



Effects of salinity on selected reproductive physiological parameters of striped snakehead fish *Channa striata*

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Abstract. This study was aimed to investigate the effects of salinity on the reproductive physiology of striped snakehead *Channa striata*. Fish (the initial weight of 401 ± 15 g fish⁻¹) were cultured in three salinities including 0 (control), 3, and 6‰ in triplicates. The density was 30 fish per 1,000 L tank. After 4 months, the fish body mass of the control treatment was the highest (712 ± 139 g fish⁻¹). In the 6‰ treatment, the hematological parameters (hemoglobin concentration, hematocrit, and white blood cells) were significantly increased if compared to those of the control treatment, but there were insignificant differences in these hematological parameters between 3 and 6‰ treatments excepting hematocrit values. Plasma osmolality and chloride ion concentrations in the 6‰ treatment increased to 301 ± 5.5 mOsmol kg⁻¹ and 104 ± 3.86 mM, respectively. The results also showed that the highest gonadosomatic index (GSI) of the females ($5.8 \pm 2.62\%$) was found in the 3‰ treatment while the lowest ($3.85 \pm 1.95\%$) was recorded in the control treatment. The vitellogenin concentration was the highest in the 6‰ treatment, whereas the absolute fecundity and the relative fecundity were the highest at the 3‰ treatment. It proves that the striped snakehead matured in 0-6‰ water.

Keywords: *Channa striata*, gonadosomatic index, reproductive physiology, salinity, vitellogenin.

Introduction. The striped snakehead, *Channa striata* (Bloch, 1793) is commercially cultured in Asian countries such as Thailand, the Philippines, Vietnam, Taiwan, and Cambodia (Paray et al 2012). The *C. striata* have been cultured in earthen ponds, cages, garden ditches, and rice fields at semi-intensive and intensive levels (Xuan et al 1994). In Vietnam, the *C. striata* have been one of the freshwater species contributing to the increased national aquaculture production. The total production has increased rapidly from 40,000-50,000 tonnes (t) in 2009 to 238,850 t in 2016 (Hien et al 2018). The development of aquaculture in Vietnam has been predicted to be greatly affected by the impact of climate-related risk factors such as salinity, temperature, and CO₂. The Mekong River Delta of Vietnam, where is the most important region of Vietnamese aquaculture, has been projected as one of three deltas in the world to be heavily affected by climate change (IPCC 2007). The salinity intrusion has been of the most concern in this delta as the sea level rise has been projected to be 75 cm (52-106 cm) at the end of this century leading to the increase of salinity in the inland areas (MONRE 2016), directly influencing all freshwater aquaculture systems including the *C. striata* farming.

Fish are dependent on both internal (nervous endocrinological and neuroendocrinological) and external (ecological) factors, which control or synchronize many activities or functions (Bœuf & Payan 2001). The ecological factors such as temperature, salinity, and photoperiod greatly affect aquatic animal life. Of which, salinity is a critical factor affecting the distribution, survival rate, metabolism, growth, and reproduction (Smyth & Elliott 2016). Salinity has been considered as one of the most important abiotic factors in aquaculture; the optimal range of salinity for growth, survival, and production efficiency is species-specific (Ruscoe et al 2004). Some species can tolerate higher salinities and a few that can survive extended exposure in high salinity up to 120‰ (Nordlie et al 1992; Nordlie & Haney 1998). In euryhaline species,

the growth is affected by salinity because the energy is used for osmoregulation thus not available for growth (Brett 1979). However, some aquatic species have an optimum salinity range in which the growth rate is the highest, and the cost of osmoregulation is the lowest (Blaber 1997). With regard to *C. striata*, previous studies have merely focused on biology, nutrition and reproduction. However, there have been studies conducted on the effects of environmental factors such as nitrite on hematological parameters at fingerling stage (Lefevre et al 2012; Huong & Vi 2013); hypoxia on the partitioning of oxygen uptake water of sub-adult size (Lefevre et al 2012), salinity on hatching, growth, and survival of larvae and fingerlings (Amornsakun et al 2017; Purnamawati et al 2019); osmoregulatory adaptations at adult stage (Nakkrasae et al 2015). Huong & Trinh (2013) reported that the 10 g *C. striata* can tolerance the salinity of 0-23‰, with the iso-osmotic point and salinity being found at 310 mOsmol kg⁻¹ and 12‰, respectively. However, studies on the effect of different levels of water salinity on the growth of the adult stage and reproductive physiology of this commercially important species have not been documented yet. We report here the effects of salinity levels on the osmoregulation, hematological characteristics, growth, and maturation of *C. striata* to provide scientific bases for the adaptation and development of this important aquaculture species in the Mekong River Delta of Vietnam in the context of climate change impacts.

Material and Method

Experimental materials. This study was conducted from April to December 2020. Two hundred seventy *C. striata* with a body mass of around 400 g were obtained from a commercial farm in Vinh Long province, Vietnam. Fish were then held in 2,000-L fiberglass tanks at the wet laboratory of the College of Aquaculture and Fisheries, Can Tho University, to acclimate to tank condition for two weeks before the experimentation. The experimental fish were fed to satiation twice daily with floating commercial pellets (43% of crude protein, Stella S3 - Tomboy Aquafeed JSC - Skretting, Vietnam). Brine water was obtained from salt fields in Soc Trang province, a coastal province of the Mekong Delta. At the wet laboratory, brine water was disinfected with chlorine (50 ppm) and then diluted with tap-water to different salinities. This experiment was carried out in accordance with national guidelines on the protection of animals and experimental animal welfare in Vietnam (Law of Animal Health 2015).

Experimental design. The study was designed with 3 triplicated treatments (0, 3, and 6‰) in 4 months. A simple RAS (recirculating aquaculture system) consisting of two 500-L biofilter tanks and three 1,000-L culture tanks was set up for each treatment. The RAS was prepared 2 weeks prior to the experimentation. Thirty fish were randomly distributed to each experimental tank. For the salinity treatments (3 and 6‰), the fish were acclimated to the desirable salinities by increasing 1‰ every 12 hours using disinfected brine water. Fish were fed twice a day to satiation at 8:00 and 17:00 hour with floating commercial pellets as described above; uneaten pellets were removed 30 minutes post-feeding to prevent water pollution. Water quality was checked every three days using WTW Multi Oxi 3206 – Germany to measure dissolved oxygen (DO) and water temperature, while pH was measured by WTW Multi 3510 IDS – Germany. Salinity levels in tanks were checked daily, using a handheld refractometer (RES-10ATC). Nitrite (NO₂⁻) and total ammonia nitrogen (TAN) concentrations were weekly recorded using methods of Griess Ilosvay, Diazonium, and Indophenol blue. Water in tanks was exchanged weekly in a ratio of 30% of total volume in combination with bottom cleaning. During the experiment, the water quality parameters of all tanks were maintained in the suitable range of fish, those values were 27.5±1.59°C for temperature, 7.04±0.50 for pH, 5.60±1.03 mg L⁻¹ for DO, 0.76±0.38 mg L⁻¹ for nitrite, and 1.65±0.49 mg L⁻¹ for TAN.

Sampling and analysis. After 4 months of culture, fish blood was sampled from three fish from each tank, then the fish were weighed and dissected for other measurements. An individuals' head was covered with a cool moist towel to minimize stress and 1 mL of blood from the caudal vein was quickly collected using heparinized syringes and kept in

ice. Blood samples then were divided into two parts. The first part of the blood sample was used for the measurement of hematological parameters. The number of red blood cell count (RBC) was determined manually in a 1:200 dilution of the blood sample in Natt-Herrick's solution as a diluent stain using a Neubauer hematocytometer (Natt & Herrick 1952). Microhematocrit tubes were used to determine the hematocrit value (Hct) after centrifugation at 12,000 rpm for 5 min (Larsen & Snieszko 1961). Hemoglobin concentration (Hb) was determined using the cyanohemoglobin method; a 10 µL blood sample was mixed with 2.5 mL of Drabkin reagent (Harikrishnan et al 2003). Hb of samples was determined at 540 nm using a spectrophotometer (Cary 50 Conc). The total of white blood cells (WBC) was determined according to the unified methods for the hematological examination of fish (Hrubec et al 2000). The second part of the blood sample was centrifuged at 6,000 rpm for 6 minutes at 4°C to obtain plasma then stored at -80°C until analysis. The plasma osmolality was measured by using a Micro Osmometer (Advanced Instruments Model 3300, USA); chloride ion (Cl⁻) was measured by a chloride titrator (Sherwood model 926S MK II Chloride analyzer, Sherwood Scientific Ltd., Cambridge, UK). Plasma vitellogenin concentration was indirectly determined by measuring spectrophotometrically the amount of Alkali-labile phosphate as an indicator of vitellogenin, which is highly correlated to the level of vitellogenin in fish (Verslycke et al 2002). Alkali-labile phosphate was extracted from 30 µL of plasma according to the technique of Wallace & Jared (1968).

The weight of fish was determined at the beginning and after 4 months by weighing 10 individual fish per tank:

$$\text{Weight gain (WG) [WG (g) = } W_t - W_o]$$

$$\text{Daily weight gain (DWG) [DWG (g.day}^{-1}\text{) = (} W_t - W_o \text{)}/t]$$

where: W_o is the initial weight (g); W_t is the final weight (g); t is the experimental time (day).

The fish maturation was observed at 4 months of culture. Three fish were randomly sampled from each tank to check for ovary and testis development. The gonad and testis samples were used to determine the maturity stages applying the method described by Irmawati et al (2019) and Al Mahmud et al (2016). The fish maturation was based on the gonadosomatic index (GSI) using the formula described by Sturm (1978):

$$\text{GSI (\%)} = (\text{Weight of gonad (g)}) / (\text{Weight of fish (g)}) \times 100$$

Absolute and relative fecundity: An approximately 0.4 g sample of the egg was taken from each mature ovary. The egg samples were counted and calculated for the average number of eggs in a sample:

$$\text{Absolute fecundity (AF) [AF (egg fish}^{-1}\text{) = } nG / g]$$

$$\text{Relative fecundity (RF) [RF (egg kg}^{-1}\text{) = } AF / (\text{Weight of fish (g)}) \times 1,000$$

where: n is the number of eggs in the sub-sample; G is the weight of the ovary; g is the weight of the sub-sample.

Ovaries were carefully sampled and immersed in PBS 0.1 M at pH 7.4. The procedures for ovary processing and embedding were based on the sampling design described by Da Costa et al (2007). Samples were dehydrated by series of graded ethanols set for the processing program (alcohol 70, 96, and 99%). After histological processing, the chosen parts were embedded in methyl methacrylate Technovit® 7100 solutions (Heraeus Kulzer, Germany). Microtome was used to section with a thickness of 3 µm. Sections were then mounted on glass slides and dried in a dry oven for 24 h before staining. Slides with sections were stained with Haematoxylin and Eosin. Histological images were looked and captured under microscopes (20x).

Statistical analysis. Data were analyzed using the Microsoft Excel and Statistics Package for the Social Sciences (SPSS 16.0). The mean and standard deviation (SD) were computed by Microsoft Excel. One-way analysis of variance (ANOVA) together with DUNCAN's post- hoc tests were used to determine significance for parameters among treatments. A *p*-value of less than 5% ($p < 0.05$) was judged significant.

Results

Hematological parameters. RBC increased with the salinity from $3.07 \pm 0.37 \times 10^6$ cells mm^{-3} at 0‰ to $3.44 \pm 0.30 \times 10^6$ cells mm^{-3} at 6‰; but no significant difference in RBC was found among the treatments. However, WBC of fish in the 6‰ treatment ($117 \pm 39.3 \times 10^3$ cells mm^{-3}) was significantly higher than that of the 0‰ treatment ($62.9 \pm 16.9 \times 10^3$ cells mm^{-3}). Hb and Hct were significantly higher in the 6‰ treatment if compared to those of the 0‰ treatment. Therefore, elevated salinities affected the hematological parameters of the *C. striata* (Table 1).

Table 1
Red blood cells, white blood cells, hemoglobin, and hematocrit) of *C. striata* cultured in different salinities

Salinity (‰)	White blood cells ($\times 10^3$ cell mm^{-3})	Red blood cells ($\times 10^6$ cell mm^{-3})	Hemoglobin (g 100 mL^{-1})	Hematocrit (%)
0	62.9 ± 16.9^a	3.07 ± 0.37	8.07 ± 0.39^a	51.5 ± 2.98^a
3	78.6 ± 13.7^{ab}	3.16 ± 0.56	8.39 ± 0.60^b	52.9 ± 2.52^a
6	116.7 ± 39.3^b	3.44 ± 0.30	9.39 ± 0.93^b	56.0 ± 6.41^b

Values are presented as mean \pm SD. Values with different superscript letters (a, b) in the same columns signify a significant difference ($p < 0.05$).

Plasma osmolality and chloride ion concentration. The results show that the plasma osmolality of the *C. striata* was affected by elevated salinities. The plasma osmolality of fish in the 6‰ treatment (300 ± 5.50 mOsmol kg^{-1}) was significantly higher than that in the 3‰ treatment (294 ± 6.20 mOsmol kg^{-1}) and the control treatment (287 ± 6.91 mOsmol kg^{-1}) ($p < 0.05$) (Figure 1). Similarly, the plasma chloride ion concentration at the 6‰ treatment (104 ± 3.86 mM) was significantly higher than that of the 3‰ treatment (99.9 ± 3.23 mM) and the control treatment (95 ± 5.31 mM) ($p < 0.05$) (Figure 1).

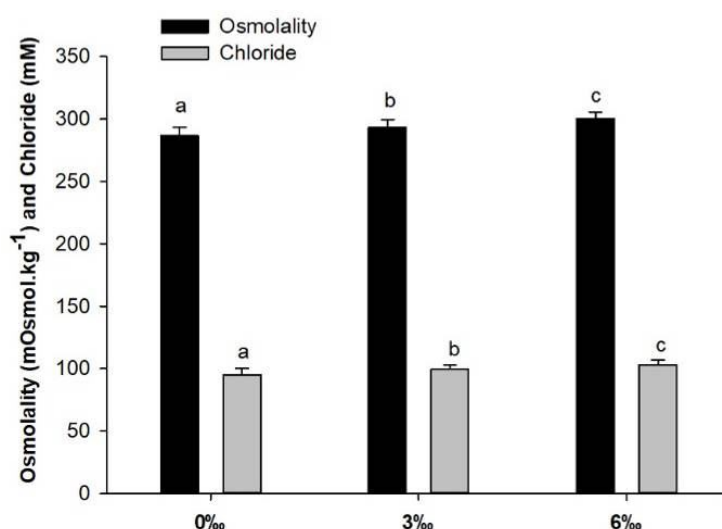


Figure 1. Osmolality and chloride ion concentration of the *C. striata* culture at different salinities. Bars of the same parameter with different letters (a, b, c) signify a significant difference ($p < 0.05$).

Growth performance. No significant difference was observed in the average final weight, WG, and DWG of fish among treatments, but the absolute values were reduced with the increase of salinities (Table 2). The final fish weight in the salinity of the 6‰ treatment reduced about 11.1% if compared to the control treatment.

Table 2
Growth parameters of *C. striata* cultured in different salinities for 4 months

Salinity (‰)	Initial weight (g)	Final weight (g)	Weight gain (g fish ⁻¹)	Daily weight gain (g day ⁻¹)
0	401±15	712±139	279±165	2.60±1.17
3	401±15	689±82.0	253±135	2.41±0.82
6	401±15	633±123	196±142	2.07±0.91

Values are presented as mean±SD.

Maturation of fish

Vitellogenin concentration, gonadosomatic index (GSI), and maturation rate. The plasma vitellogenin concentration of fish cultured in the 6‰ treatment was the highest (2.31±0.60 ugALP mg⁻¹ protein), and significant difference if compared to the control treatment. The lowest plasma vitellogenin concentration was found in fish cultured in the 0‰ treatment (1.14±0.30 ugALP mg⁻¹ protein). The gonadosomatic indexes were not significantly different among the treatments, but the higher GSI (5.80±2.62%) was seen in the 3‰ treatment, while the lowest (3.85±1.95%) was in the control treatment. In this study, maturation rates of three treatments were 100% with all the collected ovaries in different salinity levels reaching stage III and IV according to the description of Irmawati et al (2019) (Table 3).

Table 3
Vitellogenin concentration, gonadosomatic index (GSI), and maturation rate of *C. striata* cultured in different salinities for 4 months

Salinity (‰)	Vitellogenin concentration (ugALP mg ⁻¹ protein)	GSI of female (%)	Maturation rate (%)
0	1.14±0.29 ^a	3.85±1.95	100
3	1.71±0.94 ^{ab}	5.80±2.62	100
6	2.31±0.60 ^b	4.37±3.54	100

Values are presented as mean±SD. Values with different superscript letters (a, b) in the same column signify a significant difference (p < 0.05).

Absolute and relative fecundities. The highest absolute and relative fecundities of fish were found in fish reared in the 3‰ treatment (45,064±9,364 eggs fish⁻¹ and 78,527±24,843 eggs kg⁻¹ of fish, respectively). The lowest absolute fecundity was recorded in the 6‰ treatment (24,702±12,665 eggs fish⁻¹), whereas the lowest relative fecundity was shown in the control treatment (41,950±17,666 eggs fish⁻¹) (Figure 2).

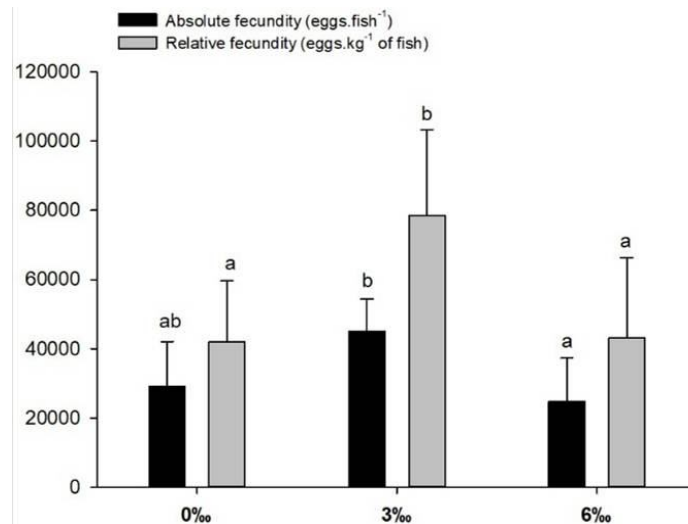


Figure 2. Absolute fecundity (eggs fish⁻¹) and relative fecundity (eggs kg⁻¹ of fish) of the *C. striata* cultured in different salinities. Bars of the same parameter with different letters (a, b) signify a significant difference ($p < 0.05$).

Ovary development and histological observation of oocyte. After 4 months of culture, the ovaries of the *C. striata* female increased in size with a thin and transparent membrane. Oocytes became visible and yellowish-orange in color. The blood vessels were well developed. Most of the oocytes reached the early maturation stage in which vesicles filled the entire ooplasm (Figures 3, 4, and 5).

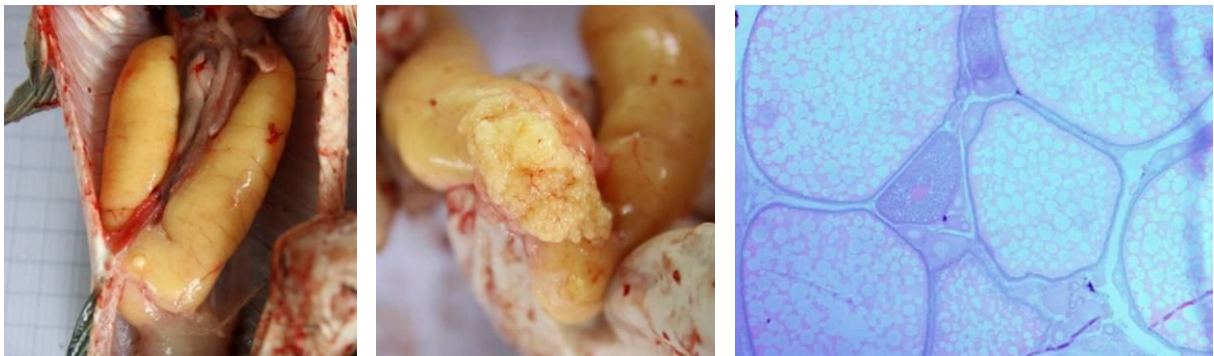


Figure 3. The appearance of ovary and histology of the oocyte of *C. striata* cultured in the control treatment (0‰).



Figure 4. The appearance of ovary and histology of the oocyte of *C. striata* cultured in the 3‰ treatment.

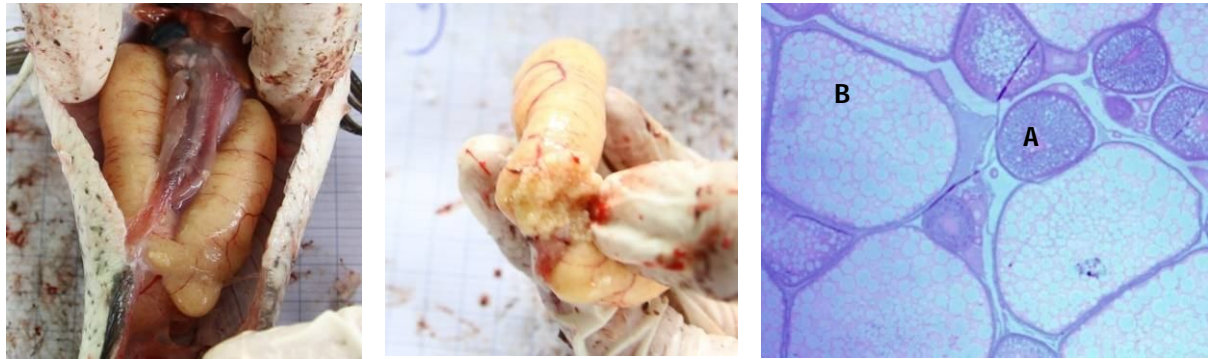


Figure 5. The appearance of ovary and histology of the oocyte of *C. striata* cultured in the 6‰ treatment (A: stage III; B: stage IV).

Discussion

Hematological parameters. Blood parameters (Hb, Hct, RBC, and WBC) reflect the health status of any organisms. Fish exposed to stress will have physiological changes to preserve consistency and body stability. Bani & Vayghan (2011) reported that the concentration of Hb is an indicator for environmental changes, which might be a result of being exposed to salinity (Schütt et al 1997). In the present study, the increase in Hb concentration of fish cultured in salinities of 3 and 6‰ showed the response of fish to the change of living environment. Moreover, the increase in Hb concentration in elevated salinities leads to an increase in the number of RBC because Hb plays as a protein carried by RBC. In addition, the increase in the number of RBC showed a response to the rising demand for oxygen consumption resulted from increasing metabolism and osmoregulation. Huong & Tu (2010) stated that RBC plays a vital role in oxygen transfer and fish exposed to salinity becomes more active and metabolic to regulate osmolality leading to an increase in oxygen consumption demand thereby the RBC is increased. Shahkar et al (2015) found that the plasma Hct of juvenile ship sturgeon (*Acipenser nudiventris*) increased as salinity increased from 0 to 8‰. According to Plaut (1998), the increase of Hct in the first stages of acclimation to the saline water is related to the change in water content in the blood owing to the change in salinity of the environment. Al-Hilali & Al-Khshali (2016) found that common carp (*Cyprinus carpio*) cultured at salinities of 0.1, 5, and 15‰ where the Hb was 12.2, 13.3, and 15.8 mg 100 mL⁻¹ and the Hct were 33.1, 36.2, and 45.3%, respectively.

In the case of WBC, its main function is to protect the fish from pathogen infection (Huong & Tu 2010). The increased salinity could cause shock and stress in fish. Therefore, the animal reacts by increasing the number of WBC playing a role in the non-specific immune response to a stressor (salinity) so as to maintain ion balance in the blood (Anyanwu et al 2007). Similar results were reported by Al-Hilali & Al-Khshali (2016) on *C. carpio* and Rauf & Arain (2014) on tilapia (*Oreochromis mossambicus*) exposed to higher salinities. The study on East Java strain tilapia (*Oreochromis niloticus*) by Soegianto et al (2017) also found that the number of WBC significantly increased when fish exposed to salinities of 10 and 15‰. Similar results were reported by Akinrotimi et al (2012) on *Tilapia guineensis* (adult and juvenile sizes) exposed to different salinities of 0, 5, 10, and 15‰ for 7 days.

The inorganic ion chloride is one of the osmotic effectors accounting for at least 90% of blood osmolality in most teleosts (Gilles & Delpire 1997). Thus, the increase in chloride ion concentration when fish are exposed to higher salinities could indicate that ion uptake mechanisms are not yet down-regulated, leading to the higher concentration of chloride ion in plasma (Kolbadinezhad et al 2012). The findings of chloride ion in this study were consistent with the results reported in *Wallago attu* (Lam et al 2014), *Pangasianodon hypophthalmus* (Huong & Quyen 2012), *Trichogaster pectoralis* (Phuoc & Kiem 2011), *Anabas testudineus* (Huong et al 2013) and *O. niloticus* (Soegianto et al 2017) that chloride ion increased with the increase of salinity. Most aquatic species are osmoregulators; they either live in freshwater (hypoosmotic to fish plasma) or seawater

(hyperosmotic to fish plasma) environments (Evans 2011). Fish live in an environment where osmolality is higher or lower than that in the blood of fish, therefore they have a regulatory mechanism to maintain osmoregulatory balance (Huong & Tu 2010). In the present study, the *C. striata* lived in high salinity conditions for a long period (4 months) resulting in the mechanism to regulate osmolality. The results of this study were in agreement with Huong & Trinh (2013) that plasma osmolality of *C. striata* increased with increased environmental salinity.

Growth and maturation. Most freshwater species need to regulate to their blood osmolality in the range of 280-360 mOsmol kg⁻¹ and use energy for this process leading to a decrease in growth rate (Evans et al 2005; Varsamos et al 2005). The reduction of growth parameters (specific growth rate and growth rate) was reported in climbing perch (*A. testudineus*) fingerlings reared in 0 to 15‰ salinity (Nahar et al 2016). Phuc (2015) found that the weight gain of *P. hypophthalmus* reared in five salinities (0, 2, 6, 10, 14, and 18‰) was high in the first four salinity levels and was the lowest in the 18‰ treatment.

Vitellogenin (Vg) is a species-specific protein synthesized by hepatocytes released into the bloodstream and actively sequestered by maturing oocytes (Campbell & Idler 1976; Hara et al 2016). In fish, the primarily exogenous synthesis of vitellogenin is initiated by gonadotropins and regulated by estrogens (Rudneva 2013). These results proved that *C. striata* was able to mature with salinity up to 6‰ (Figure 3). The vitelline membrane or vitelline envelope is a structure surrounding the outer surface of the plasma membrane of an ovum (the oolemma). It is composed mostly of protein fibers, with protein receptors needed for sperm binding which, in turn, are bound to sperm plasma membrane receptors (Nicolas 1999). Tham (2007) reported that the vitelline content increased very rapidly from stage III to stage V in swamp eel (*Monopterus albus*). Khanh et al (2010) found the plasma protein phosphate content of spotted scat (*Scatophagus argus*) markedly increasing in stages III and IV of the ovaries; the Vg concentration was the highest at IV (3.12 µg ALP mg⁻¹ protein) and was the lowest at stage I (1.26 µg ALP mg⁻¹ protein) significantly different ($p < 0.05$).

GSI is one of the important parameters of fish biology, which gives a detailed idea regarding the reproduction and reproductive status of fish species and helps in ascertaining the breeding period of fish (Sindhe & Kulkarni 2004). Changes in GSI are mostly determined by variations in yolk concentration during different oocyte stages and thus it provides information about maturation and seasonal patterns in gonad development (Wallace & Selman 1981; West 1990) and GSI has been widely used to evaluate reproduction timing (Lowerre-Barbieri et al 2011). McPherson et al (2011) proposed a model to evaluate maturity staging based only on GSI that was successfully applied to *Clupea harengus*. Flores et al (2015) used the GSI as an alternative way to estimate the ovary maturity of *Merluccius gayi*. The GSI of *C. striata* in this study was used to estimate the maturity of the fish. Hanh & Tam (2014) studied the reproductive biology of dwarf snakehead (*Channa gachua*) and reported that the sexual maturity of *C. gachua* in the wild is depended on the season, which GSI varying from 2.22 to 2.61%, with the highest value in July (2.61%) and lowest on March (0.53%). Amtyaz et al (2013) observed seven stages of gonadal development in male and female striped piggy fish (*Pomadasys stridens*) and suggested that the highest GSI value in males was 5.79% in stage VI and the lowest was 1.02% during VII stage, while in females, the highest value was 6.36% during stage VI and the lowest GSI values were 1.13% and 1.12% in stages I and II, respectively. The GSI of sompat grunt (*Pomadasys jubelini*) during the spawning period were 4.64% to 5% (Adebiyi 2013). Hai & Tam (2019) revealed that the *P. hypophthalmus* at 19 months old was able to reproduce in brackish water at 5‰ and it was not significantly different in GSI of females between 0‰ and 5‰ treatments. A description given by Ghaedi et al (2013) is that matured *C. striata* (stage III), the ovary is large with a thin and transparent membrane. Oocytes are orange in color, peripheral and central blood vessels are evident, while histology showed that yolk vesicles will be increased, which fill the entire ooplasm. Irmawati et al (2019) described that the ovary of *C. striata* increases in size, and oocytes become visible and yellowish orange in color at

stage IV. In this study, the ovaries in stage IV were found in all three treatments. By contrast, the testes of the males were not found at sampling times in all treatments indicating that the males were immature. Coinciding to the results of the reproductive characteristics of *C. striata* in Lake Rawa Pening, Djumanto et al (2019) found that the mature females with gonadal maturity in stage IV were abundant while the male maturity stage IV was only 12.4%. Morioka et al (2016) reported that the maturity of *C. striata* males was very low throughout the year, which the GSI varied between 0.03 and 0.106%. Based on macroscopic appearance of ovary and histology of the oocytes of the fish, it becomes clear that *C. striata* cultured salinity conditions up to 6‰ have a capacity to mature although the ovaries took a longer period of time to fully develop compared to the lower salinity treatments.

The fecundity of a fish is defined as the number of eggs that are likely to be laid during a spawning season (Bagenal 1957). In *O. niloticus*, the absolute fecundity of the fish was about 829 eggs individual⁻¹ time⁻¹ in 4-5‰, when the salinity was increased by twofold, the absolute fecundity tended to decrease 1.2-fold, and salinity increased 3 times, the absolute fecundity decreased twofold (Toan et al 2012). In another study on the effects of various salinity levels (0, 5, 10, 15, and 20‰) on the breeding of *C. carpio*, the results showed that the highest fecundity and fertility were obtained on salinities of 0 to 10‰ and significantly decreased on 15 and 20‰; it was suggested that *C. carpio* may lay a maximum number of eggs up to 10‰ (Malik et al 2018). The present study on *C. striata* indicates the best fecundity being at the salinity of 3‰.

Conclusions. Salinity affects on the physiological responses and osmoregulation of *C. striata*. Hematological parameters (Hb concentration, Hct, and WBC), osmolality and ion chloride concentration of fish reared in saline water increased resulting in a decrease in growth. The females reared in the salinities of 3‰ and 6‰ increased the gonadosomatic index and vitellogenin concentration, and the absolute fecundity and relative fecundity are highest in 3‰. These results prove that the female maturation is good in freshwater and brackish water up to 6‰ salinity, the best salinity being 3‰.

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