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SHORT COMMUNICATION

Artificial reproduction and reproductive parameters of silver catfish *Schilbe intermedius* (Siluriformes: Schilbeidae) – implications for the conservation and domestication of this threatened species

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Abstract
The silver catfish *Schilbe intermedius* (Rüppell, 1832) is single-spawning species spread in Africa and may reach 50 cm in length. Since there are no studies on the artificial reproduction of *S. intermedius*, the aim of the present study was to induce for the first time spawning by hormonal injection and to determine the reproductive parameters for this species. Artificial induction was carried out by the injection of Ovaprim (0.5 ml kg^{-1}) to males and females. Different eggs measurements were carried out by micrometer. Egg stripping was carried out ten hours after hormone injection at 27.17 ± 0.22 °C (mean ± standard deviation) with mean spawning rate 58.15 ± 2.88 %. Relative fecundity was 613.25 ± 71.83 oocytes/g with mean diameters 0.94 ± 0.10 mm and 1.11 ± 0.06 mm, respectively, before and after eggs fertilization. Fecundity and hatching rates ranged, respectively, from 60.30 to 68.02 % and 56.11–60.96 %. Egg hatching occurred about 22 or 28 h after fertilization at 26.02 °C, and the larvae average length was 1.24 ± 0.14 mm. Yolk sac resorption occurred 48 h after hatching and larvae acquired their morphological structures in about 72 h after hatching. This information will be important in improving the artificial reproduction protocols of *S. intermedius* in controlled breeding programs.

Keywords *Schilbe intermedius* · Hormone induction · Fecundity · Hatching · Yolk sac · Larvae

Introduction

Schilbe intermedius Rüppell, 1832 (Schilbeidae) is spread in Africa and may reach 50 cm in length (De Vos 1984; Paugy et al. 1999). It was found as a potential aquaculture species (Merron 1991; Skelton 2001; Fermon 2010). It is used in small aquaculture in countries like Benin (FAO 2006). It is very appreciated by consumers owing to the fineness of its meat (Bills et al. 2010). However, its domestication is limited due to constraints in getting its larvae from natural waters. Moreover, the basic techniques for breeding *S. intermedius* from the larval stage to marketable size are not well-known, except a few studies on its parasitology, feeding ecology, population structure and reproductive biology (Smit et al. 2000; Teferra et al. 2003; Mosepele et al. 2006; Ahouansou Montcho et al. 2011). The species has not been listed as endangered and there is a risk of extinction in Benin, as this fish is being caught massively in aquatic ecosystems with various techniques and gear that violate fishing regulations (Tossavi et al. 2015), thereby large specimens (ripe fish) are becoming increasingly scarce (Ahouansou-Montcho et al. 2011). Further threats are anthropogenic activities like the riparian habitat destruction and water pollution. In order to ensure for the future full availability of *S. intermedius*, domestication trials are undertaken by the Research Laboratory on Wetlands (LRZH) of the University of Abomey-Calavi (UAC). Interest in farming this type of fish is growing in Asia with *Micronema bleekeri* Gunther, 1864 (Long et al. 2008) as in Africa Gabon with *Schilbe multitaeniatus* Pellegrin, 1913 and *Schilbe grenfelli* Boulenger, 1912 (Liwouwou et al. 2013, 2014; Liwouwou 2016).

For the successfull domestication of any species it is important to ensure a successfull reproduction to get a lot of

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larvae and fingerlings (Woynarovich and Horváth 1981). According to Woynarovich and Horváth (1981), artificial reproduction presents several advantages such as getting larvae all through the year (out of natural spawning season), easy genetic improvement of the stock, easy hybridization, breaking of "parasite chain". This technique also enables the monitoring of embryonic and larval development.

Studies of reproductive parameters are very important to conservation and commercial fish farming. Indeed, a clear knowledge of the fecundity provides significant data to evaluate the commercial potentialities of fish stock and also can be used to assess the abundance and reproductive potential of the spawning stock (Sarker et al. 2002). Moreover, Gonado-Somatic Index (GSI) is one of the important parameters of the fish biology, which gives a detailed idea regarding the fish reproduction, reproductive status of the fish species and help in ascertaining the breeding period of fish (Kaur et al. 2018). For various reasons, the expected oocyte number in spawning is usually higher than the production of fingerlings (Santos et al. 2013). Thus, other biological variables such as embryonic and larval development are important to fish conservationists to find ideal conditions for the production of fingerlings and to obtain higher rates of survival in captivity. Furthermore, conservation efforts in the field could be more successful if corroborated by captivity studies. Therefore, one of the first steps in helping conservation biologists rescue endangered species is the study of their development in captivity (Honji et al. 2012). Control of artificial reproduction is the basic knowledge required to improve the artificial propagation of any cultured species. This is also applicable to aquaculture. For instance, knowledge of the onset of exogenous feeding and yolk-sac absorption is important to know when to begin supplemental feeding. Hence, it is an integral step toward developing management and rearing technology for new species targeted to commercial production (Ferosekhan et al. 2015). This information is even more important in this study, because the artificial reproduction essays carried out on *S. intermedius* (Bondombe Wa Yalokombe 2014) don't provide enough details on reproductive parameters.

Considering the importance of *S. intermedius*, the information of its artificial reproduction is an important requirement for optimization of the large scale seed production, especially for conservation, culture and management. Therefore, the goal of this study was to carry out artificial reproduction of *S. intermedius* and to determine in a controlled captive condition the reproductive parameters for this threatened species.

Materials and methods

Experimental conditions

Experiments on artificial reproduction were carried out in the hatchery of the Research Laboratory on Wetlands (LRZH) of the University of Abomey-Calavi. For this purpose we used the artificial reproduction technique carried out with *Clarias gariepinus* Burchell, 1822 and *Heterobranchus longifilis* Valenciennes, 1840 (Micha 1973; De Kimpe and Micha 1974; Legendre et al. 1992) and those from our own preliminary experiments on *S. intermedius*. Broodstock were captured in « Acadjas » (brush park in lake and river) installed in Ouémé River in Agonlin-Lowé (N 06°39'378''E 02°28'571''). They were transported by the method described by Tossavi et al. (2016) in the research station on fish farming diversification of the LRZH where they were acclimated and stocked per 500 specimens' lot in rectangular ponds containing 5 m^3 water. They stayed in ponds until selection of mature broodstock for reproduction. During this period, fish were fed daily on 5 % of biomass ration with frog tadpoles and then progressively substituted by artificial commercial feed Coppens (45 % proteins; 10 % lipids). Experiments on artificial reproduction were carried out during the natural reproduction season that only lasts two or three months (from August to October) and always during the flood. For this experiment with *S. intermedius*, the fishing of broodstock for scientific research purposes was authorized by decision N° 079/MAEP/SGM/DPH/SAGP/Se of July 07, 2015.

Selection of broodstock

Mature broodstock were selected based on external sexual features: females with bulging genital papilla, developed and soft abdomen (Fig. 1b) and able to release oocytes after a slight pressure (Fig. 1c); males (Fig. 1a) with big tough testicle able to release milt after a slight pressure (Santos et al. 2013). Thus four females and eight males (two males for one female) were selected, weighed, measured individually and stocked separately according to sex in two circular cemented ponds containing about 250 L water each (3.14 × 0.25 × 0.33 m). Ponds water was equilibrated at pH 7 by chlorine evaporation, ponds were equipped by shade system that maintains temperature at 27.17 ± 0.22 °C and oxygenation system to maintain dissolved oxygen rate ≥ 5 mg L^{-1}.

Treatment by hormone

Ovaprim (SGnRHa + Domperidone) was used for final maturing induction in the fishes. Both females and males received 0.5 ml kg^{-1} of live weight of this hormone (Table 1). Injection was carried out at 8 am in the dorsal muscle between the dorsal fin and the lateral line. After injection, fish were put back in their pond and monitored in order to detect every sign indicating eggs and milt are ready to be released. The monitoring of gametes maturing was carried out in females by observation of their side, abdomen palpation and by the presence of oocytes in the water.

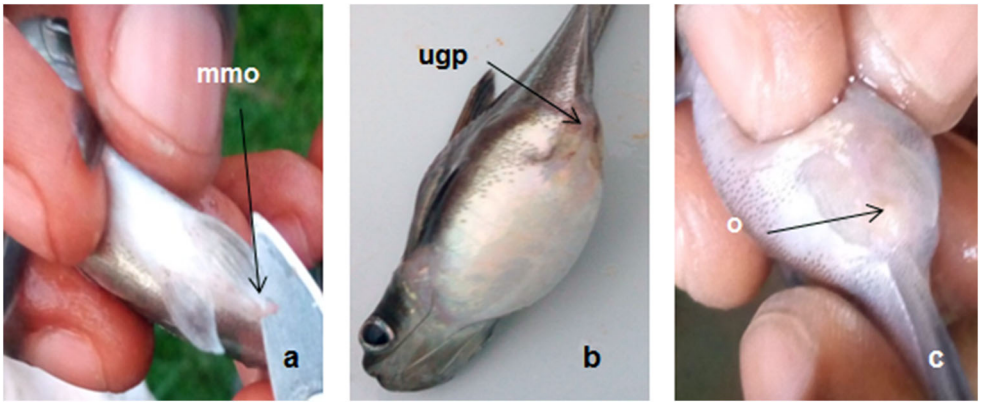

Fig. 1 Photo of sex differentiation in *Schilbe intermedius*. **a** Male, male mating organ (mmo); **b** female, urogenital papilla (ugp); **c** female release oocytes (o) by slight pressure

Collection of gametes

After the latency (10 h), oocytes and milt were collected respectively from males and female broodstock. Eggs were stripped in dry bowl. Spawned eggs and spawning rate were estimated for each female. Eggs samples were taken and counted in order to determine the total fecundity of each female. Milt was obtained by scarifying males. Testicles were taken, weighed, cut and finely crushed by using a lancet.

Fertilization, hatchery and larval rearing

Dry fertilization was carried out by mixing eggs and milt with bird feather. Salt serum (0.9 % NaCl) was added to this mixture and then mixed to enable oocytes fertilization by spermatozoids. Fertilized eggs were then spread in incubators (mesh ≤ 0.5 mm) before being transferred to hatchery ponds watered by a closed circuit with 0.5 L/min renewal. Physico-chemical parameters of hatchery ponds water were: temperature 25.2–27.1 °C (26.02 ± 0.53), dissolved oxygen 5.3–6.5 mg L^{-1} (5.9 ± 0.35) and pH 7.00–7.4 (7.1 ± 0.15).

After yolk sac resorption, larvae were daily fed at satiety on zooplankton issued from mono-specific culture of rotifers but also according to Honji et al. (2012) with *Artemia nauplii* (EG grade, INVE, Dendermonde, Belgium). Feed was supplied once hourly.

Data treatment

Absolute fecundity (AF) is the total number of eggs produced by the female, relative fecundity (RF), spawning rate (SR), fecundity rate (FR), hatching rate (HR), gonado-somatic index (GSI) were calculated through the following formula:

Table 1 Some characteristics of *Schilbe intermedius* broodstock selected and treated with Ovaprim during the artificial reproduction carried out in the Research Laboratory on Wetlands in October 2016

Sex of the broodstock	Different measurements			Dose of Ovaprim (ml kg^{-1})	Quantity of Ovaprim injected (ml)
	IW (g)	TL (cm)	SL (cm)		
Female 1	12.5	11.5	10.0	0.5	0.00625
Female 2	15.16	13.2	11.3	0.5	0.00758
Female 3	27.0	17.4	14.6	0.5	0.0135
Female 4	32.9	18.6	16.0	0.5	0.01645
Male 1	8.9	11.5	10.0	0.5	0.00445
Male 2	9.5	12.5	10.5	0.5	0.00475
Male 3	10.8	13.1	11.0	0.5	0.0054
Male 4	11.90	14.0	11.5	0.5	0.00595
Male 5	14.27	14.0	11.6	0.5	0.007135
Male 6	14.22	13.7	11.2	0.5	0.00711
Male 7	18.6	17.6	13.5	0.5	0.0093
Male 8	17.9	17.4	13.4	0.5	0.00895

Individual weight (IW), total length (TL), standard length (SL)

AF = stripped eggs + eggs released in water + remaining eggs in ovaries

RF (eggs/g) = absolute fecundity/female weight (g)

SR (%) = 100*((stripped eggs + eggs released in water)/absolute fecundity)

FR (%) = 100*(number of fertilized eggs/number of hatched eggs)

HR (%) = 100*(number of larvae/number of fertilized eggs)

GSI (%) = 100*(ovaries weight/fish weight)

The number of incubated eggs was determined by counting eggs number in 0.3 g oocytes sampled and estimation was carried out for the total oocytes quantity. Fertilized eggs number was determined by counting zygotes number in microscope (yolk concentration at medium, increase in the perivitelline space) of a total of 200 eggs sampled from the incubator.

Fifty eggs per female were used for the determination of hydrated and non-hydrated eggs diameter. Larvae height after hatching was determined by sampling randomly 50 larvae from hatching ponds. Different measurements were carried out by using Adobe Photoshop software (Version: 5.1.0.0.), image of object to be measured (egg, larvae) and micrometer.

The latency time was determined by multiplying the duration between injection and spawning time with water temperature (°C).

Statistical analyses

Descriptive statistic and linear regression of biological parameters such as absolute fecundity, number of incubated eggs, number of fertilized eggs, total length and total weight were carried out by using the StatView software (version 5.0.1.0) and mean and range were calculated.

Results

The eight male broodstock (mean weight 13.26 ± 2.98 g [mean ± SD]; mean length 14.225 ± 1.63 cm [mean ± SD]) and the four female broodstock (mean weight 21.89 ± 8.06 g; mean length 15.175 ± 2.82 cm) injected with Ovaprim (0.5 ml kg^{-1} of live weight) produced, respectively, milt and oocytes that are useful for artificial reproduction.

Gonads in males and females of *S. intermedius* are paired and open into the uro-genital orifice. Testicles are situated in the dorsal general cavity and prolonged by deferent channel leading to the genital papilla. At maturity, they are whitish (Fig. 2a). Concerning ovaries, they are suspended dorsally in the peritoneal cavity. Ovaries are richly vascular (Fig. 2b). The mean value of GSI in females was 26.49 ± 3.40 (mean ± SD).

To maximize fecundity rate, gonads of two males were used for one female eggs fertilization. Final maturity of gonads was obtained 10 h after hormone injection at 27.17 ± 0.22 °C corresponding to 271.7 degree-hours to spawning. Ripe oocytes of *S. intermedius* are opaque, yellowish, adhesive and covered by viscous liquid (Fig. 2c). Measurements carried out on eggs and larvae are mentioned in Table 2. This table shows non hydrated eggs diameter (eggs after stripping) 0.94 ± 0.10 mm. This diameter increased by 18 % after eggs hydration and reached 1.11 ± 0.06 mm.

Mean values and intervals of reproduction parameters in *S. intermedius* are mentioned in Table 3. During the current study, the absolute fecundity was 7786.66–17242.33 oocytes. Spawning rates were 53.12–62.34 % and GSI varied from 22.18 to 33. 31 %. Fecundity and hatching rates ranged between 60.30 and 68.02 % and 56.11–60.96 %, respectively.

Results of linear regression analysis between the absolute fecundity, number of incubated eggs, number of fertilized eggs and individual weight or total length in *S. intermedius* are presented in Figs. 3 and 4, respectively.

The hatching time in *S. intermedius* varied from 22 to 28 h at 26.02 °C, corresponding to 554.4–758.8 degree-hours (632.65 ± 63.07). Whitish larvae obtained stuck on the hatching pond side. Their total length varied from 1.08 to 1.7 mm.

Discussion

The current study showed hormone induction with Ovaprim in *S. intermedius* and could be considered satisfactory, because males and females injected produced milt and ripe oocytes, respectively . The response of *S. intermedius* toward Ovaprim is similar in other siluriformes species such as *Micronema bleekeri* Bocourt, 1866 (Long et al. 2008), *Clarias gariepinus* Burchell, 1822 (Legendre et al. 1992; Váradi et al. 1999; Olaniyi and Omitogun 2013) and *Heterobranchus bidorsalis* Geoffroy Saint-Hilaire, 1840 (Olaniyi and Omitogun 2014). In addition, this success could be explained by the fact that the experiment was carried out in the natural reproduction period of the species that has a unique spawning in the rainy season (Albaret 1982). Indeed, during our preliminary experiments on this species reproduction, every assay of artificial reproduction out of this unique period led to failure. Oocytes maturation in *S. intermedius* is a very

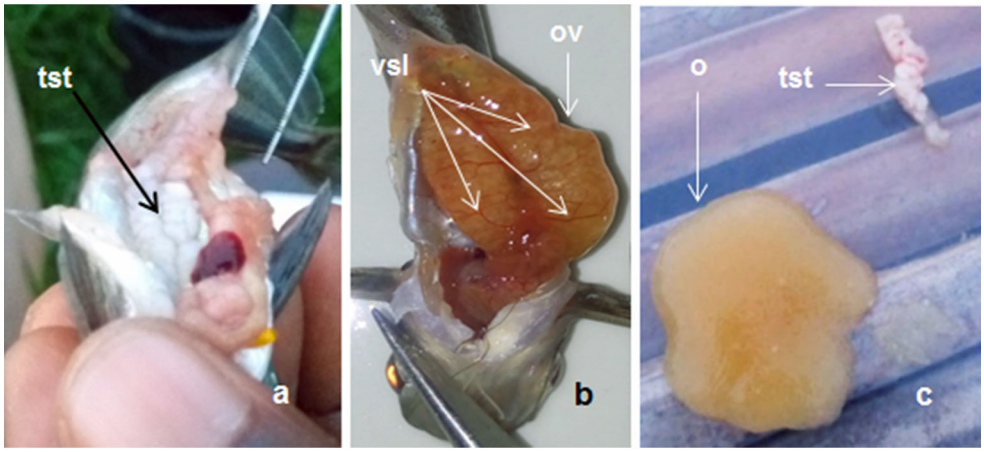

Fig. 2 Photo of male and female broodstock' gonads in *Schilbe intermedius*. **a** Male broodstock showing testicles (tst) with combs; **b** mature female broodstock with richly vascular ovary (ov) (vessels, vsl); **c** oocytes (o) obtained by stripping and isolated male testicles

slow, cyclic and seasonal process. Out of the natural spawning period, females carried non mature eggs that never reached pre-reproductive maturity despite hormone induction.

In this fish species, gonads in males and females are paired and situated in the dorsal general cavity. This is similar to those observed generally in teleosts (Legendre and Jalabert 1988).

Temperature is an important environmental variable that influences the metabolism of living beings. Its variation plays a role in fish reproduction (Bénech and Ouattara 1990). Besides, degree-hours (relationship between hormone injection and spawning time with the water temperature) is an important tool for spawning and hatching estimation. Spawning happened 271.7 degree-hours (10 h) in *S. intermedius* after the injection of Ovaprim at 27.17 ± 0.22 °C though it happened 217.5 degree-hour (7 h 30 min at 29 °C) after injection of the same dose of the hormone CGH to the species *M. bleekeri* (Long et al. 2008). The difference could be explained by the nature of the hormone. The result obtained in *S. intermedius* is also different from that obtained by Olaniyi and Omitogun (2014) in the African catfish *H. bidorsalis* (378 degree-hours) though artificial induction was realized with the same hormone (Ovaprim) and at the same temperature (27 °C). This difference could be explained by the different doses of hormone (1 ml/kg against 0.5 ml/kg in the current study) injected to broodstock during these two studies but also by the influence of the reproductive period. Indeed, during the unique natural spawning period of *S. intermedius* ovaries contained oocytes at pre-reproductive maturity stage that reached final maturity shortly after hormone injection. The 10 h latency recorded in *S. intermedius* during the current study is similar to 11–12 h recorded at 26–27 °C in *C. gariepinus* (Adebayo and Papoola 2008; Ducarme and Micha 2003).

Eggs of *S. intermedius* are ovate, opaque, yellowish, adhesive and covered by a viscous liquid. These features are common to catfishes eggs (Santos et al. 2013). The yellow color of oocytes characterizes the presence of carotenoid pigments indispensable for growth due to its content in endogenous oxygen and energy source for embryonic development (Balon 1977; Kitahara 1984). The mean diameter of non-hydrated eggs of *S. intermedius* was 0.94 ± 0.10 mm. This diameter is similar to those recorded in the same species by Bondombe Wa Yalokombe (2014) and in the closely related species *S. multitaeniatus* (Liwouwou et al. 2014). *Schilbe intermedius* eggs diameter are the same as in *C. gariepinus* (0.9–1.1 mm, Olaniyi and Omitogun 2013), *H. bidorsalis* (1 ± 0.1 mm,

Table 2 Values (mean ± standard deviation) of non-hydrated eggs diameter (NHED), hydrated eggs diameter (HED), yolk sac diameter (VD) and larvae total length (LTL) after artificial reproduction of *Schilbe intermedius*

Eggs measurement	N	Mean±SD	Interval
NHED	50	0.94±0.10 mm	0.80–1.09 mm
HED	50	1.11±0.06 mm	1.01–1.3 mm
VD*	50	0.39±0.03 mm	0.33–0.5 mm
LTL*	50	1.24±0.14 mm	1.08–1.7 mm

N: Number of samples measured; * Measurement after hatching

Table 3 Values (mean ± standard deviation) of reproduction parameters in *Schilbe intermedius*

Parametres	N	Mean±SD	Interval
Absolute fecundity	4	12860.96±3303.53	7786.66–17242.33
Relative fecundity (eggs/g)	4	613.25±71.83	524–747
Spawning rate (%)	4	58.15±2.88	53.12–62.34
Gonado-somatic Index (%)	4	26.49±3.40	22.18–33.31
Incubated eggs number	4	7363±1825	4137–10,034
Fertilized eggs number	4	4828.25±1320.75	2495–6623
Fecundity rate (%)	4	64.87±2.28	60.30–68.02
Hatching rate (%)	4	58.54±1.94	56.11–60.96

N: Number of females

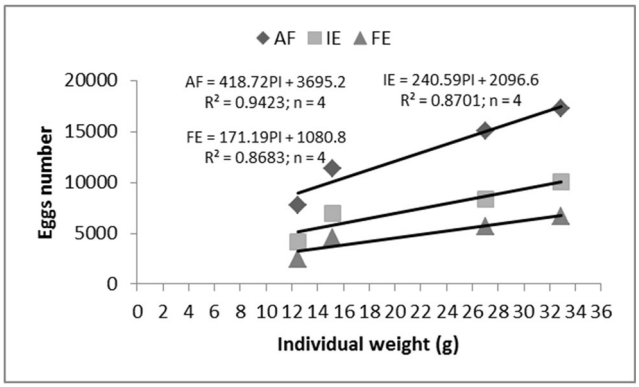

Fig. 3 Linear regression between absolute fecundity (AF), number of incubated eggs (IE), number of fertilized eggs (FE) and individual weight (IW) simultaneously obtained in four females of *Schilbe intermedius* during artificial reproduction carried out in the Research Laboratory on Wetlands in October 2016

Olaniyi and Omitogun 2014), but smaller than other catfish such as *Euchilichthys guentheri* (Schilthuis, 1891) (2.12 ± 0.39 mm, Tembeni et al. 2014) and *Trachelyopterus galeatus* Linnaeus, 1766 (2.2–2.4 mm, Santos et al. 2013). Variation in eggs diameter may be due to genetic characteristics of the species (Puvaneswari et al. 2009). After hydration, the average diameter increases to 1.11 ± 0.06 mm (an increase of 18 %) that is similar to 20 % recorded by Olaniyi and Omitogun (2014) in *H. bidorsalis* eggs (from 1 ± 0.1 mm to 1.2 ± 0.2 mm).

For *S. intermedius* we counted 613.25 ± 71.83 oocytes/g of ovum. This value represents almost the double of 351 oocytes/g determined in *T. galeatus* (Santos et al. 2013). This difference could be explained by oocytes diameter that was 2.323 ± 0.51 mm for *T. galeatus* against 0.94 ± 0.10 mm for *S. intermedius*. GSI of mature females of *S. intermedius* varied from 22.18 to 33.31 % with a mean value of 26.49 ± 3.40 %.

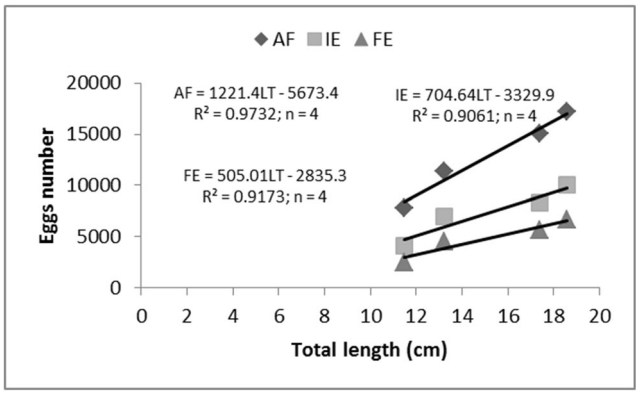

Fig. 4 Linear regression between the absolute fecundity (AF), number of incubated eggs (IE), number of fertilized eggs (FE) and total length (TL) simultaneously obtained in four females of *Schilbe intermedius* during the artificial reproduction carried out in the Research Laboratory on Wetlands in October 2016

These results are similar to those recorded by Paugy (2002) (23.4 %) in *S. intermedius*. They are also similar to those obtained in *S. multitaeniatus* (26 %) by Liwouwou et al. (2014).

The absolute fecundity recorded in *S. intermedius* during the current study varied from 7786.66 to 17242.33 oocytes. Prior studies carried out on the same species revealed a fecundity of 22,421 oocytes (Ahouansou-Montcho et al. 2011), 27,107 oocytes (Merron and Mann 1995) and 6004 oocytes (Chikou 2006). Although, the absolute fecundity recorded in *S. intermedius* during the current study ranged from 7480 to 90,724 oocytes recorded in *S. multitaeniatus* (Liwouwou et al. 2014). According to Sivashanthini et al. (2008), fecundity varies in relation to species and depends on age, length, weight and environment. Thus, *S. intermedius* has high fecundity compared to other catfish species such as *T. galeatus* (from 1505 to 4651 oocytes, Santos et al. 2013) and *Anabas testudineus* Bloch, 1792 (from 2785 to 4851 oocytes, Zalina et al. 2012). The high fecundity of *S. intermedius* could be explained by the small diameter of its oocytes. This is in accordance with the studies of Paugy (2002) that showed small eggs tended to increase fecundity. Besides, the current study showed an increase in fecundity, number of incubated eggs (spawned eggs) and number of fertilized eggs in relation to weight and total length of *S. intermedius* females. Similar trends were observed in prior studies (Micha 1973; Ghafari and Jamili 2010; Lawson 2011; Bondombe Wa Yalokombe 2014; Liwouwou et al. 2014). It was also reported that species with unique spawning have high fecundity due to the synchronization of oocytes development (Santos et al. 2013).

Hatching of *S. intermedius* eggs occurred at 632.65 ± 63.07 degree-hours (between 22 and 28 h) after fertilization at 26 °C. In contrary, Bondombe Wa Yalokombe (2014) reported in the same species incubation durations ranging from 18 to 52 h at 29 °C. This difference could be explained not only by temperature but by the difference among incubation media. Indeed, Bondombe Wa Yalokombe (2014) incubated eggs with *Eicchornia crassipes* roots placed in ponds. In such semi-natural environment, the monitoring of physico-chemical parameters is difficult and values recorded are not necessarily those required for good embryonic development. Adebayo et al. (2007) recorded that hatching of *C. gariepinus* eggs started from 22 h after fertilization at 25.5 °C. This duration is similar to that recorded in the current study. Ramanathan et al. (1985) recorded that the incubation period of *Mystus punctatus* (Jerdon, 1849) varied from 18 to 24 h at 28.5 ± 1.8 °C. This slight difference between incubation times of *M. punctatus* compared to those of *S. intermedius* could be explained by the influence of temperature. Zaki and Abdula (1983) recorded short incubation time in *C. gariepinus* at high temperature. In the current study, fertilization rates varied

from 60.30 to 68.02 % (64.87 ± 2.28 %) and were similar to those (45 to 76 %) recorded in the Asian Schilbeidae *M. bleekeri* (Long et al. 2008) and other siluriforms such as *Steindachneridion parahybae* Steindachner, 1877 (69.50 ± 10.20 %, Honji et al. 2012) and *T. galeatus* (60 %, Santos et al. 2013). Concerning hatching rates, they varied from 56.11 to 60.96 % (58.54 ± 1.94 %) and are lower than 85 to 90 % recorded in *M. bleekeri* (Long et al. 2008) and 68.33 ± 3.06 % recorded in *H. bidorsalis* (Olaniyi and Omitogun 2014). Embryo development and incubation period in most of fish species depend on temperature and vary in relation to species (De Graaf and Janssen 1996).

In the current study, mean values of total length of newly hatched *S. intermedius* larvae and yolk sac diameter were 1.24 ± 0.14 mm and 0.39 ± 0.03 mm, respectively. These values are lower than those recorded in *T. galeatus* (4.2 ± 0.1 mm and 1.673 mm, Santos et al. 2013). These variations were due to eggs diameter in the different species. Indeed, according to Bagarinao and Chua (1986), there is a positive correlation among eggs diameter, larvae height and weight after hatching. It is also important to notice that yolk sac diameter informs on the availability of nutritive reserves quantity for embryonic and post-embryonic development (Riehl and Patzner 1998).

Many recent studies have shown the importance of conservation biology in the rescue of endangered wildlife (Honji et al. 2012; Okomoda et al. 2017). There are implications for the conservation of *S. intermedius* from the present study. The reproductive parameters determined here allow for the development of strategies to obtain success in captivity breeding and the artificial propagation. Since *S. intermedius* is endangered, this information is critical in contributing to his aquaculture and conservation.

Conclusions

This study is a first investigation on the artificial reproduction and reproductive parameters *Schilbe intermedius*. The results obtained here demonstrated the success of artificial reproduction for this species. However, to ensure the survival of larvae, exogenous feeding must begin two days after hatching. These data provide information that can be used to control the domestication of this species in order to ensure the diversification of fish farming in Africa. The data from this study provided important biological information for the artificial propagation, management and conservation for this endangered species.

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Declarations The fishing of *S. intermedius* broodstock for scientific research purposes was authorized by decision N° 079/MAEP/SGM/DPH/SAGP/Se of 07 July 2015.

National and international guidelines that were followed for using animals in this study are:

- framework law n ° 2014-19 of 07 August 2014 relating to fishing and aquaculture in the Republic of Benin.
- Directive 2010/63 / EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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