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Effects of environmental enrichments on ovarian development of Buitta Catfish (*Sperata* sp.: Family Bagridae) in captivity ☆

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ABSTRACT

Environmental enrichment (EE) is an important factor that helps improve both the physical and psychological behavior of farmed animals. This factor also controls social interactions and provides more stimulants to influence the reproductive performance of animals in captivity. As EE plays an important role in animal reproduction, the present study was designed to investigate the effects of different types of tank bottom enrichments on the ovarian development of Buitta (*Sperata* sp.) catfish in captivity. Barren (T_A), muddy (T_B), and sandy (T_C) enrichments were utilized for four months to observe the physical and psychological changes of the catfish. The results showed significant differences ($p < 0.05$) in the weight gain, gonadosomatic index (GSI), and hepatosomatic index (HSI) of the fish, however, no significant difference was found in the fish fecundity. The most prominent changes include weight, ripeness, the biochemical composition of body tissues, and the frequency distribution of the migratory nucleus in the oocytes. Moreover, the diameter of oocytes that occurred in the enrichment T_C ($p < 0.05$) was significantly higher than the enrichments T_A and T_B. Histological observation found at least two stages of the ovarian oocytes development process in each ovary indicating the asynchronous self-reproduction of the fish. Additionally, biological macromolecules analysis found higher protein content in the muscle (86.04%), liver (52.97%), and oocyte (64.71%) and a higher deposition of lipid within the oocytes (32.33%) and liver (27.06%) for enrichment T_C, while these values were lower for the other two treatments. Finally, the study suggests that a sandy environment should be used to obtain an acceptable level of oocyte development in the female Buitta fish in captivity.

Introduction

Buitta, a member of the genus *Sperata* (Family: Bagridae) is one of the most important freshwater catfish species in South Asia including Bangladesh (Froese & Pauly, 2011; Gupta, 2015; Iqbal et al., 2018). The primary habitat of the species is running water like rivers, but some populations can live and spawn in stagnant waters like lakes, haors (a vast stagnant water body), lagoons, and swamps (Gupta, 2015). The species is one of the most abundant sport-caught fish from the haor off Bangladesh that has an important role in commercial fishery. The genus *Sperata* comprises two known species and one unknown species (Reference: NCBI:txid2093998) that is called Buitta in Bangladesh (Iqbal et al., 2018). Based on genomic evidence as well as variation in morphometric and meristic measures the unknown species of Buitta is thought to be a putative third species, however, it has not been officially recognized as a new species. The wetlands habitats initiate breeding from April to December, where the peak spawning time is

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around June to July (Akter et al., 2015). However, the spawning time and favorable conditions in captivity of the species have not been reported yet (Iqbal et al., 2018). The International Union for Conservation of Nature (IUCN) Bangladesh has declared Buitta as an endangered species due to the reduction of its natural feeding and spawning grounds, fluctuation of water physio-chemical parameters, and human intervention (IUCN, 2000). Therefore, it is necessary to collect reproductive information of female Buitta in captivity for aquaculture development.

Previously, several studies found that environment enrichment influences oocyte development in broodfish, including diet quality, age, genetics, physiology, health status, and environmental cues of rearing conditions (Bobe & Labbé, 2010; Buchet et al., 2008; Kabir et al., 2012; Lanes et al., 2012; Muhammad et al., 2019). The environmental stimuli that help to improve the physical and psychological conditions, as well as the reproductive performances of animals in captivity, include the shape and size of the rearing tank, water depth, and husbandry density or farming modifications. For example, the oocyte development along with quality and quantity of the European seabass, *Dicentrarchus labrax* (Buchet et al., 2008), the Atlantic horse mackerel, *Trachurus trachurus* (Ndjaula et al., 2009), and the common cuttlefish, *Sepia officinalis* (Sykes et al., 2013) are influenced by their environment enrichment in rearing tanks. A previous study performed by Ahmad et al. (2019) found that carp can perform better reproduction in captivity than in natural environments due to controllable ambient conditions and sample assortment. Controlling reproductive function in captivity is critical for the sustainability of commercial aquaculture production and in many fishes, it can be achieved by stimulating environmental enrichment or spawning substrate. Therefore, the stimulation of environmental enrichment may also enhance the oocytes maturation process of Buitta and help improve the breeding performances of this species. The process may also help to support stock enhancement efforts and population conservation of the species in the haor basin. Therefore, identifying favorable enrichments is an important issue that can help improve the reproduction of Buitta in captivity (Iqbal et al., 2018).

Most *Sperata* sp. prefer rocky and sandy bottom habitats, where female Buitta forms nest on the bottom of their natural breeding ground during the reproductive season (Gupta, 2015). The bottom substrate might influence Buitta ovarian development and can enhance the reproduction of the species. Hence, the objectives of the current study were to evaluate the effect of the bottom substrate on oocyte development in female Buitta based on changes in reproductive indices, histological observations on oocyte stages, and biochemical composition of body tissues.

Materials and methods

Experimental fish and rearing condition

Broodfish were captured by local artisanal fishermen from Hakaluki haor, Sylhet, Bangladesh, and directly transferred to our hatchery complex in a 500 L plastic container. Fishes were stocked at 10 individuals per rectangular cement tank measuring 4 m × 1 m × 1 m (length × wide × depth). Thirty days before starting the experiment, 90 fish were individually weighed and equally assigned to nine tanks with a 4:1 (female: male) sex ratio. The average weights were 346.42 ± 17.33 g and 280.70 ± 14.4 g for females and males, respectively. The nine experimental tanks were distributed into three triplicate treatments with different bottom substrates (Barren: control treatment 1-T_A, Muddy soil: treatment 2-T_B, and sandy soil: treatment 3-T_C). The tanks of T_B and T_C were covered with 30.5 cm of mud and sand bottom layers, respectively. Each experimental tank was established within an airflow system with a plastic pipe for oxygen and the water was supplied through the pipeline in the experimental tanks from an overhead tank of water. All tanks were covered with a black plastic net. During the experimental period, tanks were cleaned monthly by 50% water exchange to take away sediments as well as to reduce nitrogenous wastes within the system. All fish were fed with commercial fish feed (Mega fish feed, Bangladesh: protein 32%, lipid 5%, carbohydrate 8%, ash 18%, calcium 1.8%, phosphorus 0.6%,) at 3% of body weight at 9 am and 18 pm daily for 4 months. It is worth mentioning that the feeding rate was adjusted throughout the experiment by periodically measuring fish weight and accounting for mortality. Fish were monitored regularly to determine the survival rate throughout the study period.

Growth and reproductive development

At the end of the experiment, all surviving females were caught from each tank and anesthetized with MS222. The color of each fish's genital papillae was visually assessed, and the diameter of the papillae was measured with slide calipers. Furthermore, the survival rate of broodstock in each tank was quantified and the final weight of each remaining fish was recorded using a portable digital balance (Model: EB-10002C, China). Three anesthetized female broodfish from each tank were sacrificed, the body cavity was opened, the ovary and liver were removed, and the fish were individually weighed. A sampling of oocytes, fecundity, oocytes weight and diameter, and ripe oocytes rate was determined as previously described by Ahmad et al. (2019). An oocyte was identified as a ''ripe oocyte" when its germinal vesicle (nucleus) has migrated to its periphery. The reproductive and growth performance of each broodfish was computed as: Female brood survival (%) = (Number of surviving females/Total initial number of females) × 100; Relative growth (%) = {(Final weight - initial weight)/initial weight} × 100; gonadosomatic index (GSI) (%) = (Gonad weight/-body weight) × 100; hepatosomatic index (his) (%) = (Weight of liver/body weight) × 100; Viscera-somatic index, viscerosomatic index (VSI) (%) = (Viscera weight/body weight) × 100; Fecundity = (Total number of oocytes in ovary/Total weight); Ripe oocyte (%) = (Number of oocytes which germinal vesicle (nucleus) was move to the near one edge of the oocyte/Total number of oocytes counted) × 100, and egg weight was calculated from the weight of a known number of eggs. About 25 g of oocytes from the ovary of each sampled fish and 25 g of tissue samples from muscle and liver were cut and kept in plastic vials. Then, they were frozen at −20 °C for proximate composition analyses (i.e., protein, lipid, and ash).

Histological and biochemical analysis

The preserved sample tissues were fixed with 10% formaldehyde solution for 24 h. The ovaries were dehydrated, embedded in paraffin, and sectioned with a microtome into 8 μm thick sections according to the standard protocol of (Davenport, 1960). Staining was performed by Mayer's haematoxylin and eosin. Classification for the oocyte stages was determined by the availability of the most advanced development of oocytes within the ovary sections (Brown-Peterson et al., 2011; Kabir et al., 2012; West, 1990). Apart from counting on the number of gravid oocytes in each slide, every oocyte cell was measured for its diameter, then, calculated for an average oocyte diameter in each treatment. The biochemical composition analysis was comprised of the levels of protein, lipid, and ashes. The sampled tissue of body muscle, liver and oocytes were analyzed under the AOAC protocol (AOAC, 2000).

Hydro-ecological variables

Water temperature, pH, and dissolved oxygen (DO) were recorded once a week throughout the 4-months for each tank using portable digital instrumentation (Model HI98194, Hanna) in the morning. The levels of hardness, nitrite, and ammonia level were measured using a test kit (Model FF-3, HACH), and turbidity was monitored weekly using a Secchi disc at noon.

Statistical analysis

One-way analysis of variance (ANOVA) was used as a statistical tool for determining differences among treatments. Wherever the F-test was significant Duncan's multiple range test was used to compare the means of the three different treatments. The differences were considered significant at $p < 0.05$. All applied statistical analyses were done using SPSS package version 20.0 (free trial version). The results are presented as the means ± standard deviations.

Results

Growth and reproductive development

The results showed that the tank bottom with sandy soil (T_C) significantly ($p < 0.05$) enhanced ovarian development of Buitta, which was presented by significantly higher values of GSI (8.77 ± 0.01), oocyte diameter (0.68 ± 0.08 cm), egg weight (0.54 ± 0.09 mg) and percentage of ripe oocytes (91.66 ± 5.13%) than the controlled treatment (T_A) (GSI = 7.74 ± 0.28; oocyte diameter = 0.50 ± 0.01 cm; egg weight = 0.37 ± 0.02 mg; and percentage of ripe oocytes = 4 0.00 ± 2.64%). When comparing the two types of bottom lining, the sandy soil bottom gave a higher oocyte diameter and percentage of ripe oocytes than those of the muddy bottom. However, no significant differences were observed between the GSI and egg weight. The color of the urogenital papilla of T_C supported the well-developed ovary of this treatment. Interestingly, lining the pond bottom with sandy soil significantly promoted the growth and HSI of Buitta when compared to the muddy bottom and no bottom lining (Table 1). However, the survival rate and VSI were not significantly ($p > 0.05$) different among treatments. On the other hand, broodfish rearing in the T_A tank had shown a significantly lower GSI and HSI compared to those reared in T_B and T_C tanks. The highest GSI and his values have been observed in broodfish kept on a sandy bottom (T_C). Furthermore, the VSI had not shown any significant ($p > 0.05$) differences between the three tanks bottom condition. The ovipositor color of female broodfish in T_C had displayed a reddish color compared to other treatments, which is considered a sign of a healthier condition of the fish. The fecundity of broodfish from different treatments was not significantly ($p > 0.05$) different. The egg quality in terms of total egg weight and ripeness was significantly different ($p < 0.05$) among the treatments. The highest oocytes weight was observed in treatment T_C, while no obvious effect was seen on the oocytes weight in the broodfish reared in T_B and T_C tanks. Besides, the highest ripeness of eggs was also observed in treatment T_C.

Table 1
Weight gained, reproductive development, and oocytes development of Buitta fish reared on different tank bottom conditions. Data expressed as means ± standard deviation (SD).

Traits	Tanks		
	T_A	T_B	T_C
Initial weight (g)	346.77 ± 20.23	344.33 ± 15.27	349.33 ± 18.50
Final weight (g)	356.83 ± 11.40^a	379.50 ± 1.30^b	397.10 ± 3.59^c
Relative growth (%)	5.18 ± 2.80^a	10.35 ± 4.77^b	13.89 ± 6.22^c
Survival rate (%)	98.61 ± 2.40^a	100.00 ± 0.00^a	100.00 ± 0.00^a
HSI	1.01 ± 0.04^a	1.46 ± 0.09^b	1.69 ± 0.02^c
VSI	3.73 ± 0.29^a	3.42 ± 0.27^a	3.97 ± 0.25^a
GSI	7.74 ± 0.28^a	8.38 ± 0.62^{ab}	8.77 ± 0.01^b
Urogenital papilla color	Pink to reddish	Pink to reddish	Reddish
OD (cm)	0.50 ± 0.01^a	0.63 ± 0.01^b	0.68 ± 0.08^c
Fecundity (eggs*Female BW^{-1}) × 10^3	63.89 ± 4.05^a	56.37 ± 6.20^a	57.61 ± 7.89^a
Egg weight (mg)	0.37 ± 0.02^a	0.46 ± 0.06^{ab}	0.54 ± 0.09^b
Ripe oocytes (%)	4.00 ± 2.64^a	17.33 ± 5.50^b	91.66 ± 5.13^c

Note: T_A: Barren; T_B: Muddy; and T_C: Sandy Bottom. Different superscripts in each row represent significant difference ($p < 0.05$). OD: Oocyte diameter; BW: Body Weight.

Histological observation of ovaries

Buitta fish have an asynchronous ovary with at least two phases of oocytes that were observed in the same fish. The oocyte development stages based on the histological study in female Buitta could be divided into four stages: the *peri* nucleolus oocytes (PNO), yolk vesicle oocyte (YVO), yolk granule oocytes (YGO), and migratory nucleus oocyte (MNO) (Fig. 1). The distribution of the different percentages of various stages of oocyte development in female Buitta is shown in Table 2 and represented in Fig. 2. Except for the YGOs, all stages of oocyte development were significantly ($p < 0.05$) different among fish reared on different bottom types of treatments.

Histological results from the all-female broodfish ovary in T_A had shown that primary oocytes were significantly ($p < 0.05$) dominant compared to other treatments. On the other hand, broodfish from the T_C tank contained the highest percentage of the MNO stage ($p < 0.05$) compared to T_A and T_B treatments. Furthermore, it was noticed that at least two stages of oocytes were present in each ovary section of broodfish in this study.

Biochemical content of body muscle, liver, and oocyte

The proximate composition of body muscle, liver, and oocytes of female Buitta is displayed in Table 3. Protein and lipid content within body muscle and oocyte tissues from the T_C tank was significantly ($p < 0.05$) high compared to the other tanks' bottom types. However, there was no significant ($p > 0.05$) difference in the protein content of the liver tissue of broodfish from every tank bottom type. Broodfish from the T_C tank contained higher protein content in the muscle (86.04%), liver (52.97%), and oocyte (64.71%). Moreover, the T_C tank contained a higher deposition of lipid within the oocyte (32.33%) and liver (27.06%) compared to other treatments. Besides, T_C had resulted in a significantly ($p < 0.05$) high value of ash in muscle, oocyte, and liver.

Hydro-ecological variables

The hydro-ecological variables during the experimental period are shown in Table 4. The major hydro-ecological parameters comprised water temperature, DO, pH, and alkalinity. All parameters were not significantly ($p > 0.05$) different among experimental tanks. However, turbidity, hardness, and nitrite were significantly ($p < 0.05$) elevated in the T_A tank compared to other tanks during the study period.

Discussion

During the breeding season, female Buitta fish naturally create their nest on the bottom of the breeding ground. Therefore, adding favorable environmental enrichments to the bottom of the rearing tank may promote oocyte development and influence the

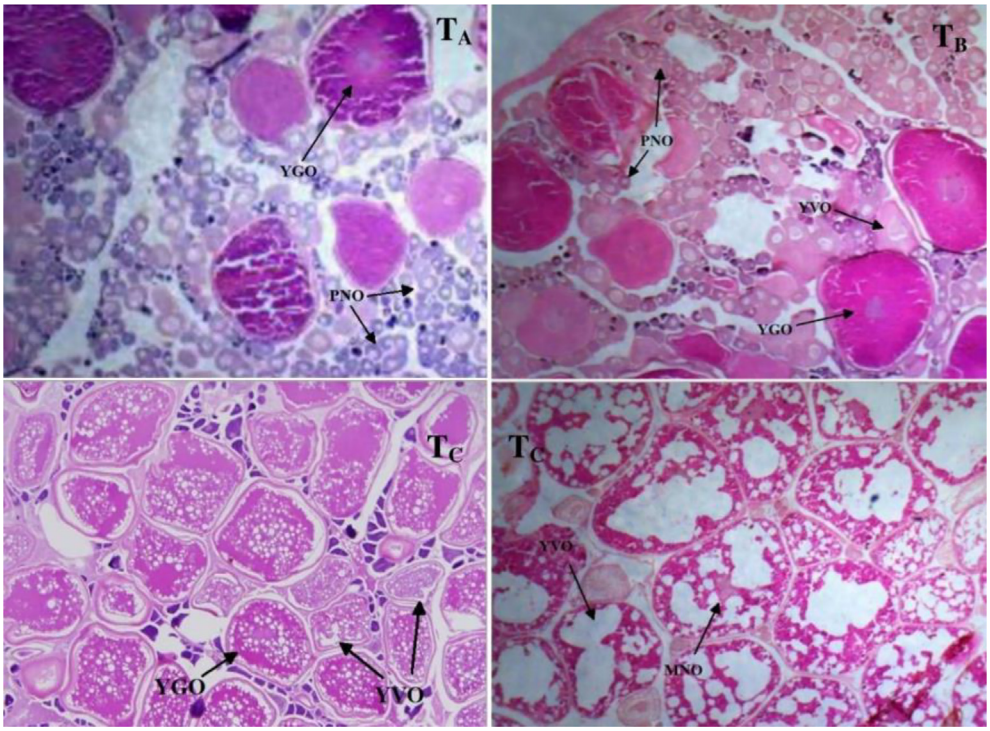

Fig. 1. Histological images of ovarian oocytes maturation of the Buitta fish reared on different tank bottom conditions (Barren, T_A; Muddy, T_B; and Sandy, T_C). PNO: *Peri* nucleolus oocyte; YVO: Yolk vesicle oocyte; YGO: Yolk granule oocyte; MNO: Migratory nucleus oocyte.

Table 2
Frequency distribution of different stages of oocytes in the ovary of Buitta reared on different tank bottom conditions (n = 9).

Variables	Tanks		
	T_A	T_B	T_C
Primary oocyte	68.88 ± 5.02^{c}	54.44 ± 8.38^{b}	6.66 ± 3.33^{a}
Yolk vesicle oocyte	18.88 ± 5.09^{ab}	26.66 ± 6.66^{b}	11.11 ± 1.92^{a}
Yolk granule oocyte	12.22 ± 1.92^{a}	13.33 ± 3.33^{a}	19.99 ± 5.77^{a}
Migratory nucleus oocyte	00.00 ± 0.00^{a}	5.55 ± 1.92^{a}	62.22 ± 8.39^{b}

*T_A: Barren; T_B: Muddy; and T_C: Sandy Bottom. Note: Different superscripts in each row represent significant difference ($p < 0.05$).

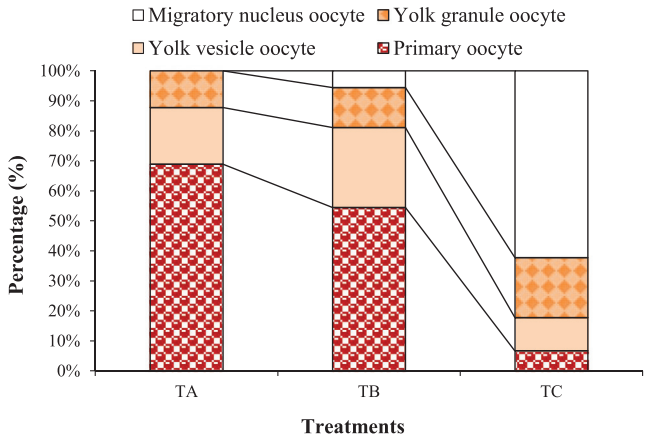

Fig. 2. Frequency distribution of different stages of oocytes in the ovary of Buitta in the three treatment tanks with different bottom substrates (T_A: Barren; T_B: Muddy; and T_C: Sandy Bottom) (n = 9).

reproduction rate of the fish. Several studies suggested that rearing tank shape and size, water depth, flow, and husbandry density or farming modifications can influence gametocyte development as

Table 3
Proximate composition (g/ 100 g, dry weight) of muscle, liver, and oocytes of Buitta reared on different tank bottom conditions.

Variables	Tanks		
	T_A	T_B	T_C
Muscle			
Protein	82.66 ± 0.7^{a}	83.49 ± 1.85^{a}	86.04 ± 0.15^{b}
Lipid	4.97 ± 0.25^{a}	4.89 ± 0.29^{a}	6.43 ± 0.47^{b}
Ash	6.32 ± 0.43^{a}	6.64 ± 0.43^{a}	7.74 ± 0.31^{b}
Liver			
Protein	50.87 ± 1.30^{a}	51.22 ± 1.04^{a}	52.97 ± 1.34^{a}
Lipid	25.35 ± 0.69^{a}	26.93 ± 0.28^{b}	27.06 ± 0.14^{b}
Ash	4.62 ± 0.53^{a}	4.75 ± 0.31^{a}	5.93 ± 0.25^{b}
Oocyte			
Protein	62.97 ± 1.36^{ab}	61.43 ± 0.60^{a}	64.71 ± 0.77^{b}
Lipid	27.78 ± 0.47^{a}	29.48 ± 0.75^{b}	32.33 ± 0.98^{c}
Ash	5.98 ± 0.23^{a}	5.83 ± 0.30^{a}	7.91 ± 0.20^{b}

*T_A: Barren; T_B: Muddy; and T_C: Sandy Bottom. Note: Different superscripts in each row represent significant difference ($p < 0.05$).

Table 4
Hydro-ecological variables of Buitta fish reared on different tank bottom conditions.

Variables	Tanks		
	T_A	T_B	T_C
Dissolved oxygen (mg·L^{-1})	5.05 ± 0.12	5.12 ± 0.20	5.06 ± 0.24
pH	6.97 ± 0.16	7.12 ± 0.12	7.28 ± 0.38
Temperature (°C)	30.66 ± 1.52	29.66 ± 1.52	30.00 ± 2.64
Turbidity (cm)	20.33 ± 2.08^{b}	18.66 ± 3.05^{b}	11.00 ± 1.00^{a}
Hardness	85.33 ± 6.35^{b}	72.00 ± 2.64^{a}	69.66 ± 1.52^{a}
Nitrite (mg·L^{-1})	0.05 ± 0.01^{b}	0.04 ± 0.01^{ab}	0.03 ± 0.01^{a}
Ammonia (mg·L^{-1})	0.16 ± 0.02^{a}	0.17 ± 0.01^{a}	0.21 ± 0.02^{b}
Alkalinity (mg·L^{-1})	70.66 ± 6.42	78.00 ± 2.64	71.66 ± 1.52

*T_A: Barren; T_B: Muddy; and T_C: Sandy Bottom. Note: Different superscripts in each row represent significant difference ($p < 0.05$).

well as oocytes quality and quantity improvement of female broodstock (Brooks et al., 1997; Buchet et al., 2008; Muhammad et al., 2019; Sykes et al., 2013). Thus, all the reproductive indices including histological observation on ovarian oocytes, and the proximate analysis of fish muscle, liver, and oocyte development were estimated to better understand the impact of different tank bottom enrichments on Buitta's reproduction.

According to our present study, the T_C tank showed significantly ($p < 0.05$) high reproductive performance presented in the values of the GSI, HSI, ripe eggs, individual egg weight, and mean of oocytes diameter compared to the other two treatments. This latter finding indicated the increased progress of fish to sexual maturation by increasing the oocyte growth in the ovary. Furthermore, the increasing value of GSI observed from the T_C tanks bottom substrate suggested the reproductive development in Buitta catfish, which is in agreement with previous results performed by different researchers (Buchet et al., 2008; Ndjaula et al., 2009; Shein et al., 2004; Sykes et al., 2011). However, other factors including feeding and diet are also responsible for influencing fish reproductive performance (Kabir et al., 2015; Muhammad et al., 2019; Reidel et al., 2010). In this study, the T_C tank stimulated the broodfish to consume more feed, and subsequently, this increased the production of energy that helped somatic and oocytes development during the breeding season. Changes in the GSI values occurred due to the growth and ripening of oocytes within the ovary, while the increase in the HSI mean values was due to the synthesis of liver proteins such as phosvitin and vitellin. These two types of proteins influenced the maturation of oocytes of the female Buitta fish that was reared in captivity. Therefore, the study can suggest that the tank bottom substrate of sandy soil in T_C tank played a significant role in the development of ovarian oocytes, GSI, and HIS of the fish. Previous findings also suggested that all these reproductive aspects are related to the fish growth and GSI values, gonadal changes, sexual maturity, as well as ovarian oocyte development (Çek & Yilmaz, 2009; Kabir et al., 2012). Numerous studies had reported that housing modifications may reduce the total number of eggs, delay oocyte development in final maturation and influence egg size and ripeness (Buchet et al., 2008; Ogunola et al., 2018; Sykes et al., 2013).

The current study found that different types of bottom substrate did not influence Buitta's fecundity as no significant difference was observed in the numbers of oocyte production. The simple explanation for this result is that the increase in the number of oocytes might be correlated with strong maternal and paternal care, and the occurrence of variations might be influenced by fish diet, age, size, feeding rate and time, and biochemical composition of oocytes (Coldebella et al., 2011; Izquierdo et al., 2001; Nguyen et al., 2010; Sink & Lochmann, 2008).

The oocyte development of the female Buitta fish might have 4–8 stages (Çek & Yilmaz, 2009; Ghaedi et al., 2013; Kabir et al., 2012; Reidel et al., 2010). Based on the histological examination of this study, oocyte development of female Buitta was classified into four stages. At least two stages of oocyte were observed from the same fish in the study indicating an asynchronous self-reproduction of the Buitta female broodfish. Although perinuclear oocytes were found significantly high in number in the T_A and T_B throughout the study period (Table 3), the YGO stages were not found to be prominent in each of the observed female ovary in different treatments. The characteristics and mode of ovarian oocytes development were found similar to *Epinephelus septemfasciatus* (Shein et al., 2004), *Trachurus trachurus* (Ndjaula et al., 2009), *Clarius gariepinus* (Çek & Yilmaz, 2009) and *Pangasianodon hypophthalmus* (Kabir et al., 2012). Furthermore, based on the distribution pattern of the oocytes, it is suggested that a tank with sandy bottom (T_C) might enhance egg quality (ripeness, egg weight, and OD) and stimulate the oocyte growth phase, which, subsequently, ripened the oocytes rapidly. The female Buitta catfish that was reared on a sandy bottom tank showed earlier gravid oocytes due to the sand grain bottom. In addition, the color of oocytes was lighter among fish due to their lower metabolic activities. A better metabolism helps to better accumulate the glycoprotein in the liver, which is an important substance for vitellogenic accumulation of fish oocytes (Kabir et al., 2015; Muhammad et al., 2019).

The biochemical composition among fish from different treatments was influenced by the different tank bottom conditions. The highest values of protein, lipid, and ash content within the ovarian oocytes and body tissues were observed on the sandy bottom tank (T_C). On the other hand, broodfish that were reared on the bare tank bottom (T_A) had shown the lowest quantity of protein in the muscle, liver, and oocytes, which suggests that this tank bottom condition was inappropriate and may be stressful to accomplish the requirements of sexual maturation of Buitta catfish in captivity. Data from other studies also indicated that different tank bottom substrates appear to be associated with variations in broodfish GSI, fecundity, size, and ripening of oocytes (Ndjaula et al., 2009; Sink & Lochmann, 2008; Sykes et al., 2011; Sykes et al., 2013).

The stage of oocyte development in the T_A and T_B treatments did not reach far beyond the migratory nucleus stage. Although all experimental tanks had almost similar levels of water temperature, DO, and pH. Results suggest that the bottom substrate and the hydro-ecological cues might have been inappropriate and induced stress upon the broodfish (Buchet et al., 2008; Chellappa et al., 2009; Pankhurst & Munday, 2011). The bare tank bottom (T_A) showed high turbidity, hardness, and nitrite in fish indicating that this option should not be used during the final maturation of the migratory nucleus oocytes. The T_A treatment was responsible for generating stress in the fish due to the presence of unfavorable substrate in the tank bottom and it should be neglected during the reproduction time of the fish (Buchet et al., 2008; Sykes et al., 2013). Based on the abovementioned data, it is suggested that the sandy soil might be a good stimulator and provided a comfortable ecological habitation for enhancing Buitta's sexual maturation.

Conclusion

The study has demonstrated that a tank with 30.5 cm sandy soil (Tc) would be the most effective stimulator for sexual maturation in Buitta's females. Therefore, this type of habitat should be developed for future conservation as well as the reproduction of the fish. The information accumulated throughout the current study can be used for better management of Buitta's female broodstock culturing protocol in Bangladesh. The results will support the promotion of this species as a candidate for future economic important aquaculture farming. However, further experiments on temperature, tank water volume, space and size, and broodstock selection during peak spawning are needed for the development and good practice of Buitta's aquaculture.

Ethical clearance

The experiments were approved by Animal Ethics Committee of Sylhet Agricultural University, and performed according to the Animal Ethics Procedures and Guidelines of the People's Republic of Bangladesh.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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