)

To perform population parameters for these two major species, each specimen was measured to the nearest 0.1 cm for total length with a measuring-tape and weighed to the nearest 0.01 g using an electronic precision balance. The mean lengths and weights of the classes were used for data analysis using the format accepted by FiSAT (Gayanilo and Pauly, 1997).

Assessment of growth parameters from length frequency data

The ELEFAN routine in FiSAT II was applied to estimate the growth parameters (L∞) and (k), assuming that the body growth followed the von Bertalanffy growth equation (Gayanilo *et al.*, 2002). The growth model has the formula:

$$L(t) = L\infty[- \exp(-K(t- t_0))]$$

where L(t) is the length at age t, L∞is the asymptotic length, k is a growth coefficient, and t_0 corresponds to the theoretical age at which the fish length is zero.

The ELEFAN routine fits the growth curve that passes through a maximum number of peaks in the length frequency distribution (Pauly, 1984). An index of goodness of fit, (Rn), was determined by automatic computer (Gayanilo *et al.*, 2002). In order to compare the growth rates in this study with those of other authors, the standard growth index (φ') was used as a measure of overall growth performance (Pauly and Munro, 1984). The index is defined as:

$$\varphi' = \text{Log10 } (K) + 2\text{Log10 } (L\infty)$$

Longevity was calculated from Pauly's (1984) equation:

$t_{max} = 3 / K$

The theoretical age at length zero (t_0) was estimated using Pauly's (1979) empirical equation:

$$\text{Log10 } (-t_0) = -0.392 - 0.275 \text{ Log10 } (L\infty) - 1.038 \text{ Log10 } (K)$$

Assessment of the instantaneous mortality coefficients and related parameters

Once the growth parameters of the von Bertalanffy growth equation were obtained, total mortality Z was estimated by the length converted catch curve method as implemented in ELEFAN. The linearized length-converted catch curve (Pauly, 1984) was constructed using the formula:

$$\text{Ln } (Ni / \Delta t_i) = a + b\, t_i$$

where Ni is the number of individuals in length class i, Δt is the time needed for the fish to grow through length class i, t is the relative age (computed with $t_0 = 0$) corresponding to the midlength of class i. The slope (b) of the curve with its sign changed gives Z.

The regression lines were extrapolated to approximate the probability of capture given natural mortality (M). FiSAT II provides an option to estimate this value using the empirical equation of Pauly (1980) as following:

$$\text{Log}_{10} (M) = -0.0066 - 0.279 \text{ Log}_{10}(L\infty) + 0.6543 \text{ Log}_{10} (K) + 0.463 \text{ Log}_{10} (T),$$

$SD_{(Log\ M)} = 0.245$

where (T) is the annual mean of habitat temperature (in degrees Celsius). The indicated value is equal here to 27°C (Djidohokpin *et al.*, 2017b). This method of estimating M is widely used throughout the tropics where time series of reliable catch and effort data and several years of Z values are not available (Pauly, 1980). Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained using this formula $E = F / Z$. The exploitation rate indicates whether the stock is slightly ($E < 0.5$) or strongly ($E > 0.5$) exploited, based on the assumption that fish stock is optimally exploited when $F = M$ or $E = 0.5$ (Gulland, 1971).

The estimates of length-at-first-capture (Lc or L_{50}) were derived from probabilities of capture generated from the catch curve analysis. The extrapolated points of the length-converted catch curve were used to approximate the probability of capture for each length group using the running average method to estimate the selection parameter L_{50} through linear interpolation.

Recruitment patterns

Recruitment patterns were generated from the estimated growth parameters by backward projection of length frequency data, as done in ELEFAN, onto the time axis (Moreau and Cuende, 1991). This type of back-calculation usually allows identification of the number of seasonal pulses of recruitment that have been generated by the represented population in the length frequency data (Gayanilo *et al*., 2002).

RESULTS AND DISCUSSION

Growth parameters

A summary of the parameters that describe growth in length (K, L∞, t_0), derived growth performance index (φ') and longevity (t_{max}) is provided in Table 1. The maximum estimate of asymptotic length L∞ was observed for *Schilbe intermedius* (25.20 cm), and the minimum within the Mochokidae for *Synodontis schall* (21.84 cm). The values for K estimated for the fishes ranged from 0.52/year for *S. intermedius* to 0.93/year for *S. schall*. The growth estimates as shown in Table 1, indicates that the value of t_0 was given as -0.49 for *S. schall* and -0.61 for *S. intermedius*, and the growth performance index (φ') was 2.64 for *S. schall* and 2.51 for *S. intermedius*. For these estimates, through ELEFAN the goodness of fit (Rn) varied from 0.10, as shown with *Schilbe intermedius*, to 0.41 for *Synodontis schall*. Figure 2 showed the growth curves generated from ELEFAN for the 2 fish species during the course of this study.

Table. 1: Growth parameters of for *Synodontis schall* and *Schilbe intermeduis* sampled in the Tovè River from October 2015 to September 2016 in comparison to populations of these species in other Benin localities

		Parameters						
Species	**Locality**	**TL∞(cm)**	**K(y^{-1})**	**to(y^{-1})**	**Tmax (y^{-1})**	**Rn**	**φ'**	**References**
Synodontis schall	Tovè River (Benin)	21.84	0.93	-0.49	3.22	0.41	2.64	Present study
	Pendjari River (Benin)	35.00	0.71	-0.52	4.23	0.56	2.93	Montcho (2011)
	Ouémé River (Benin)	32.00	0.32	-0.50	9.00	0.21	2.52	Chikou (2006)
Schilbe intermedius	Tovè River (Benin)	25.20	0.52	-0.61	5.76	0.10	2.51	Present study
	Lake Nokoue (Benin)	26.00	0.70				2.67	Niyonkuru *et al.* (2003)
	Pendjari River (Benin)	35.00	0.50	-0.60	6.00	0.58	2.78	Montcho (2011)
	Ouémé River (Benin)	24.68	0.30	-0.43	10.00	0.12	2.52	Chikou (2006)

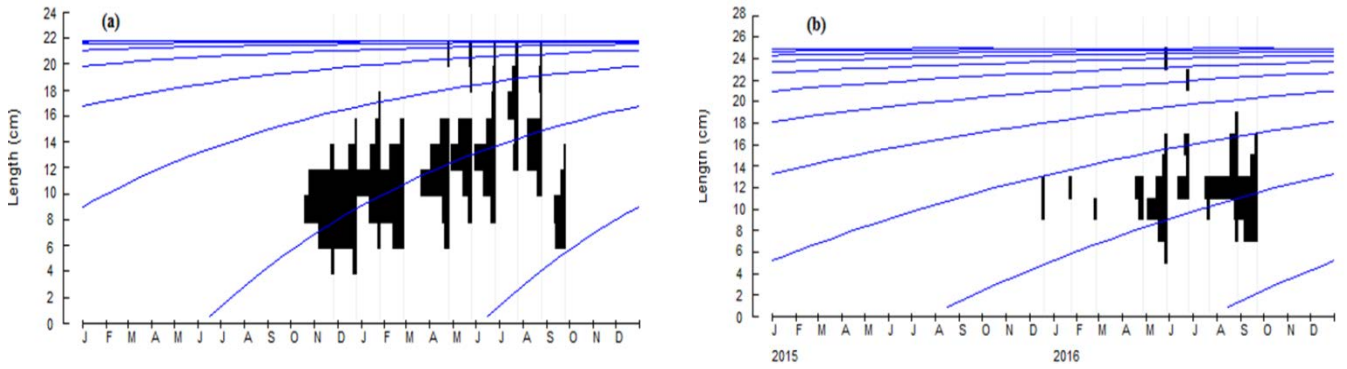

Fig. 2. Length frequency data superimposed on the growth curve of *Synodontis schall* (a) and *Schilbe intermedius* (b) sampled in the Tovè River from October 2015 to September 2016

Instantaneous mortality coefficients and exploitation rates

The length converted catch curves are presented in Fig. 3. Instantaneous mortality rates Z, M and F and exploitation rate E are given in Table 2.

Table. 2: Estimates of mortalities and related parameters obtained for *Synodontis schall* and *Schilbe intermedius* sampled in the Tovè River from October 2015 to September 2016 in comparison to populations of these species in other Benin localities

		Parameters							
Species	**Locality**	Z (y^{-1})	M (y^{-1})	F (y^{-1})	E	L_{25} (cm)	Lc (cm)	L_{75} (cm)	**References**
Synodontis schall	Tovè River (Benin)	4.13	1.82	2.31	0.55	3.32	5.35	7.27	Present study
	Pendjari River (Benin)	2.72	1.27	1.45	0.53	13.2	15.00	16.80	Montcho (2011)
	Ouémé River (Benin)	2.01	0.83	1.18	0.59		2.43	3.76	Chikou (2006)
Schilbe intermedius	Tovè River (Benin)	1.28	1.20	0.08	0.06	5.35	7.20	9.10	Present study
	Ouémé River (Benin)	2.56	0.86	1.70	0.66		5.50	7.01	Chikou (2006)
	Pendjari River (Benin)	1.67	1.01	0.66	0.40	20.20	22.6	24.9	Montcho (2011)

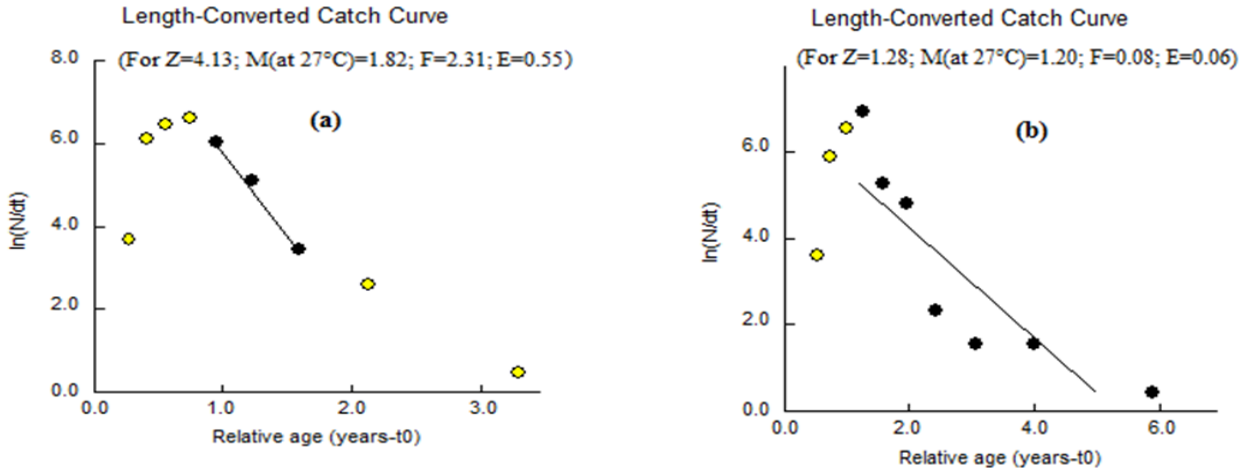

Fig. 3. Length-converted catch curve for *Synodontis schall* (a) and *Schilbe intermedius* (b) sampled in the Tovè River from October 2015 to September 2016

Total mortality was estimated to be 4.13 y^{-1} for *Synodontis schall* and 1.28 y^{-1} for *Schilbe intermedius* in Tovè River. Most individual mortality was due to natural mortality M, estimated as 1.82 and 1.20 y^{-1}, for *Synodontis schall* and *Schilbe intermedius*, respectively. Fishing mortality F was low in *Schilbe intermedius* (0.08 y^{-1}), but higher for *Synodontis schall* (2.31 y^{-1}) (Fig.3a, b)

The exploitation rate E was 0.55 for *Synodontis schall* and 0.06 for *Schilbe intermedius* in Tovè River. Only the E value of *Synodontis schall*, was slightly above the assumed optimum value (Eopt = 0.5).

In Tovè River, the curve of relative yield per recruit Y'/R relative to the exploitation ratio E, indicated an optimal exploitation rate (E_{max}) of 0.439 for *Synodontis schall*, a rate relatively similar to the E_{max} estimated for *Schilbe*

intermedius (0.421) (Fig.4a, b). The exploitation rate $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is 10% of its entire stock) and $E_{0.5}$ (exploitation rate under which the entire stock is halved) were estimated at 0.369 and 0.286, respectively, for *Synodontis schall*, and 0.355 and 0.278 for *Schilbe intermedius*.

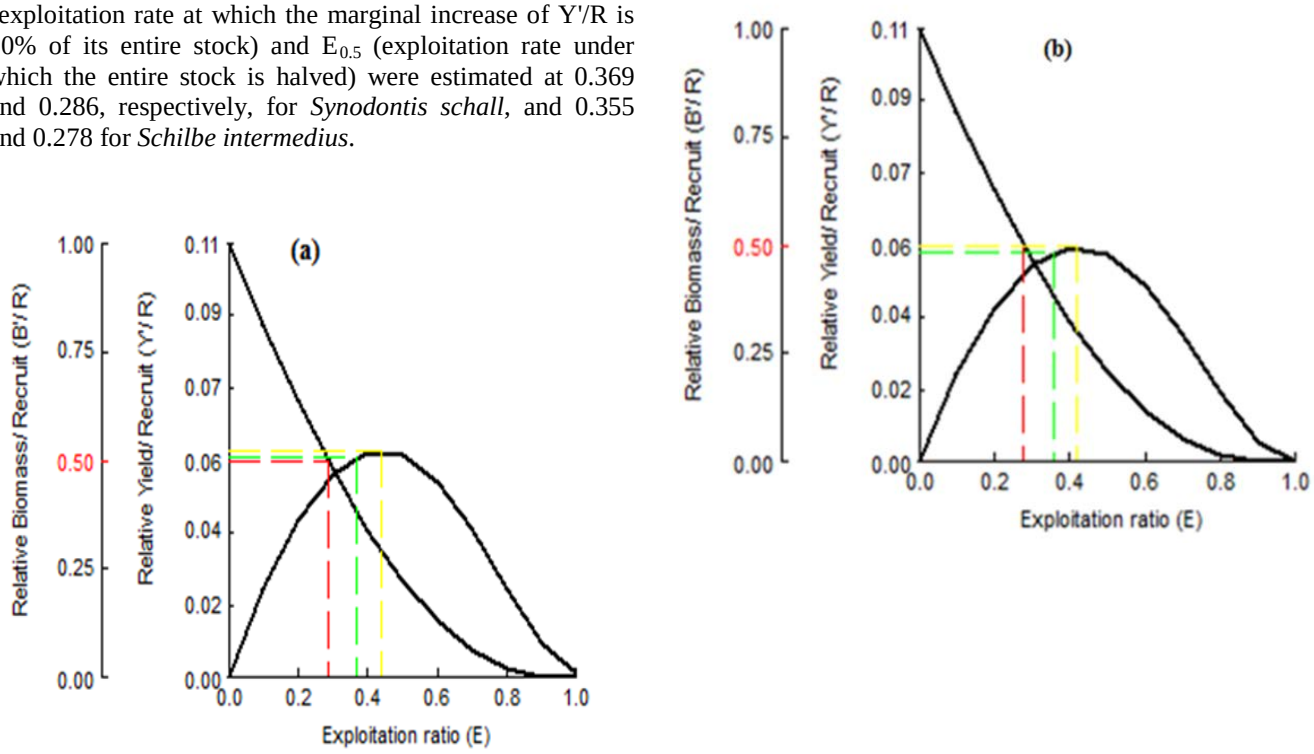

Fig. 4. Relative yield-per-recruit and biomass-per-recruit curves for *Synodontis schall* (a) and *Schilbe intermedius* (b) sampled in the Tovè River from October 2015 to September 2016 using the selection ogive option. The three dashed right-angled lines correspond to $E_{0.5}$, $E_{0.1}$ and E_{max}, respectively

Lengths at first capture and recruitment patterns

For the current study, the logistic selection model showed that the estimated length Lc of 50% of all the fish caught by the gear in *Synodontis schall* was 5.35 cm, while it was 7.20 cm for *Schilbe intermedius* (Fig. 5a, b). Similarly, the model found that 25% and 75% of all the fish of *Synodontis schall* had an estimated length of 3.35 cm and 7.25 cm, respectively, while 25% and 75% of the total caught in *Schilbe intermedius* had an estimated length of 5.35 cm and 9.10 cm respectively.

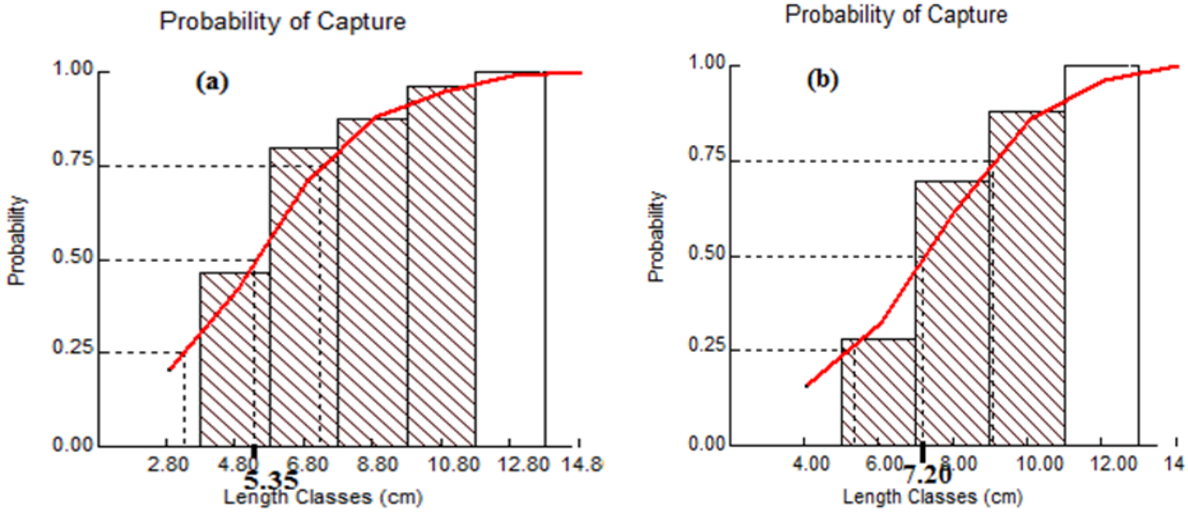

Fig. 5. Probability of capture of *Synodontis schall* (a) and *Schilbe intermedius* (b) sampled in the Tovè River from October 2015 to September 2016 estimated from the ascending axis of the catch curve

Recruitment patterns of *Synodontis schall* and *Schilbe intermedius* in Tovè River were not similar (Figs. 6a, b), with a notable bimodal distribution indicating two distinct spawning events (April-May and July-August) for *Schilbe intermedius* and a single distribution where the main recruitment occurred between July-August for *Synodontis schall*.

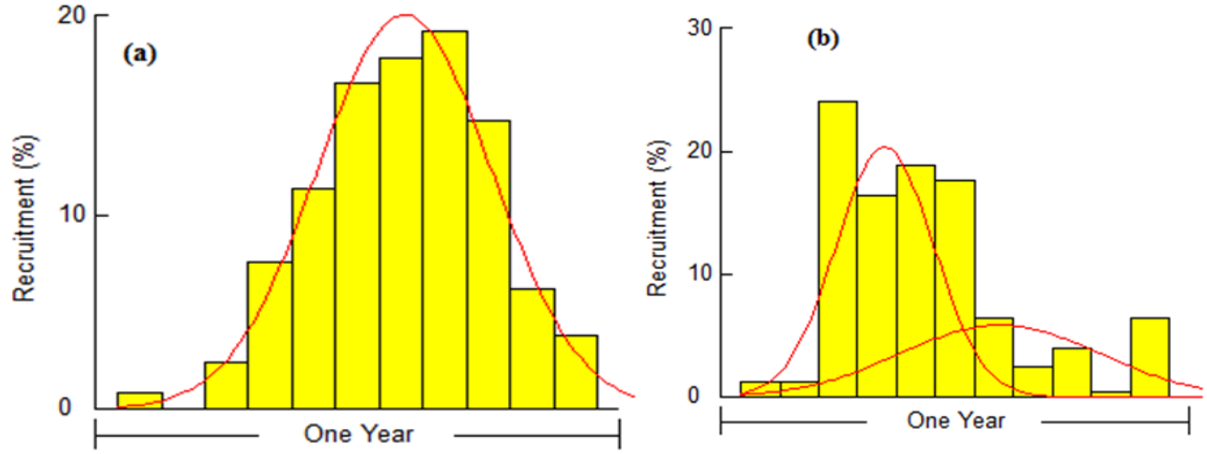

Fig. 6. Recruitment pattern of *Synodontis schall* (a) and *Schilbe intermedius* (b) sampled in the Tovè River from October 2015 to September 2016

DISCUSSION

The estimates for von Bertalanffy growth parameters ($L\infty$, K and t_0) for *Synodontis schall* and *Schilbe intermedius* in Tovè River seem realistic, as $L\infty$ was reasonably close to the maximum length observed in the samples (Niyonkuru *et al.*, 2003; Chikou, 2006 and Montcho, 2011), t_0 was smaller than zero, and K varied between 0 and 1 per year, as expected for fish species with a long life span (Pauly, 1978). The few differences between the values would be due to the fishing pressure. According to Welcomme (1999), the strong tendency of fish length to decrease as fishing pressure increases means that length-linked changes occur in several demographic parameters.

The growth performance indexes φ' calculated in the present study, 2.64 and 2.51 for *Synodontis schall* and *Schilbe intermedius* respectively, fall within the range of those reported in the literature. It is also notable that the growth parameters were quite similar between the two species. Baijot and Moreau (1997) estimated that the φ' mean value for some important fishes in Africa have a range of 2.65 - 3.32, which they considered as low. This slow growth rate may be induced by changes in the physical and chemical characteristics of the water (Ofori *et al.*, 2002). While analyzing between them the values of the two species studied in this study, our results confirm the assertion of Montcho (2011) according to the increase of the $L\infty$ values leading t_0 a decrease in the value of K. Total mortality, natural mortality and fishing mortality were higher in *Synodontis schall* than in *Schilbe intermedius*. For the two species, natural mortality due to predation, shortage of food, diseases, pollution, spawning stress and senility (King and Etim, 2004) was much higher in *Schilbe intermedius* than fishing mortality. This trend was also observed by Montcho (2011) in other Benin water bodies (Pendjari River). This antagonism between the M and F values in both species justifies the obtained E values (0.55 and 0.06 for *Synodontis schall* and *Schilbe intermedius*, respectively), which indicate that only *Synodontis schall* is slightly overexploited when compared to the optimum value E = 0.5). The over exploitation could impact recruitment if individuals are captured while laying eggs (Sossoukpè *et al.*, 2013). Indeed, in the Tovè River, *Synodontis schall* is more vulnerable to fishing, i.e. fishing gear than *Schilbe intermedius* (e.g. the number of *Synodontis schall* (N = 501) caught in the present study in order to achieving our objectives far exceeds that of *Schilbe intermedius* (N = 206).

A second indication that only the stocks for *Synodontis schall* are overexploited was obtained by comparing the size at first capture, *L*c, i.e. the length at which 50% of the fish measuring that size are vulnerable to capture, with L_{50}. Size at first capture was estimated at 5.35 cm in *Synodontis schall* and 7.20 cm in *Schilbe intermedius.*

According to Aripin and Showers (2000), the exploitation level is already high for virtually all of small sized species like *S. schall*. This situation is also described by Froese (2004) as recruitment overfishing; other fishes are caught before they can realize their full potential.

The mainly short-lived (3.22 years) of *Synodontis schall* estimated by longevity (t_{max}) would be owing to her over exploited. The apparent underexploitation of the populations of *Schilbe intermedius* could easily switch to overexploitation in the future if sensitization sessions advocating sustainable fishing methods are not organized.

Recruitment has been described as a year-round phenomenon for tropical fish and shrimp species (Qasim, 1973; Weber, 1976). The major fish populations studied here exhibited two recruitment peaks, which conforms with Pauly's (1982) assertion of a double recruitment pulse per year for tropical fish species and for short lived species. The major peak of recruitment for studied species was in the months of the year, which coincides with the rainy season in the South Benin. This was reported by many authors who have investigated the spawning periods for tropical fish populations in Africa (Lowe-McConnell, 1975; Welcomme and De Merona, 1988).

The results reported in this study represent a preliminary demographics parameters data analysis of fish species in Tovè River. However, other aspects such as finding habit and reproduction strategy could be investigated to enrich or extend data base of management and conservation of the fish species of the Tovè River.

CONCLUSION

The current study of the population status of *S. schall* and *S. intermedius*, based on the samples collected from

artisanal catches in Tovè River shows that only *S. schall* is optimally exploited by the current fishing regime. However, the higher fishing mortality in Tovè River may reflect the increasing use of scoop nets. Therefore it could be recommend the development of a monitoring program to detect shifts in the exploitation rates, indices of overexploitation and changes in life-history traits that may reflect harvest-induced change.

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