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Original Article

Demographic parameters and exploitation rate of five key fishes of Okpara Stream, Oueme River, Benin, West Africa

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Abstract: The current study was carried out on Okpara Stream in Northern Benin to evaluate the demographic factors with inferences on fisheries status of five dominant fish species, which were sampled monthly intervals for 18 months. Asymptotic length ($L\infty$) ranged from 36.23 cm (*Brycinus macrolepidotus*) to 18.8 cm (*Hemichromis fasciatus*). Growth rates (K) varied between 1.6 yr^{-1} and 0.66 yr^{-1} with growth performance index (Φ') ranging from 2.4 to 3.1. Theoretical age at length zero (t_0) varied -0.95 year for *Marcusenius senegalensis* to -0.59 year for *Shilbe intermedius*. Except for *B. macolepidotus*, total mortalities were higher than 2 $year^{-1}$ and length at first capture (L_{50}) ranged 7.72-12.09 cm. *Marcusenius senegalensis* and *S. intermedius* showed one annual peak of recruitment, whereas *H. fasciatus*, *Oreochromis niloticus* and *B. macrolepidotus* displayed two peaks. The results indicated that the stocks of these five species were underexploited. However, the low length at first capture (L_{50}) recorded for some species, requires the implementation of early fisheries management scheme to assure a sustainable exploitation of these fishes.

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Introduction

In most regions of the world, fishing is one of the foremost activity for human subsistence because of generating substantial incomes for grassroots (Ekouala, 2013). As reported by FAO (2018), in year 2016, global world fish production reached 171 million metric tons that was estimated at about 362 billion US dollars. In Benin, fisheries appeared to be a key component of rural activities and the fishery's sector contributed substantially to the national economy. Indeed, total production of inland and marine fisheries reached 42400 tons estimated at about 42,400,000,000 FCFA or 80,761,904 USD (FAO, 2019). Moreover, the increase of the African population in general and that of Benin in particular, has led to a high fishing pressure and to the overexploitation of inland and marine fish resources (Welcomme, 2001). Thus, in addition to the drastic decrease of the fish production in most water bodies, exploitable stocks were dominated by small-sized individuals (Dulvy et al., 2003; Mullon et al., 2005; Chikou, 2006; FAO, 2010; Sossoukpe et al., 2013). Therefore, a rational management scheme of the fish stocks is needed to assure the conservation and the sustainable exploitation of the fish resources. In fish population stock, estimating parameters such as asymptotic length (L_∞), growth coefficient (K), fishing/natural mortalities (F/M) and exploitation rate (E), are means of conservation and management (Abohwere and Falaye, 2008; Tah et al., 2010). These fish stock management tools are powerful instruments for development policies and decision making in fisheries sector. Data on age and growth are particularly important for describing the status of a fish population and for predicting the potential yield of the fishery. They also facilitate estimation of production, stock size, recruitment and mortality (Lowe-McConnel, 1987).

Though several aspects of the fish population dynamic and community structure have been

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investigated in many aquatic ecosystems in Benin, little is known about the demographic parameters and exploitation rate of marine and inland fish species. Such studies have been restricted to few species such as *Galeoides decadactylus, Sardinela madarensis* and *Chloroscombrus chrysurus* from the marine environment (Sossoukpe et al., 2016a, b; 2017), *Sarotherodon melanotheron* from Lac toho (Lederoun et al., 2015), *S. galileus* from Lac Doukon et Lac Togbadji (Lederoun et al., 2016) and *Tilapia guineensis, Hemichromis fasciatus, Eleotris vittata, Clarias gariepinus, Chrysichthys auratus, Hepsetus odoe, Parachanna obscura* and *Heterotis niloticus* from Sô River (Hazoume, 2017).

Okpara Stream is the main tributary of the Oueme River, and in spite of its fisheries importance and degradation pressures, little is known about the demographic parameters and exploitation rates of its fish stocks. As reported by Sidi Imorou et al. (2019a), Okpara Stream dwelled 53 species belonging to 29 genera and 14 families. Dominant species are *Hemichromis fasciatus* (29.49%), *Marcusenius senegalensis* (16.43%), *Shilbe intermedius* (10.44%), *Oreochromis niloticus* (8.90%) and *Brycinus macrolepidotus* (9.23%) aggregating numerically 74.49% of the fish community total relative abundance (Sidi Imorou et al., 2019b). These species display a high commercial, economic and nutritional importance for the grassroots. Therefore, the current study aims to investigate growth rates, mortality coefficients and exploitation rates of the five key fish species, namely *H. fasciatus*, *M. senegalensis*, *S. intermedius*, *O. niloticus* and *B. macrolepidotus* of Okpara Stream to gather fisheries documentation that will contribute to ensure successful management of these fishes.

Materials and Methods

Study area: This study was carried out on Okpara Stream, a tributary of Oueme River (200 Km), located between 8°14'-9°45'N and 2°35'-3°25'E. This riverine water belongs to the Northern hydrographic system and traverses the Borgou Province of Northern Benin and that of Zou in Central Benin. Annual ambient

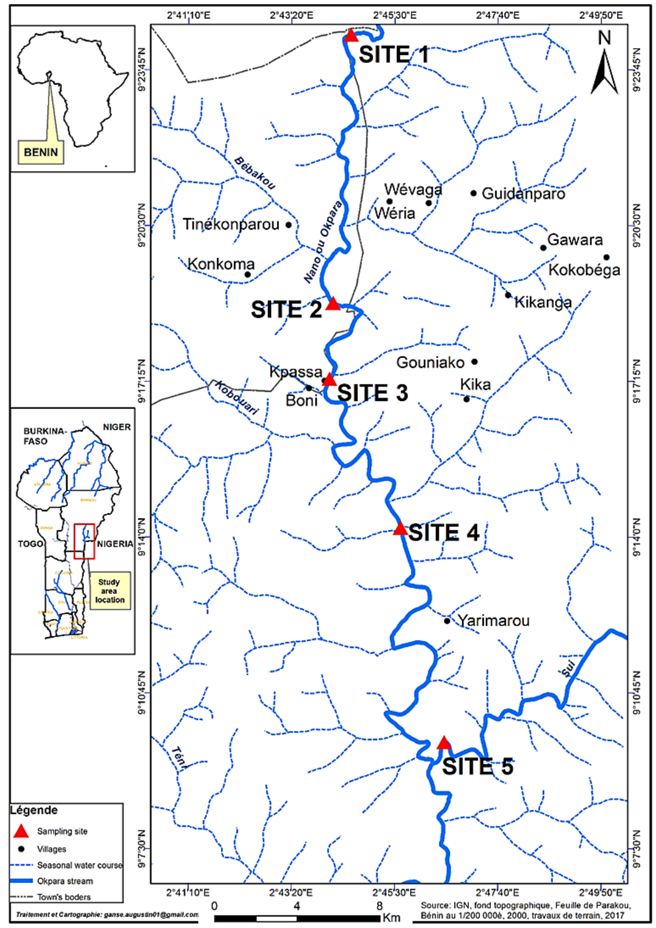


Figure 1. Location of Okpara's stream and sampling sites. Site 1= Perere Township, Site 2 = Gadela village (Parakou Township), Site 3= Kpassa village (Tchaourou Township), Site 4= Yarimarou village (Tchaourou Township), and Site 5 = Sui village (Tchaourou Township).

temperature around the stream averaged 26.6°C and the low temperatures were recorded in December and January. The climate is tropical and comprised two seasons: the dry season in November to April and wet season in May to October. The annual pluviometry averaged 1200 mm, peaked at about 1300 mm in July, August and September. The soil is covered by a wooded savanna characterized by the presence of *Parkia biglobosa*, *Khaya senegalensis* and *Vitellaria paradoxa*. Also, the plant community comprised marshy meadows, bamboo and fallow bushes. The Okpara stream is the main source of fish resources for the grassroots and provides water for irrigated agriculture. In addition, a dam was built on the stream to supply the surrounding populations with drinking water.

Sampling sites: Five sampling sites were selected (Fig.

1) based on localities, accessibility, fisheries importance and level of site degradations (Sidi Imorou et al., 2019a). Site 1 is situated in Perere town at Okpara up stream and site 2 is located in Parakou town at Gadela village (Okpara up stream) about 2 km from SONEB dam. Site 3 is located at Kpassa village where a dam was built to serve as a source of drinking water for the populations of Tchaourou and Parakou towns and surrounding villages. Site 4 is situated around Okpara downstream at Yarimarou village (Tchaourou town) where the dam withdraws its water. Site 5 is also located around Okpara downstream at Sui village of Tchaourou. At these five sites, samplings were done in the "aquatic vegetation habitat" at the edge of the stream and in the "open water habitat" exempt of vegetation and characterized by a high depth.

Fish collection and identification: Fish samplings were done for 18 months by monthly intervals in all habitats at the five sampling sites with experimental gillnet and seine (Sidi Imorou et al., 2019a, b). In addition, fish samplings were directly made in fishermen artisanal captures by taking one third of each fisherman catches. All rare and uncommon species were included in the sample (Okpeicha, 2011). Fishing gears such as gillnets, seines, cast nets, hooks, and traps were used by the fishermen to collect the fishes. After collection, the fish samples were first identified *in situ* using fish identification references such as Van Thielen et al. (1987), Skelton (1993), and Lévêque and Paugy (2006). The fish assemblages were preserved in a cooler and then transported to the Laboratory of Ecology and Management of Aquatic Ecosystem to confirm the identifications. The valid scientific names of the fish species have been confirmed on Fishbase (Froese and Pauly, 2018). In the laboratory, length of each specimens was measured to the nearest 1 mm with a measuring board, weighted to the nearest 1 g with an electronic scale (Camry) and preserved in 10% formalin and latter in 70% ethanol to make easier other biological observations such stomach content analysis and aspects of reproductive biology (Schreck and Moyle, 1990; Murphy and Willis, 1996).

Data analysis: Basic parameters are length-weight relationship (LWR), age-based growth, mortality (Z), exploitation rate (E), and condition factor (K) (Ricker, 1975). Length data were combined monthly and converted into length frequencies with a constant class interval of 2 cm. The mean lengths and weights of classes were used for data analysis using accepted FiSAT's format (Gayanilo and Pauly, 1997).

Growth parameters (L_∞, K and t_0) and growth performance index (φ'): Growth parameters are important to determine the stock state. The model of von Bertalanffy (1938) of ELEFAN I program in FiSAT II is the most used in studies of fish's growth:

$$TL = L\infty\{1 - \exp[-K(t - t_0)]\} \text{ (King, 1995)}$$

Where, TL (cm) is the total length of the fish, L_∞ (cm) = asymptotic length of fish, $L\infty$ = maximum length that a fish could reach if it lived many years, K (yr^{-1}) = growth coefficient, and t_0 (yr) = theoretical age of the fish individual when its length is zero. T_0 is determined by the following Pauly's equation:

$$\log_{10}(-t_0) = -0.392 - 0.275 \operatorname{Log}_{10}L\infty - 1.038 \operatorname{Log}_{10}K \text{ (Pauly, 1979).}$$

Where t_0 (yr) is the age of the fish at various lengths and calculated by the inverse of von Bertalanffy growth equation. K and $L\infty$ estimates were used to determine the growth performance index (φ') of the species (Munro and Pauly, 1983; Pauly and Munro, 1984) according to the formula:

$$\varphi' = \operatorname{Log}10K + 2\operatorname{Log}10\ L\infty$$

Where φ' is growth performance index. This index is an indicator of fish's well-being.

Mortality parameters: The instantaneous annual rate of total mortality (Z) was evaluated by the construction of linearized curve of length converted into catch (Sparre and Venema, 1992). Instantaneous natural mortality rates (M) were determined by Pauly's (1980) empirical equation:

$$\operatorname{Log}_{10}M = -0.0066 - 0.279 \operatorname{Log}_{10}L\infty + 0.6543 \operatorname{Log}_{10}K + 0.463 \operatorname{Log}_{10}T$$

With T = annual temperature of Okpara stream waters. The fishing mortality (F) rate was determined by the formula:

$$F = Z - M$$

Probability of capture (L_{50}), longevity (T_{max}) and epxloitation rate (E): Estimates of length at first

Table 1. Growth parameters of von Bertalanffy function output by FiSAT of exploited fishes in Okpara Stream (Oueme River, North-Benin) in comparison to populations from other African waters.

Species	Locality	Country	L_∞ (cm)	K (yr^{-1})	t_0 (yr)	φ'	References
B. macrolepidotus	Okpara stream	Benin	36.23	0.73	-0.68	2.98	Current study
	Lake Ayame I	Cote d'Ivoire	32	0.46	-	2.67	Tah et al. (2010)
H. fasciatus	Okpara stream	Benin	18.8	0.88	-0.67	2.40	Current study
	Lake Nokoue	Benin	16.75	1	-	2.45	Niyonkuru (2007)
	So stream	Benin	18.38	0.96	-0.48	2.51	Hazoume (2018)
	Lake Ayame I	Cote d'Ivoire	27	0.57	-	2.62	Tah et al. (2010)
	Ebrie	Cote d'Ivoire	25	0.85	-	-	Villanueva (2004)
M. senegalensis	Okpara stream	Benin	18.90	1.6	-0.95	2.76	Current study
O. niloticus	Okpara stream	Benin	35.18	1.2	-0.90	3.1	Current study
	Lake Ayame I	Cote d'Ivoire	35.5	0.48	-	2.78	Tah et al. (2010)
	Lake Victoria	Kenya	61.3	0.35	-	-	Getabu (1992)
	Tanguiga Reservoir	Burkina Faso	17.6	0.46	-	2.15	Bajot and Moreau (1997)
S. intermedius	Okpara stream	Benin	25.2	0.66	-0.59	2.62	Current study
	Lake Nokoue	Benin	26	0.7	-	2.67	Niyonkuru (2007)

Table 2. Longevity, mortality and exploitation rate of the five key fishes of Okpara Stream (Oueme River, North-Benin).

Species	T_{max} (yr)	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E	Z/K	L_{50} (cm)	L_{50}/L_∞
B. macrolepidotus	4.11	1.79	1.39	0.4	0.22	2.45	7.90	0.22
H. fasciatus	3.41	3.45	1.95	1.50	0.44	3.92	8.78	0.47
M. senegalensis	1.88	3.65	2.786	0.86	0.24	2.28	10.54	0.56
O. niloticus	2.50	2.30	1.941	0.36	0.16	1.92	7.72	0.22
S. intermedius	4.55	2.13	1.441	0.69	0.32	3.23	12.09	0.48

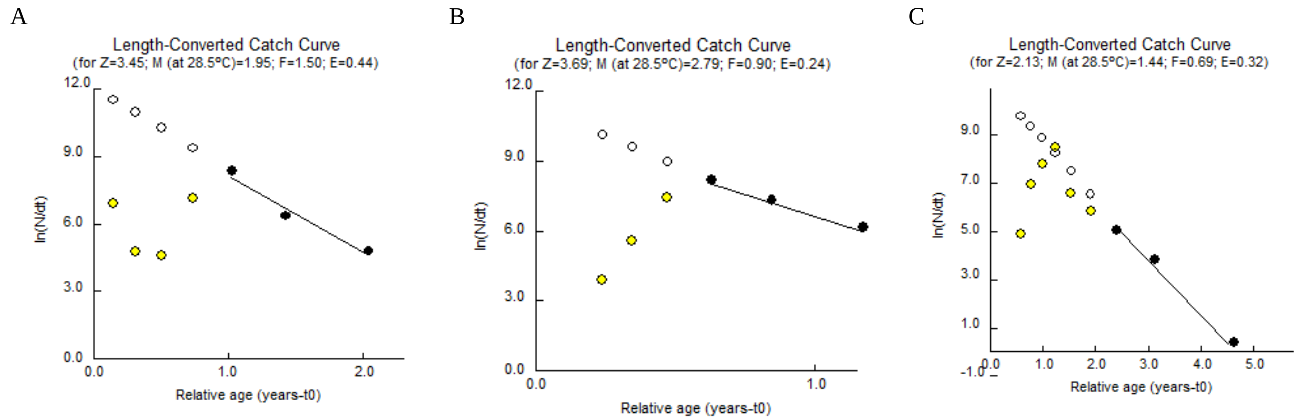
T_{max} = Longevity, Z= total mortality, M=natural mortality, F=fishing mortality, E=exploitation rates, L_{50}=Length at first capture, K=growth coefficient, L_∞= asymptotic length.

capture (L_{50}) were derived from capture probabilities generated by FiSAT's capture curve analysis. The estimate of the average growth coefficient K was used to generate longevity as follows: $T_{max} = 3/K$ (Anato, 1999). The exploitation rate (E) was calculated by FiSAT from the linearized curve of length converted to capture curve of each species: E = F/Z, with F = fishing mortality and Z = annual total mortality. This value gives a rough estimate of whether the stock is overexploited or not (Pauly, 1983). When E>0.5, the stock is overexploited. When E is approximately equal to 0.5, the yield is optimized and F is approximately equal to M (Gulland, 1971).

Results

Growth parameters: Growth parameters are shown in Table 1. The asymptotic length, L∞ ranged 18.8 (*H. fasciatus*) to 36.23 cm (*B. macrolepidotus*). The values of growth rates (K) varied between 0.66 yr^{-1} for *S. intermedius* and 1.6 yr^{-1} for *M. senegalensis*. Growth performance index (φ') ranged 2.4 for *H. fasciatus* and 3.1 for *O. niloticus*. The theoretical age at length zero (t_0) varied -0.95 (*M. senegalensis*) to -0.59 year (*S. intermedius*).

Longevity, instantaneous mortality and exploitation rates: The length converted catch curves (Fig. 2) generated the value of total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate that are presented in Table 2. For most species (4/5), Z were higher than 2 $year^{-1}$ excepted for *B. macolepidotus* (1.79 yr^{-1}) and the higher value of Z is 3.65 yr^{-1} for *M. senegalensis*. The natural mortality ranged from 2.786 (*M. senegalensis*) to 1.441 yr^{-1} (*S. intermedius*), and the fishing mortality (F) ranged 1.50 yr^{-1} for *H. fasciatus* and 0.36 yr^{-1} for *O. niloticus*. The exploitation rates ranged 0.44 for *H. fasciatus* to 0.16 for *O. niloticus*. These rates were weak compared to the optimum (E = 0.5) when fishing mortality is equal to natural mortality (F = M) (Pauly and Munro, 1984). The values of longevity were relatively high



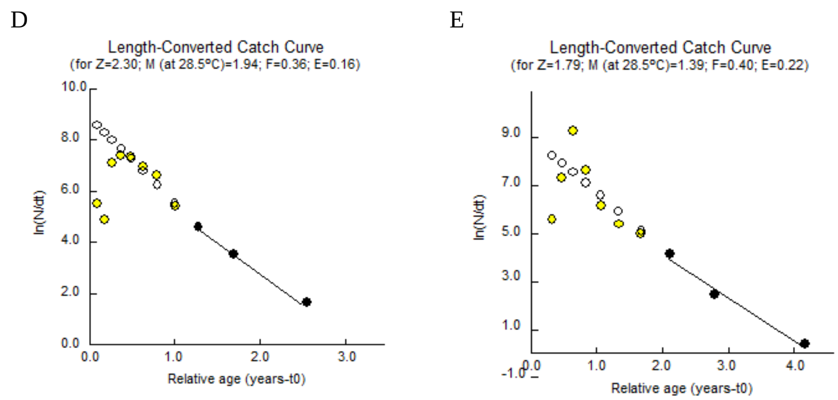


Figure 2. Length converted catch curves of dominant fishes of Okpara Stream (Oueme River, North-Benin): A = *Hemichromis fasciatus*; B =*Marcusenisius senegalensis*; C = *Schilbe intermedius*; D = *Oreochromis niloticus*; E = *Brycinus*

and the highest was found for *S. intermedius* (Tmax = 4.55 year) and the lowest value was found for *M. senegalensis* (T_{max} = 1.88 year). The ratio between Z and K was superior to 1 for the five species and ranged from 1.92 (*O. niloticus*) to 3.92 (*H. fasciatus*) (Table 2). With regards to the ratio between L_{50} and L_∞, the lowest value was recorded for *B. macrolepidotus* and *O. niloticus* (L_{50}/L_∞ = 0.22) and the highest value was recorded for *M. senegalensis* (L_{50}/L_∞ = 0.56) (Table 2).

Length at first capture and recruitment: The length at first capture (L_{50}) is the estimate length of fishes at 50% probability of capture (Fig. 3). In this study, the highest L_{50} was recorded for *S. intermedius* (12.09 cm) and the lowest one for *O. niloticus* (7.72 cm) (Table 2). The recruitment structure (Fig. 4) of fishes showed one annual peak of recruitment for *M. senegalensis* and *S. intermedius*. Species like *H. fasciatus*, *O. niloticus* and *B. macrolepidotus* showed two peaks of recruitment in a year (Fig. 4).

Discussions

The asymptotic length (L_∞ = 18.8 cm) value recorded for *H. fasciatus*, the dominant species, agreed with that reported by Hazoume (2017) in the Sô River (18.38 cm) in Benin. However, these values of L_∞ were lower than those reported by Villanueva (2004) in Ebrie Lagoon (25 cm) and by Tah et al. (2010) in Lake Ayame I (27 cm) in Ivory Coast. Also, the value recorded for *O. niloticus* (35.18 cm) in this study agreed with that reported by Tah et al. (2010) in Lake Ayame I (35.5 cm) of Ivory Coast. In contrast, *O. niloticus* showed higher L_∞ = 64.6 cm in Lake Victoria in Kenya (Getabu, 1992) while *S. intermedius* exhibited an asymptotic length (25.2 cm) nearly identical to that reported by Niyonkuru (2007) in Lake Nokoue (26 cm) in Benin.

In this study, the growth rates (K) between 1.6 and 0.66 yr^{-1} recorded for these key species were higher than those reported by Tah et al. (2010) in Lake Ayame, by Villanueva (2004) in Ebrie Lagoon, by Getabu (1992) in Lake Victoria and by Bajot and Moreau (1997) in Tanguiga Reservoir of Burkina Faso. Nevertheless, in the current study, *H. fasciatus* displayed a lower growth rate (0.88) compared to those of Lake Nokoue (1.0) and Sô River (0.96). This

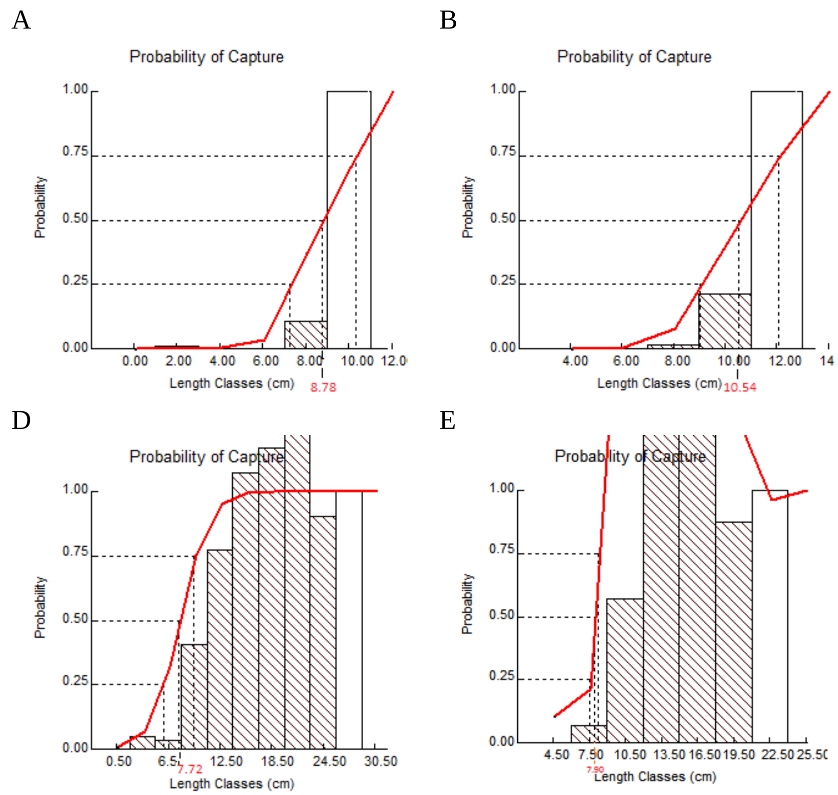


Figure 3. Probability of capture and length of first capture of fishes in Okpara stream (Oueme River, North-Benin): A = *Hemichromis fasciatus*; B =*Marcusenisius senegalensis*; C = *Schilbe intermedius*; D = *Oreochromis niloticus*; E = *Brycinus*

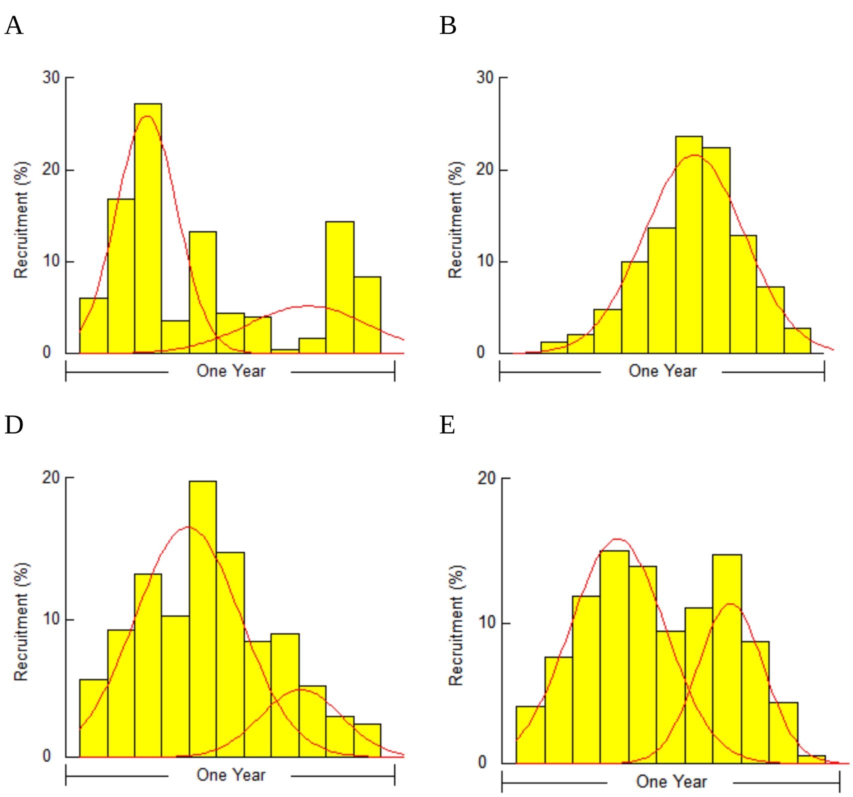


Figure 4. Recruitment patterns of dominant fishes in Okpara Stream (Oueme River, North-Benin): A = *Hemichromis fasciatus*; B =*Marcusenisius senegalensis*; C = *Schilbe intermedius*; D = *Oreochromis niloticus*; E = *Brycinus macrolepidotus*.

could be explained by the fact that in transitory ecosystems such as coastal lagoons (Lake Nokoue, brackish sites of Sô River), fishes quickly reach their maximum size with shorter life span than those living in freshwaters (Longhurst and Pauly, 1987; Tah et al., 2010). In addition, the high abundance of *H. fasciatus* in Okpara River could cause intraspecific food competition, reducing the growth rate of this topcarnivorous species.

The growth performance index (φ') ranged between 2.40 (*H. fasciatus*) and 3.1 (*O. niloticus*). The φ' fall within 2.65<φ'<3.32, the range of φ' values reported by Baijot and Moreau (1997) for slow-growing fish species. The ecosystem disturbances factors could have negatively affected the well-being of the fishes and leading to reduced growth performances. Most of these degradation factors of Okpara Stream were the dumping of domestic garbage, the withdrawal of water by SONEB, a Benin Water Company, the withdrawal of water for irrigation, the use of chemical fertilizers/pesticides for agriculture, the introduction of invasive exotic fishes such the *O. niloticus* and the proliferation of water hyacinth, an invasive floating plant.

The average value of φ' recorded in this study agreed with to those reported by Hazoume (2017) in Sô River in Benin and by Adeyemi et al. (2009) in Gbedikere Lake in Nigeria exhibiting average growth performances φ' = 2.75 ± 0.41 and φ' = 2.79 ± 0.19, respectively. However, the current value of φ' in Okpara Stream was lower than those reported by Ahouansou Montcho et al. (2011) in Pendjari River in Benin and by Du Feu (2003) in Kainji Lake where φ' values averaged 3.22 ± 0.31 and 3.19 ± 0.31, respectively. Inversely, Niyonkuru (2007) found an average value of φ' = 2.58 ± 0.19, lower than that recorded in this study. These differences could be mainly attributed to environmental conditions and food availability.

Overall, fish longevity (Tmax) ranged between 1.88 yr (*M. senegalensis*) and 4.55 yr (*S. intermedius*). These values were lower than those reported by Hazoume (2017) on Sô River where T_{max} was higher and reached 11.66 yr, probably because the Sô River floodplains stand as breeding and nursery/growing grounds for several fish species. In Okpara Stream, natural mortality (M) of fishes was higher than those of the Sô River by Hazoume (2017). These results imply that as natural mortalities (M) of fishes increase, longevities (T_{max}) decrease.

In the current investigation, for all species, natural mortalities (M) were greater than fishing mortalities (F) and the exploitation rates (E) were lower than 0.5. As results, stocks of *B. macrolepidotus*, *H. fasciatus*, *M. senegalensis*, *O. niloticus* and *S. intermedius* were underexploited in Okpara Stream (Tah et al., 2010). Villanueva (2004) and Tah et al. (2010) came up with the same observation and trends in some West African lagoons/estuaries such as Lake Ayame I of Ivory Coast. Nevertheless, in the current study, for each species, the ratio of total mortality (Z) to K is greater than 1, leading to a situation where mortalities dominated growth (Barry and Tegner, 1989).

With regards to length at first capture (L_{50}), species such as *B. macrolepidotus* and *O. niloticus* had L_{50} of 7.9 and 7.72 cm, respectively. These values were lower than those reported by Tah et al. (2010) in Lake Ayame I, L_{50} = 11.57 and L_{50} = 14.03 cm for *B. macrolepidotus* and *O. niloticus*, respectively. Recruitment are occurred throughout the year with two peaks per year for the majority of species (*H. fasciatus*, *O. niloticus* and *B. macrolepidotus*), indicating two main periods of spawning. This observation agreed with the findings of many African fisheries biologists (Pauly, 1982; Welcomme and De Merona 1988; Ahouansou Montcho et al., 2011) who found that tropical fish species reproduced twice a year, and mainly during the wet season. In the current study, all the five fish species displayed some exploitation rates (E = F/Z) ranging between 0.16-0.44, less than 0.5, suggesting that the stocks of these fishes in Okpara Stream were underexploited (Pauly and Moreau, 1997).

Conclusion

The relatively high growth rates (K) and growth performance index (φ') displayed by *B. macrolepidotus*, *M. senegalensis*, *H. fasciatus*, *O. niloticus* and *S. intermedius* indicated that these fish species showed a good adaptation to ecological condition of Okpara Stream. Also, the low exploitation rates (K) indicated that the stocks of these fishes in Okpara Stream were underexploited. Nevertheless, the low length at first capture (L_{50}) of some fishes such *O. niloticus, B. macrolepidotus* and *H. fasciatus* is harmful for the survival, the conservation and the sustainable exploitation of these species. Early fisheries management scheme should be implemented to guaranty the “ecological health” of the fish community and its sustainable exploitation.

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