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Reproductive Strategies of the Catfish *Clarias buettikoferi* (Pisces, Clariidae) in the Tanoe-Ehy Swamp Forest (South-Eastern Côte d'Ivoire)

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Abstract: A wide variation of reproductive strategies occurs in tropical fishes. Tropical catfishes from rivers and lakes are thought to breed mainly at the onset or during rainy seasons, when juveniles have better chances to overcome environmental constraints, obtain food resources and ovoid predators. The Tanoe-Ehy forest swampy environment which is characterized by periodic acute flooded and dry seasons offers the opportunity to verify these assumptions for Clariid catfish *Clarias buettikoferi* Steindachner 1894 inhabiting this specific habitat. Fishes were caught from March 2012 to February 2013 using gillnets and fyke nets. The breeding activity occurred mainly in the rainy seasons. Higher condition factor were recorded when water level increased in the swampy forest, showing that fishes take advantages of flooded banks for their feeding. Overall sex ratio was skewed in favor of males during breeding seasons (May-July and September-October). When absolute fecundity data were processed separately according to different hydrological seasons, different clear-cut relationships were observed between this parameter and fish length. These data showed that female's *C. buettikoferi* produced more oocyts during flooded seasons than in dry seasons as previously mentioned for other tropical catfish.

Key words: African Catfish · Breeding · Condition Factor · Fecundity · Sex Ratio

INTRODUCTION

Catfishes are one of the economically important groups throughout the world, in many countries, they form a significant part of inland fisheries; several species have been introduced in fish culture; numerous species are of interest to the aquarium industry where they represent a substantial part of the world trade [1]. Catfishes have a unique suite of morphological, ecological and behavioral traits that equip them to succeed in diverse freshwater ecosystems including lakes, rivers, lagoons and estuaries [2-4]. They have a suprabranchial organ (reduced or virtually absent in some genera), formed by arborescent structures originating from the second and fourth epibranchials, that enable them to utilize atmospheric air [1]. Research on tropical Clariid catfishes has shown basic trends in some biological traits: 1) Sex ratio during breeding period used to be skewed in favor of males specimens, because females are thought to be in specific habitats where juveniles are better protected against environmental constraints and predators; 2) The breeding periods occurred generally at the onset of the rainy seasons, where juveniles take advantages of flooded banks for their food availability; and 3) the fecundity of individuals fish is believed to vary accordingly with the availability of nutritional resources in the environment [5-7]. In the Tanoe-Ehy swamp forest (TESF), which is the very last remaining forest block in the south-eastern corner of Côte d'Ivoire, the catfish *Clarias buettikoferi* Steindachner 1894 is the main fish

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species caught by traditional fishermen [8, 9]. This species has a relatively wide distribution in West Africa, it occurs along the coast from the Gambia to Côte d'Ivoire [10]. However, in spite of this relative importance of *C. buettikoferi*, little information is available on its biology and ecology, although these are known to be important in the production and management of fish stocks [11]. The TESF is characterized by two acute dry seasons during which the majority of the area is dried out, leaving only very small river flow and two rainy seasons in which the forest is inundated. Scientific knowledge on tropical catfishes were mainly from fishes of rivers and lakes [7, 12-17] and little is known on fishes inhabiting swamp environments such as the Tanoe-Ehy swamp forest. Based on former study on the reproduction of Clariid catfishes this study plan to verify the following assumptions: 1) the breeding of *Clarias buettikoferi* may occur during the flooded seasons due to the possible availability of important amount of food resources; and 2) the availability of food resource during flooded period in the forest suggests that spawning occurs preferably at that time with a higher number of oocysts.

MATERIALS AND METHODS

Study Area: Specimens of *Clarias buettikoferi* were collected in the aquatic environment of the Tanoe-Ehy forest located in South-eastern Côte d'Ivoire between latitudes 5°6'N and 5°12'N and longitudes 2°54'W and 2°43'W. It is a swampy forest of a surface area of approximately 6000 ha bounded with the Tanoe River and the Ehy lagoon (Figure 1). Hydrological seasons of the forest are characterized by two flooded seasons (Mai-July and October-November) and two wet seasons (August-September and January-April) (Figure 2).

The Tanoe-Ehy swamp forest has recently been identified as a high priority site for the conservation of critically endangered Primates in West Africa. However, the forest is still under threat from hunting, logging and all other forms of forest resource exploitation including agricultural clearings and overexploitation of non-timber forest products [18].

Collection of Specimens and Sampling: Fish samples were collected once every month from 5 sites throughout the swampy environments of the forest between March 2012 and February 2013. The fishing gears comprised gill net (8-25 mm stretched mesh size) and fyke net (10 mm stretched mesh size). Specimens collected were identified following Teugels [10] and standard lengths (SL) and body weight were measured for each fish to the nearest mm and g respectively. Gonads were checked macroscopically for maturity stage (Table 1) and then weighted to the nearest 0.1 g. Gonads in advanced vitellogenesis were fixed in 5% formalin for subsequent estimation of fecundity.

Gonadosomatic Index: The gonadosomatic index (GSI) was estimated by:

$$GSI = \frac{W_g}{W_e} \times 100$$

where Wg = gonad weight (g); and We = eviscerated weight (g).

Sex Ratio: The sex of each specimen was identified by examination of the gonads. The proportion of the two sexes relative to one another was used to calculate the sex ratio.

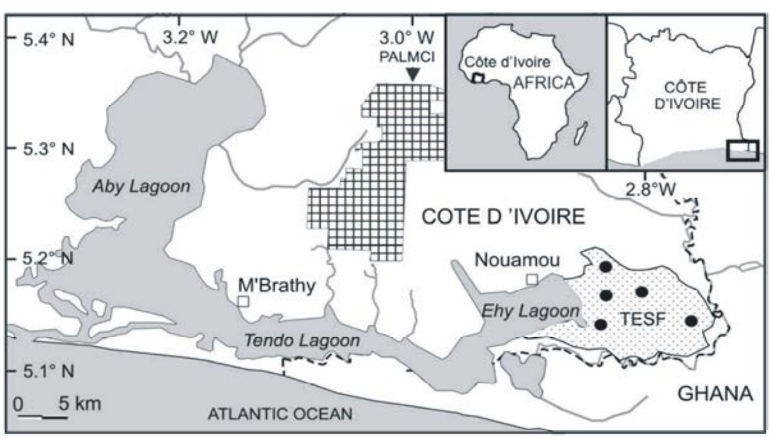

Fig. 1: Sampling sites (•) in the Tanoe-Ehy swamp forest (TESF) (South-eastern Côte d'Ivoire)

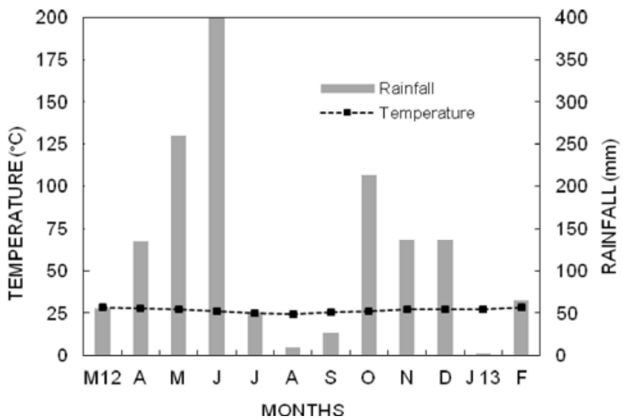

Fig. 2: Temperature and rainfall variations of the Adiake region between March 2012 and February 2013 (From SODEXAM, Côte d'Ivoire)

Table 1: Stages of gonadal development of *Clarias buettikoferi*

	Macroscopic characteristics	
Stage of gonadal development	Ovaries	Testes
I	Ovaries were very tiny, translucent. Oocyts were not visible.	Testes were small, thin, and tread-like in shape
II	Ovaries were tiny, opaque, and light yellow in colour. Very small oocyts were visible	Testes were semitransparent, moderately thick, milt not visible
III	Ovaries were large, opaque, light yellow in colour and Oocyts were clearly visible.	Testes were well developed, opaque, and whitish in colour. blood vessels were seen on the surface. Milt could not be released when the testes were under pressure.
IV	Ovaries were enlarged, yellowish in colour with a prominent net work of blood vessels. Oocyts could be released when the ovaries are under pressure.	Testes were well developed, opaque and whitish in colour. Milt could be released when the testes were under pressure.
V	Flaccid ovaries with a prominent blood vessels and reddish yellow in colour. Few oocyts can be seen.	Testes were more developed stage III, opaque whitish in colour. Milt could not be released when the testes were under pressure.

Condition Factor: Condition (K) was calculated using the Fulton's formula [19]:

$$K = \frac{W}{SL^3} \times 100$$

where W is the total weight (g) and SL the standard length (cm) of fish.

Fecundity Estimation: Fecundity which is the number of ripe eggs in the female prior to the next spawning was estimated according to Bagenal [6]. Only ovarian developmental stages IV were used for fecundity estimation. Absolute fecundity was estimated through sub-sampling by gravimetric method.

Statistical Analysis: Sex ratio of the fish was studied using Chi-square test (χ^2) and values were tested using 95% confidence level. Correlation analysis was used to check the relationship of fecundity-body length.

RESULTS

Breeding Season: Breeding season was determined on the basis of occurrence of most advanced maturity stages (stages IV and V) of female in each month during the period from March 2012 to February 2013. Based on temporal variation of different maturity stages in females *Clarias buettikoferi* (Figure 3) two mains spawning seasons can be distinguished, the first one started in May (when water level was rising up in the Tanoe-Ehy swamp forest), with a low proportion of spent individuals. It reached its peak in June and decreased gradually till August. This first spawning period corresponded to the first flooded time/season of the Tanoe-Ehy swamp forest. The second spawning period began in September (at the onset of the second rainy season), reached its maximum spawning activity in October and decreased gradually till December (which corresponded to second flooded season of the Tanoe-Ehy swamp forest). However, some individual with ripe oocyts (stage IV) and some spent females were caught out of these two periods, during dry months.

Gonadosomatic Index: GSI showed lowest values during March, August and November-February for females (minimal value noticed in December: GSI = 0.42% ± 0.19) and during March, August and October-February for males (minimal value observed in March: GSI = 0.13% ± 0.07).

For females the highest gonadosomatic index (GSI) occurred between May-June. Data decreased during July-August and reached another peak in September (maximal value noticed in June: GSI = 5.70% ± 1.10) (Figure 4). A similar pattern of GSI variation was observed for males: the first peak occurred in May and was followed by a decreasing phase during July-August, while the second peak and other decreasing phase appeared respectively in September and November-December (maximal value obtained in May: GSI = 0.45% ± 0.20).

In both sexes, peaks of GSI almost coincided with the peak of spawning activity and they occurred during rainy seasons.

Condition Factor: The lowest K values in females were observed during April-May, October-November 2012 and January-February 2013 (minimal obtained in April: K = 0.75 ± 0.09) (Figure 5) which corresponded to *Clarias buettikoferi'* breeding periods in the Tanoe-Ehy swamp forest. The highest values were recorded before peaks of breeding activity, during August-September and December (maximal value recorded in December: K = 0.90 ± 0.08). The same trends were noted for males' K value variations: low values were obtained during April-June, October and January (minimal value recorded in January, K = 0.74 ± 0.08) while the highest values were observed during March, August and December (maximal value reached in March, K = 1.03 ± 0.13) (Figure 5).

Sex Ratio: Out of the 623 adults *Clarias buettikoferi* dissected during the study, 378 (60.67%) were males and 245 (39.3%) were females. The sex ratio of catch as a whole was 1:1.54 (Female: male), significantly different from a 1:1 ratio (χ^2 = 17.5, p<0.05). The males mainly predominated in the forest flooded months (May-August and October-December), when predomination of females was evident in wet months (March-April and January-February) (Figure 6).

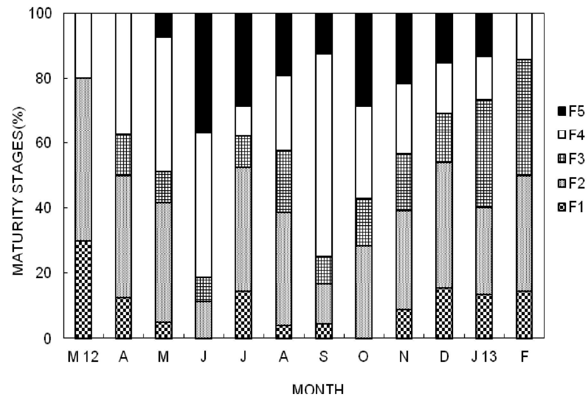

Fig. 3: Temporal variation of different maturity stages in females *Clarias buettikoferi* of the Tanoe-Ehy swamp forest (South-eastern Côte d'Ivoire), during March 2012-February 2013

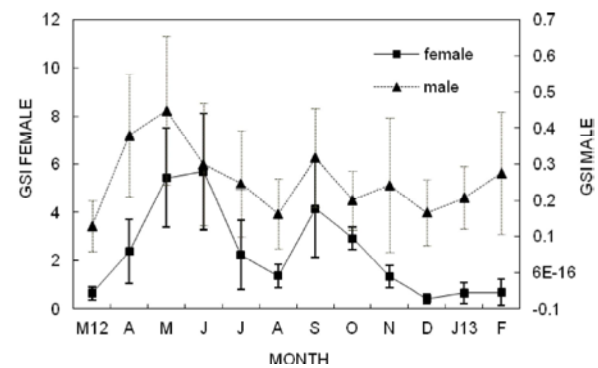

Fig. 4: Gonadosomatic index (GSI) in *Clarias buettikoferi* of the Tanoe-Ehy swamp forest (South-eastern Côte d'Ivoire), during March 2012-February 2013

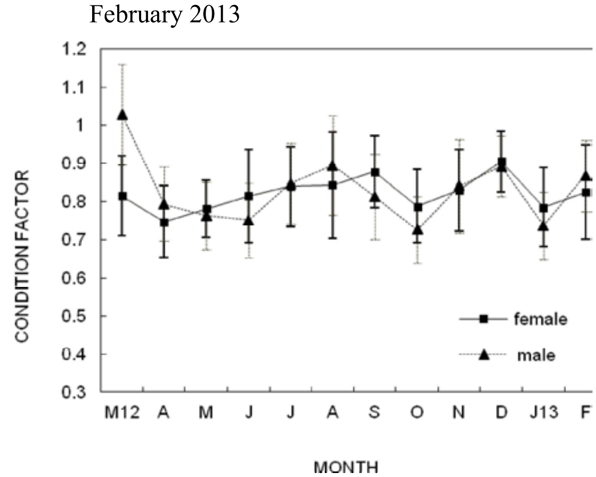

Fig. 5: Condition factor (K) in *Clarias buettikoferi* of the Tanoe-Ehy swamp forest (South-eastern Côte d'Ivoire), during March 2012-February 2013

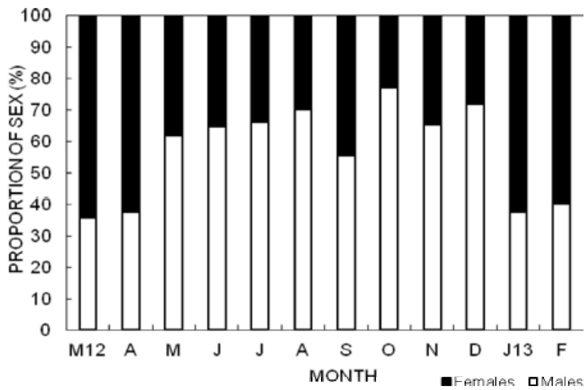

Fig. 6: Monthly variation of sex ratio in *Clarias buettikoferi* samples caught from the Tanoe-Ehy swamp forest (South-eastern Côte d'Ivoire), during March 2012-February 2013

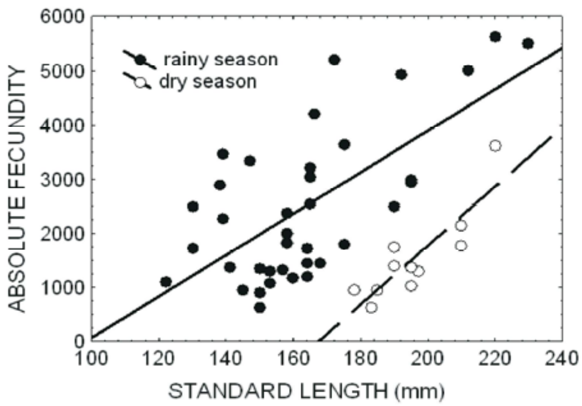

Fig. 7: Fecundity and fish standard length relationship of *Clarias buettikoferi* caught from the Tanoe-Ehy swamp forest (South-eastern Côte d'Ivoire) between March 2012 and February 2013

Fecundity: The fecundity was estimated from 46 females including 34 and 12 caught respectively during rainy and dry seasons. Absolute fecundity ranged from 632 oocyts (in a fish of standard length 122 mm and body weight 23 g) to 5628 oocyts (in a fish of standard length 230 mm and body weight 143 g) with a mean value of 2101±1473 oocyts for fish with SL=172 mm and weight= 61.9 g. There was no correlation between absolute fecundity and body length ($r=0.39$, $p>0.05$) when rainy and dry samples are pooled together. But when data are processed separately, different higher correlations were obtained for both seasons between fecundity and standard length (rainy season: $r= 0.67$, $p<0.05$; dry season: $r= 0.86$, $p<0.05$) (Figure 7). These results showed a variation in the amount of oocyts produced with seasons, with higher values recorded during the Tanoe-Ehy forest flooded seasons.

DISCUSSION

Monthly variation of GSI showed that gonadal development started with the onset of rainy seasons during March-April (for first rainy season) and September (for second rainy season). This gonadal development peaked twice between May-June and September-October, which corresponded respectively with peaks of first and second rainy seasons in the sampling area.

During July (end of first rainy season) and December (end of second rainy season) GSI decreased significantly, which indicated that maximum spawning activity is occurred during May-June and September-November. This result on *C. buettikoferi*' main breeding periods in rainy seasons are consistent with general trends previously mentioned for tropical catfishes [12, 13, 15, 16]. Many catfishes such as *Clarias gariepinus* in small reservoirs in Burkina Faso [13], *C. gariepinus* in Opa Reservoir, Nigeria [14], *C. anguillaris* in the the Cross River, Nigeria [17], *C. agboyiensis*, *C. macromystax* and *C. buthupogon* in River Anambra, Nigeria [20] and *Heterobranchus longifilis* in the inland wetlands of Cross River, Nigeria [7] were reported to breed during rainy seasons. And it is thought that the final triggering of spawning in *Clarias* species is caused by rise in water level due to rainfall [7, 15-17, 21], which occurred in the study area between April-June and September-November. Most tropical fishes are thought to breed on the rising flood because this allows juveniles to take full advantage of the flooded banks for feeding, while being protected from predation [22-24]. However, it was noticed that some *C. buettikoferi* specimens also bred during dry seasons in the Tanoe-Ehy swamp forest. This was supported by both the presence of maturity stage IV and spent females during these periods.

The condition factor (K) is an index reflecting interactions between biotic and abiotic factors in the physiological condition of fishes. It shows the population's welfare during the various stages of the life cycle [25]. In *Clarias buettikoferi* the condition factor increased during gonadal development stage (which occurred during the forest flooded seasons) and decreased when maximum spawning period was over (in dry seasons). High condition factor during the sampling site flooded season can be explained by large varieties of food items which are an advantage for gonadal material production to meet the breeding seasons for egg or milt production [14]. The condition factor and the quantity of accumulated fat are also found to follow the rhythm of the reproductive process [26]. At the beginning of this process, high values are the result of fat accumulation in the preceding phases; a gradual K decrease occurs together with decrease in fat. Afterwards, there is a gradual increase in accumulated fat and K values, suggesting a preparatory span for a new reproductive cycle.

There were significantly more *Clarias buettikoferi* male than female individuals observed during this study, due mainly to dominance of males during breeding seasons (May-July and September-October). Preponderance of male specimens over females had similarly been observed for, respectively, populations of *C. anguillaris* (Sex ratio = 1:0.6) in Cross River [17], *C. gariepinus* (sex ratio = 1:0.5) in Opa Reservoir (Nigeria) [14] and *Heterobranchus longifilis* (sex ratio = 1:0.52) in Cross River [7]. In fish, sex ratio varies considerably from species to species but in the majority of species it is close to 1:1 [19]. Any deviation from this ratio is thought to indicate the dominance of one sex over the other. This happens because of differential behavior of sexes, fishing, etc. [27]. Ham [28] suggested that sex disparity could be a result of the differential survival of certain environmental conditions, while Fagade *et al*. [29] described it as a mechanism for population regulation in fishes. It is thought that for some catfishes, once fertilization of eggs has ended males emigrate from spawning grounds towards feeding grounds located in shallow parts (where they are easily captured) and females go towards submerged vegetation and rocky areas to ovoid gear and carry out incubation and protection of offspring [6, 7, 28]. In the case of Tanoe-Ehy swamp forest; this last reason is probably an important cause of the skewed sex ratio in favor of male during breeding season: the spawning apparently occurred in habitats where females are difficult to capture.

When rainy and dry season's fecundity data were pooled together, the relationship between fecundity and body size did not demonstrate significant correlation. Adversely, a better correlation appeared among Tanoe-Ehy swamp forest fecundity and fish length data when rainy and dry season data were analyzed separately. This later result was consistent with previous research data on other Clariid catfish (*Clarias anguillaris*, *C. ebriensis*, *C. gariepinus* and *Heterobranchus longifilis*) [7, 14, 16, 17] which showed linear relationship with body length and weight and ovary weight. Although the number of female individuals at maturity stage IV caught in the Tanoe-Ehy swamp forest during dry season was limited, this result showed that the number of oocyts spawned is dependant to both fish size and hydrological season characteristics: *C. buettikoferi* has adapted its reproductive strategies such that it produced much more oocyts during the flooded seasons. Peak fecundity in other Clariid catfishes (*C. gariepinus*, from different basins and *Clarias lazera*) occurred with the onset of rains and the rising flood [24, 29]. Nutritional resources are known to play critical roles in regulating variations in fecundity [5-7]. According to Arawomo [22] and Oso *et al*. [23], the food shortage in some environmental conditions could cause low fecundity in fishes. This seemed particularly true for the Tanoe-Ehy swamp forest in which during dry season a major portion of the swampy environment is dried out, indicating a certain overall food scarcity, while during the forest flooded periods nutritional resource availability is supposed to be higher.

CONCLUSION

Results of the study on reproductive strategies of *Clarias buettikoferi* in the Tanoe-Ehy swamp forest (south-eastern Côte d'Ivoire) showed that the main activities related to this occurred during rainy seasons, when the forest is inundated. During breeding periods, sex ratio is skewed in favor of males, probably because at that time females moved towards specific places to spawn and take care of the offspring. Higher condition factor and higher fecundity were observed during the rainy season, where flooded environment is supposed to provide sufficient food resources for fish and their offspring. These data on the reproduction of *Clarias buettikoferi* were however comparable with those previously mentioned for other tropical catfish species and suggested that the capture of the species in the Tanoe-Ehy Swamp forest during dry season by fishermen should be done with appropriate sampling gear, to give more chance to female specimens in next reproduction activities during rainy season.

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