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Some aspects of the biology of *Ctenopoma petherici* (Pisces: Anabantidae) in a West African Hydroelectric Lake Dam (Lake of Ayame 2, Côte d'Ivoire)

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Abstract

The importance of *Ctenopoma petherici* in the catches of subsistence fishing in the hydroelectric lake dam of Ayame 2 (Côte d'Ivoire) deserves a particular attention to the biological data of this species for eventual monitoring of stocks. Length-weight relationship, condition factor and reproductive biology were investigated. Thus, a total of 390 specimens was collected monthly from September 2015 to August 2016 using gill nets (08 to 30 mm stretched mesh). The *b*-values are 2.91 and 2.43 for females then 2.53 and 2.60 for males in the dry and rainy seasons, respectively. These values reveal that *C. petherici* had exhibits a negative growth pattern. The mean of *K*-value is greater than 1 indicating a well-being of *C. petherici*. The sex-ratio is not different from 1:1 ratio ($\chi^2 = 0.00$, $p > 0.05$). The size at first sexual maturity is 110.3 mm (SL) for females and 99.2 mm (SL) for males. This fish species breeds all the year round in this environment with a maximum in rainy season (November and June). The coefficient of oocyte diameter variability shows that this fish species lays the eggs only once during the spawning period. The absolute fecundity ranged from 783 to 25980 oocytes with a mean of 8574 ± 7191 oocytes and the relative fecundity varied from 12 to 301 oocytes per unit body weight (g) with a mean of 136 ± 78 oocytes.g^{-1}. The present data generated will form a baseline tool for effective fisheries management and sustainable exploitation of *C. petherici* in this Lake.

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Introduction

Studies on fish biology in reservoirs are of fundamental interest. Monitoring population dynamics (exploited or not) requires knowledge of a number of biological parameters (Offem *et al.*, 2008). Reproductive parameters such as fecundity, age and size of first maturity provide information on the potential of the available stock and population dynamics (Mireku *et al.*, 2016). Among biometric relationships, the length-weight relationships are very important in fisheries research (Ecoutin and Albaret, 2003; Alhassan *et al.*, 2015). They provide information on population parameters then climatic and environmental changes. The condition factor of fishes is the most important biological parameter which provides information on condition of fish species and the entire community. It is of high significance for management and conservation of natural populations (Sarkar *et al.*, 2009; Muchlisin *et al.*, 2010).

Anabantids are native of Africa and Asia (Skelton, 1988). The African anabantids are divided into two geographically separate genus: *Ctenopoma* and *Sandelia*. *Ctenopoma* Peters, 1844 is one of the most widespread genus in tropical Africa. *Ctenopoma* species have a tropical continuous distribution from the Angolan coastal province to Senegal and they are currently restricted to freshwaters (Skelton, 1988). These species are important ecologically.

They possess an adaptation to life in hypoxic environments. Indeed, they belong to polluo-resistant fish group (Lévêque, 2006).

In Côte d'Ivoire, in addition to its ecological interest the species *Ctenopoma petherici*, Günther, 1864 is commonly available in local fish markets and it is one the cheapest sources of animal protein and other essential nutriments required in human diet. Equally, it is important economic and commercial species as it occurs in both subsistence and artisanal fisheries landings.

In spite of the immense importance of this species, there is inadequate information on its biology.

The available data on the biology of *C. petherici* concerned the length-weight relationship (Konan *et al.*, 2007). Therefore, to remedy this deficiency, the aim of the present study is to describe the growth pattern, physiological condition and the reproductive parameters of captured *C. petherici* in Lake Ayame 2.

Materials and methods

Study area

The man-made Lake Ayame 2 is located in the South-East of Côte d'Ivoire (5°34′-5°37′ N and 3°09′-3°10′ W) (Fig.1). This Lake was formed by the construction of two hydroelectric dams, Ayame 1 in 1959 and Ayame 2 in 1964 on the Bia River (Da Costa *et al.*, 2000). This reservoir has an average area of 7 km² and a length of about 4 km. This aquatic ecosystem is located in a region under the influence of equatorial transition climate characterized by two rainy seasons separated by a short dry period from August to September, and a more pronounced one from December to March (Savané and Konaré, 2010). This is at certain periods of the year fully covered by a floating plants.

Sampling and measurements

The samples of *Ctenopoma petherici* were collected monthly from September 2015 to August 2016. The fish were caught using gill nets (08 to 30 mm stretched mesh). Standard length for each fish was measured from the tip of mouth to base of the caudal fin to the nearest 1 mm.

The total body weight in gram was measured for each specimen to the nearest 1 g using an electronic weighing balance. Fish were dissected to determine sex. The gonadic maturity stage was recorded following Olurin and Odeyemi (2010) (Table 1).

The gonads and liver were removed and weighted to the 0.001 g, then fish were weighted again to the nearest 1 g. Gonads in advanced vittellogenesis were fixed in 5 % formalin for subsequent estimation of fecundity and oocyte size.

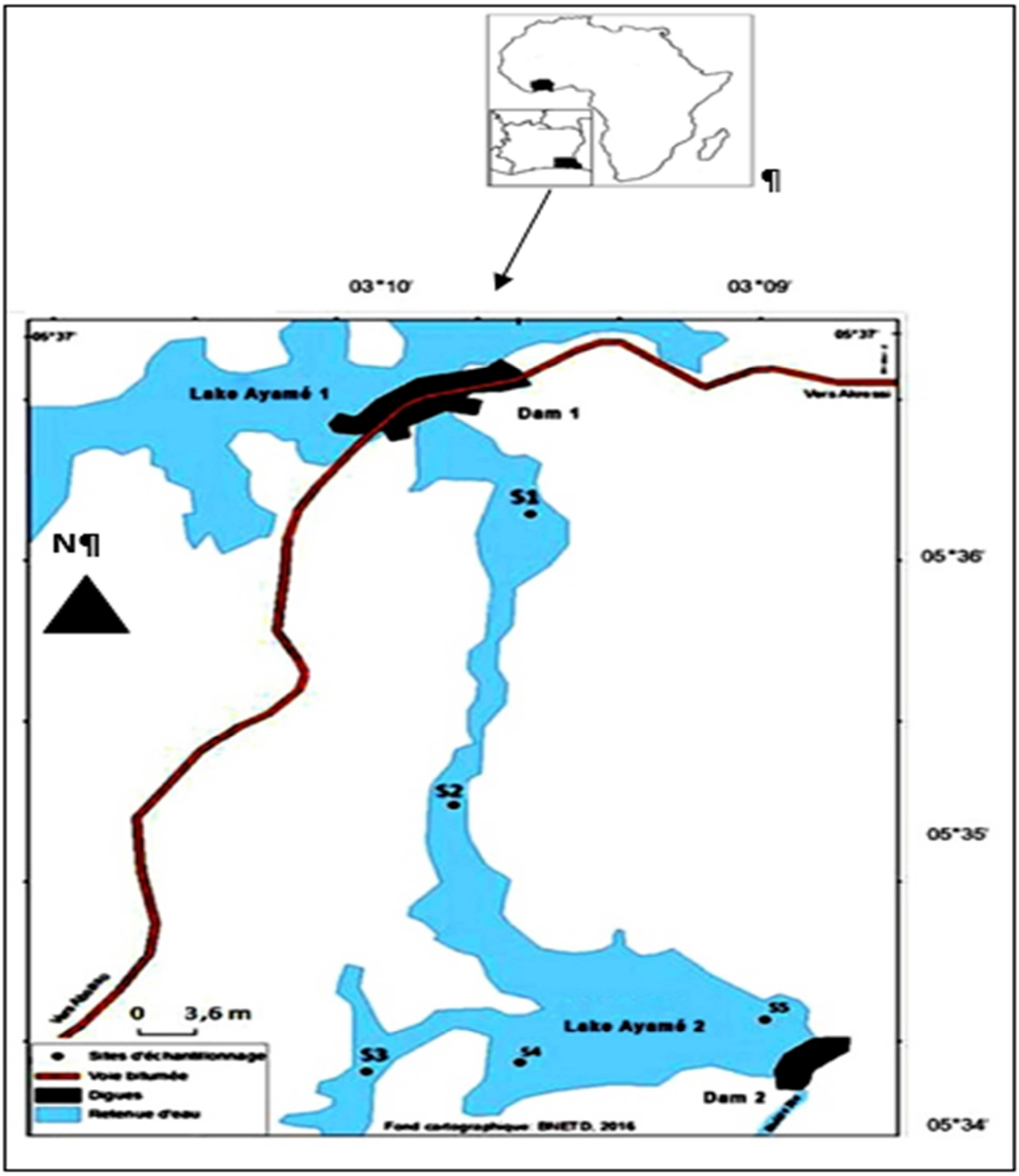

Fig. 1. Sampling sites (•) of *Ctenopoma petherici* in the hydroelectric Lake Dam of Ayame 2 (Côte d'Ivoire).

Length-weight relationship and condition factor

The length-weight relationships were determined using the power function:

$W = a\ SL^b$

The value of parameters *a* (intercept) and *b* (slope or allometry coefficient) were computed from the transformed logarithm values of length and weight using the equation Log (TW) = Log (*a*) + *b* Log (SL) where TW = total body weight of fish (g), and SL = standard length of fish (mm) (Ecoutin and Albaret, 2003).

The condition factor (*K*) was calculated according to Mouneiné (1981):

$$K = 10^5 \times \frac{TW}{SL^3}$$

where SL = standard length (mm) and TW = total body weight (g) of fish.

Reproductive parameters

Size at first sexual maturity

Size at first sexual maturity (SL_{50}) was defined as the standard length at which 50 % of individuals were in gonad stage III. Size at first sexual maturity was determined by fitting the fraction of mature specimens to logistic function non-linear (Duponchelle and Panfili, 1998). SL_{50} was expressed by following equation:

$$P = \frac{1}{1+e^{-(\alpha+\beta SL)}} \text{ with } SL_{50} = \frac{-\alpha}{\beta}$$

where P = percentage of specimens having reached stage III of maturation, SL = standard length, α and β = constants.

Gonado Somatic Index (GSI), Hepato Somatic Index (HSI) and Percentage of Mature Females (PMF)

Seasonal evolution of sexual activity was determined by monthly evaluation of the Gonado Somatic Index (GSI), Hepato Somatic Index (HSI) and Percentage of Mature Females (PMF).

These parameters have been measured using the following formula (Çek *et al.*, 2001):

$$GSI = \frac{GW}{EW} \times 100, HSI = \frac{LW}{EW} \times 100 \text{ and } PMF = \frac{N_{mf}}{N_f} \times 100$$

GW = gonad weight, EW = eviscerated fish weight, LW = liver weight, N_{mf} = mature female number, N_f = captured female number.

Fecundity and oocyte diameter

For the estimations of fecundity and oocyte diameter, only females whose ovaries reached stages IV and V of the maturation were taken into account. The absolute and relative fecundity have been estimated. Therefore, a subsample of the oocytes was weighted (g) and counted.

The absolute fecundity was the total number of oocytes per female. It was obtained by applying the following formula according to Le Bec (1983):

$$AF = \frac{n \times GW}{SW}$$

where AF = absolute fecundity, n = number of oocytes in the subsample and SW = weight of subsample, GW = weight of gonads.

The relative fecundity (RF) was the number of oocytes per unit body weight (g):

$$RF = \frac{AF}{EW}$$

AF = absolute fecundity and EW = weight of eviscerated fish. Oocyte diameter was measured in order to evaluate the ovary homogeneity. Thus, ovary was divided into anterior, medium and posterior region. For each region, 30 oocytes were removed and measured using a magnifying glass (WILD M3C) with incorporated micrometer. The estimation of mean oocyte diameter per female was calculated according the following formula:

$$\overline{OD} = \frac{\sum_1^i od}{S}$$

$\overline{OD}$ = mean oocyte diameter per female, od = oocyte diameter, S = number of measured oocytes.

Statistical analysis

In order to verify if calculated *b* was significantly different from 3, the Students *t*-test was used as expressed by the equation according to Sokal and Rohlf (1987):

$$ts = \frac{b-3}{SD}$$

where t_s is *t*-test value and SD = standard deviation of the allometry coefficient *b*. The type of growth was determined using the t_s value: if $t_s \geq 1.96$ (theoretical value of t_s indicated by Student table) this implies that $b \neq 3$ so an allometric growth (negative allometry if $b < 3$ and positive allometry if $b > 3$) and if $t_s < 1.96$ the implication is $b = 3$ so an isometric growth.

The Chi square (χ^2) test was used to test whether the sex ratios observed were significantly different from theoretical (1:1) ratio.

The coefficient of oocyte diameters variability has been determined according to Sylla *et al.* (2009) for testing ovary homogeneity.

$$CV = \frac{SD}{\overline{OD}} \times 100$$

CV = coefficient of oocyte diameters variability, SD = standard deviation and $\overline{OD}$ = mean oocyte diameter per female. If CV ≥ 30 %, this implies that the ovary structure was heterogeneous. For 2 % ≤ CV < 30 %, the ovary structure is homogeneous and CV < 2 % the ovary is very homogeneous.

All these analyses were carried out using statistica7.1 and adopted for all the *p*-value with significance level of 0.05.

Results

Length-weight relationship

The results of the length-weight analyses are presented in Table 2.

Slopes (*b*-values) of the length-weight relationship estimated for dry season were 2.91 and 2.53 respectively for females and males. In the rainy season, these values were 2.43 for females and 2.60 for males.

Table 1. Stage of gonads maturity in *Ctenopoma petherici* (Olurin and Odeyemi, 2010).

Maturity stages	Male	Female
I	Testicles are very small size	Ovaries are very small size, acolytes cannot be distinguishable to the naked eyes
II	Testicles have begun to develop and easily distinguishable	Ovaries have begun to develop, oocytes are difficulty distinguishable to the naked eyes
III	Developed testicles containing milky sperm	Advanced maturation, oocyte distinguishable to the naked eyes testes changes from transparent pale yellow
IV	Sperm is extruded in responses to very light pressure on the belly	Ovaries have achieved their development but the sexual products are still not extruded when light pressure is applied
V	Flaccid testicle containing residual sperm	Ripe ovaries, sexual products are extruded in responses to very light pressure on the belly
VI		The oocytes have been discharged, ovaries have appearance of deflated sacs and containing few left over oocytes

These *b*-values which were less than 3 ($p < 0.05$) revealed that *Ctenopoma petherici* exhibited a negative allometric growth pattern, suggesting that they tend to become thinner as they become larger in both (dry and rainy) seasons for both sexes.

Condition factor

Values of the condition factor (*K*) (Table 3) showed that for females, *K* varied from 2.54 to 5.72 with a mean of 4.62 ± 0.55 and from 2.96 to 5.70 (4.28 ± 0.59) in dry and rainy seasons respectively. For males, *K* ranged from 3.41 to 5.79 (4.62 ± 0.55) and it ranged from 3.30 to 5.52 with an average of 4.20 ± 0.41 respectively in dry and rainy seasons.

Table 3. Values of condition factor by season and by sex of *Ctenopoma petherici* caught in the hydroelectric Lake Dam of Ayame 2.

Sexes	Season	n	Min	Max	Mean ± SD
Famale	DS	111	2.54	5.72	4.62 ± 0.55
	RS	85	2.96	5.70	4.28 ± 0.59
Male	DS	95	3.41	5.79	4.62 ± 0.55
	RS	99	3.30	5.52	4.20 ± 0.41

n = specimen number, Min = minimum, Max = maximum, SD = standard deviation, DS = dry season, RS = rainy season.

These values indicated that K was highly greater than 1 showing that fishes were in better condition in the man-made Lake Ayamé 2.

Monthly variation of mean condition factors (Fig. 2) showed that peaks were obtained in dry season for both sexes. For females, the peaks were observed in December (K = 4.93) and in August (K = 4.67) while they were noted in January (K = 4.87) and in August (K = 4.50) for males. The condition factor variations according to season and sex were not significant (p > 0.05).

Reproductive parameters

Sex-ratio

A total of 390 specimens of *Ctenopoma petherici* was sexed, comprising 196 females and 194 males giving a sex-ratio of 1.01 female per male (Table 4).

Chi-square test showed that the sex-ratio was not different from 1:1 ratio (χ^2 = 0.00, p > 0.05). Monthly chi-square values indicated that the number of females and males differed significantly in April, June and August (p < 0.05).

Table 2. Length-weight relationship parameters and growth type of *Ctenopoma petherici* in the hydroelectric Lake Dam of Ayame 2.

Sexes	Season	n	R²	a	b	t	SD	Type of growth
Famale	DS	111	0.95	0.02	2.91	2.31	0.04	A^-
	RS	85	0.86	0.04	2.43	7.15	0.08	A^-
Male	DS	95	0.87	0.03	2.53	7.91	0.06	A^-
	RS	99	0.93	3.03	2.60	8.20	0.05	A^-

n = specimen number, R^2 = determination coefficient, a = intercept, b = allometry coefficient, t = value of *t*-test, SD = standard deviation, A^- = negative allometric pattern, DS = dry season, RS = rainy season.

Size at first sexual maturity

The standard length (SL) ranged from 80 to 140 mm with a mean of 106 ± 14 mm for mature females while it varied between 79 and 130 mm with a mean of 101.5 ± 11 mm for mature males. The length at first maturity (SL_{50}) was 110.3 mm (SL) for females and 99.2 mm (SL) for males (Fig. 3). No significant difference was found between the sizes at first maturity of both sexes (χ^2 = 0.28, p > 0.05).

Table 4. Chi-square values of monthly sex-ratio of *Ctenopoma petherici* in the hydroelectric Lake Dam of Ayame 2.

Month	Famale	Male	Total	Sex-ratio (F-M)	X²
September	11	6	17	1.83:1	0.83
October	10	11	21	0.91:1	0.40
November	8	13	21	0.62:1	1.08
December	15	16	31	0.94:1	0.03
January	23	18	41	1.28:1	0.51
February	21	11	32	1.91:1	2.70
March	27	17	44	1.59:1	1.87
April	11	27	38	0.41:1	5.69*
May	17	19	36	0.89:1	0.09
June	22	10	32	2.20:1	3.89*
July	18	19	37	0.95:1	0.02
August	13	27	40	0.48:1	4.10*
Total	196	194	390	1.01:1	0.00

*) significant difference (p < 0.05)

Breeding season

For the study of breeding cycle, only females were taken into account. Hence, monthly evolution of relative proportion of mature females (stages III, IV and V), Gonado Somatic Index (GSI) and Hepato Somatic Index (HSI) were examined (Fig. 4 and 5). Monthly variation of maturity stages (stages III, IV and V) and GSI showed that breeding period of *Ctenopoma petherici* appeared not restricted to definite season in the man-made Lake Ayamé 2 (Fig. 4). High percentage of mature females (≥ 50 %) was noted all year round, although weak proportions (< 50 %) were observed in January and March. GSI presented two peaks: the first highest in November (9. 06 ± 5.54) and the second slightly smaller (5.43 ± 5.75) in April.

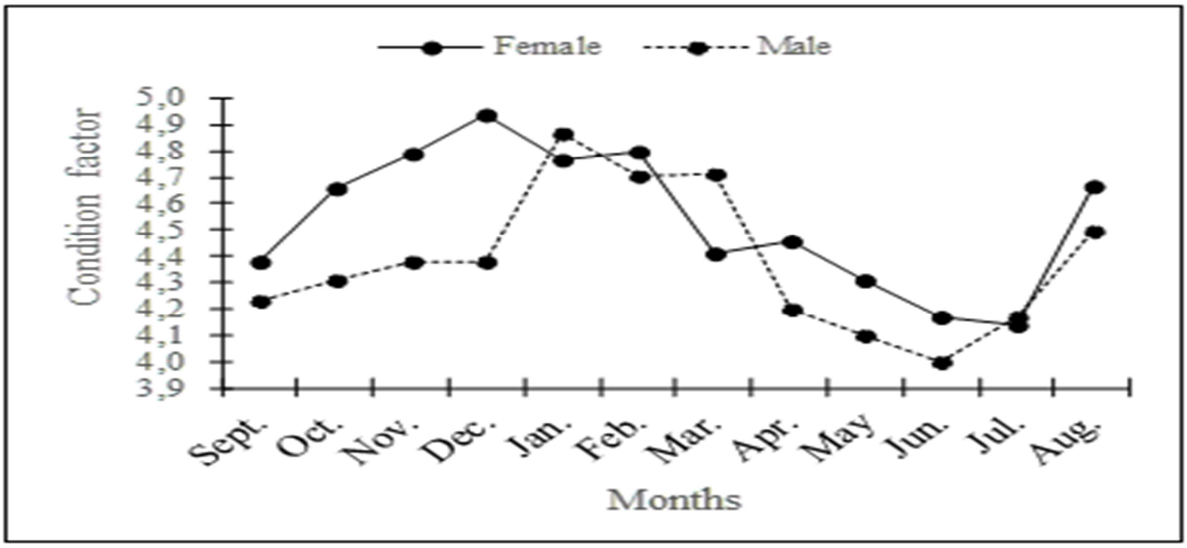

Fig. 2. Monthly variation of mean condition factors for females and males of *Ctenopoma petherici* from the hydroelectric Lake Dam of Ayame 2.

This indicates that intensity of sexual activity throughout the year is greater in rainy season than in dry season. This was confirmed by low proportion of mature females in January (39.13 %) and March (46.43 %).

Simultaneous analysis of gonado and hepato somatic index showed that the peaks of these parameters were obtained alternately (Fig. 5). When GSI increases, HSI decreases. The highest value of GSI was observed in November while the HSI was higher in June.

Fecundity and oocyte diameter

The absolute fecundity varied from 783 to 25980 oocytes with a mean of 8574 ± 7191 oocytes in female standard length between 80 and 140 mm and eviscerated fish weight from 23 to 146 g. The relative fecundity ranged from 12 to 301 oocytes per unit body weight (g) with a mean of 136 ± 78 oocytes.g^{-1}.

Oocyte diameter was estimated for ripe females. It ranged from 0.5 to 1.29 mm with an average of 0.88 ± 0.14. The coefficient of oocyte diameters variability ranged from 11.02 to 24.51 with a mean of 16.22. These values suggest that ovary structure was homogeneous in *C. petherici.*

Discussion

Length-weight relationship

The length-weight relationship is very important for proper exploitation and management of the population of fish species (Alhassan *et al.*, 2015) and allows prediction of weight from length in yield assessment (Ecoutin and Albaret, 2003). For an ideal fish that shows isometric growth, the allometry coefficient (*b*) is 3 and populations in which the exponent differs significantly from 3 exhibit allometric growths (Froese, 2006). In this study, *b*-values were significantly less than 3 indicating that for the two sexes, *Ctenopoma petherici* exhibited negative allometric growth for both dry and rainy seasons. This result implies that fishes tend to become thinner as they grow larger. Several authors attributed the growth pattern to different factors such as stages in the ontogenetic development, differences in sex and differences in geographical location with the associated environmental conditions (Mounéiné, 1981; Froese, 2006). The negative allometric growth pattern obtained in this study could be due to ontogenetic development in body proportions of the species. This same type of growth has been reported for *C. petherci* in the coastal Rivers of Côte d'Ivoire (Konan *et al.*, 2007).

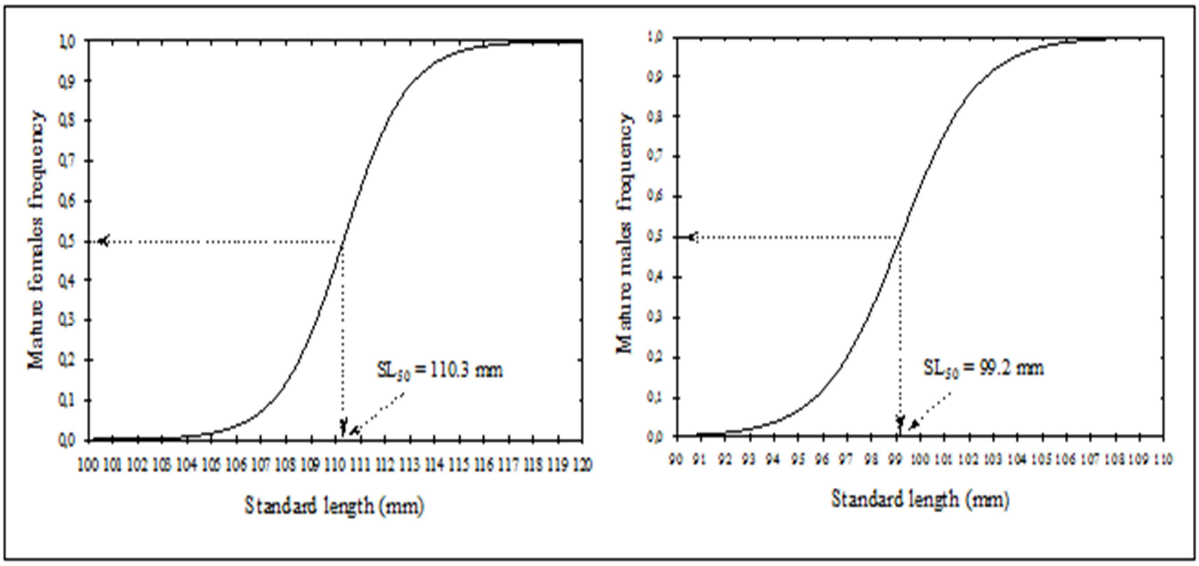

Fig. 3. Logistic function indicating size (standard length) at first sexual maturity (SL_{50}) for females and males of *Ctenopoma petherici* from hydroelectric Lake Dam of Ayame 2.

Condition factor

The condition factor is a morphometric index used to evaluate physiological status and general well-being of fish as related to its environment. This parameter has been reported to be influenced by both biotic and abiotic environmental conditions (Abowei, 2010). In fishery science, when the *K*-value is equal or greater than 1, this implies that the fishes are living well in their habitat (Ikongbeh *et al.*, 2012).

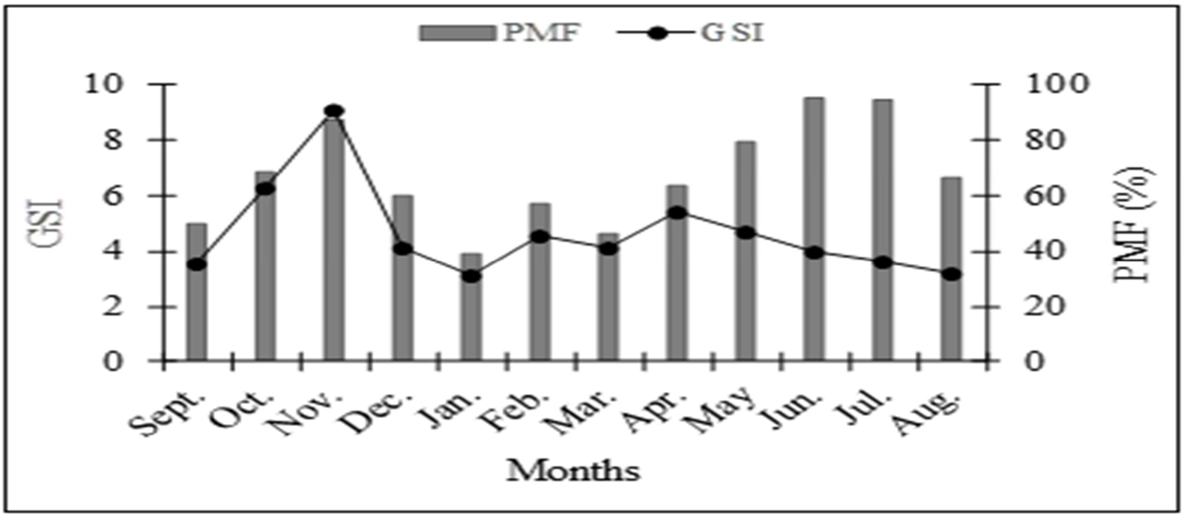

Fig. 4. Monthly variation of mean Gonado Somatic Index (GSI) for females and percentage of mature females (PMF) of *Ctenopoma petherici* in the hydroelectric Lake Dam of Ayamé 2 from September 2015 to August 2016.

In this study, *K*-value were 4.62 ± 0.55 versus 4.28 ± 0.59 for females and were 4.62 ± 0.55 versus 4.20 ± 0.41 for males in the dry and rainy seasons, respectively. These results suggested that *C. petherici* was in good physiological state in the man-made Lake Ayamé 2. The well-being of this fish species in this Lake might be due to food availability and its adaptation to life in hypoxic environments notably in dry season in which the lake water is not constantly renewed and there is depletion in dissolved oxygen characterized by a high proportion of aquatic plants. Indeed, Anabantid fishes possess an accessory respiratory organ allowing them to breathe directly atmospheric air (Norris and Teugels, 1990; Lévêque, 2006).

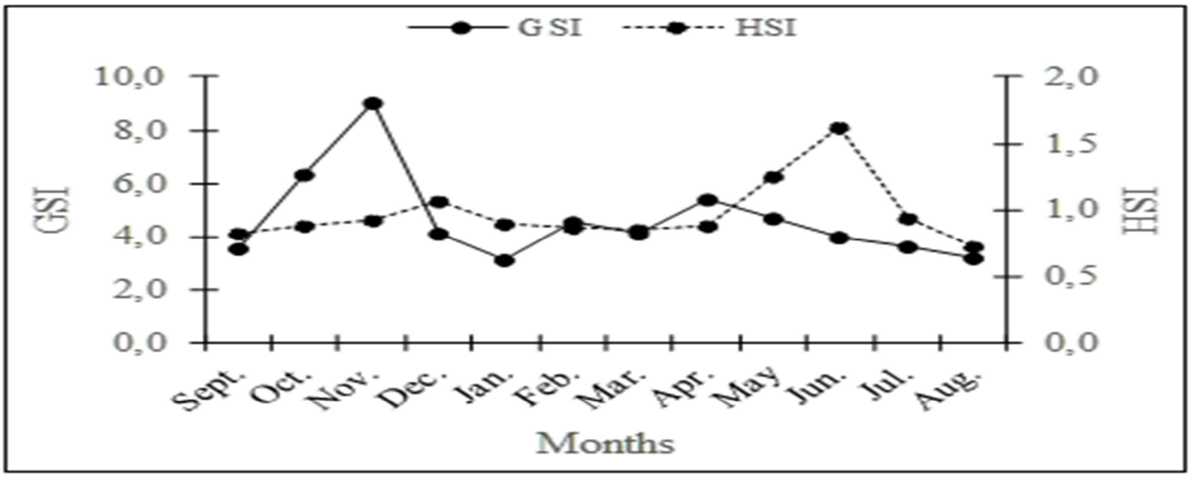

Fig. 5. Monthly variation of the mean of Gonado Somatic Index (GSI) and Hepato Somatic Index (HSI) of *Ctenopoma petherici* females in the hydroelectric Lake Dam of Ayamé 2 from September 2015 to August 2016.

Reproductive parameters

The overall ratio was not significantly different from theoretical (1:1) ratio. Similar results were obtained in another Anabantidae *C. kingleyae* in the Owa River in South-Eastern of Nigeria (Olurin and Odeyemi, 2010). However, monthly variation of sex-ratio revealed that there was in favour of males in April and August. To explain this imbalance in the sex ratio, several hypotheses such as displacement for food search, segregation of the sexes according to seasons, displacement by separate banks, selective natural mortality, different migratory activity, sampling methodology and breeding periods were formulated (Ameur *et al.*, 2003; Ma *et al.*, 2012). In the present study, preponderance of the male specimens in April and August could be attributed to intense sexual activity from April to August. Indeed, according to Offem *et al.* (2008), once fertilization of eggs had concluded, males emigrate from spawning grounds towards feeding grounds part where they are easily captured while females go towards submerged vegetation to avoid gear.

Sizes at first maturity observed were 110.3 mm (SL) for females and 99.2 mm (SL) for males. Although, there are not significant difference between both (female and male) sizes at first maturity, males reach sexual maturity before females. Such result has been reported by Atsé *et al.* (2009) in Ebrié lagoon (Côte d'Ivoire). The difference between the sizes of females and males at sexual maturity could be explained by a sex difference in growth (Tougueyeni, 1996; Atsé *et al.*, 2009).

The dominance of mature individuals observed every month and highest GSI values suggested that breeding period appeared not restricted to a definite season. Therefore, *Ctenopma petherici* seemed to breed all the year round in the man-made Lake Ayamé 2, despite a proportion of ripe females relatively weak obtained in January (39.13 %) and March (46.43 %). The spreading of breeding all year long could be due to weak variation of water level. This does not seem to have a major impact on the food resources, sources of energy needed for gonad maturation. This favourable environment every month would explain the reproduction of *C. petherici* throughout the year in Lake Ayamé 2. These results are corroborated by the findings of Boussou *et al.* (2005) in the Lake Ayamé 1 (Côte d'Ivoire). Nonetheless, the peaks coincided with the months of November and of June which are the rainy months. The synchronization of the breeding period and the rainy or flood season is a well-known strategy for many tropical fish species (Paugy, 2002). This strategy allows young people not only to take refuge in submerged areas, but also to have available food resources (Oso *et al.*, 2011; Konan *et al.*, 2013). These more favourable conditions during the rainy seasons explain the high intensity of sexual activity during these periods. The offset between the peaks of GSI and HSI revealed that mobilized energy for gonad maturation arise from liver indicating that *C. petherici* is a meagre fish.

Absolute fecundity of *C. petherci* ranged from 783 to 25980 oocytes with a mean of 8574 ± 7191 oocytes and the relative fecundity varied from 12 to 301 oocytes per unit body weight (g) with a mean of 136 ± 78 oocytes.g^{-1}. Fecundity recorded was relatively high compared to observation from other freshwater species. Konan *et al.* (2013) recorded 34 ± 14 oocytes.g^{-1} for *Thysochromis ansorgii* in Tanoé-Ehy complex in South-East of Côte d'Ivoire. The difference in fecundity is mainly due to the size of the eggs. Indeed, the number of eggs decreases with increase of the size of the oocytes (Koné, 2000). The homogeneous structure of the ovary indicates that *C. petherici* does not reproduce in a discontinuous manner but makes a single batch of eggs.

Conclusion

Ctenopoma petherici growth pattern was negative allometric type in the hydroelectric dam Lake of Ayame 2. However, the condition factor showed that this species was in good physiological condition in this reservoir. The reproduction parameters indicated that *C. petherici* breeds throughout the year. These parameters also revealed that the mobilized energy for gonad maturation arise mainly from liver.

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