Growth and feed intake of striped catfish (*Pangasianodon hypophthalmus*) fingerlings reared in different salinities

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Abstract. Striped catfish (or tra catfish) (*Pangasianodon hypophthalmus*) is one of the important species in the aquaculture of Vietnam. Its production was 1.53 million tons in 2021 (VASEP 2022). The saline water intrusion to the culture area due to climate change could affect the farming practices. This study aims to understand the osmotic and ionic regulation, feed intake and growth performance, feed evacuated through the stomach and dry matter and protein digestibility of fish exposed to different salinities. The tolerance of fish (16.3 ± 1.8 g) acclimated to different salinities by a stepwise increase in 1 ppt salinity per day was conducted at the laboratory conditions with 8 treatments from 1 to 21 ppt with the interval of 3 ppt. The mortality occurred when the water reached a salinity of 18 ppt. An isomotic point level was found at 9 ppt (270 mOsmol kg^{-1}). In high salinity, the animals failed in their ionic regulatory capacity. The growth of fish in different salinities was conducted in the fiberglass tanks of 500 L volume with triplicate for 60 days. Salinities were from freshwater to higher than the iso-osmotic point including 0 (control), 3, 6, 9, and 12 ppt. The body mass and specific growth rate of fish reared at 9 ppt was significantly higher in comparison with those in other treatments. The survival rate of the fish reared at 12 ppt was lowest (96.0 ± 2.5%). Fish reared in 12 ppt consumed more feed if compared to those in freshwater and 9 ppt. The dry matter and protein digestibility were not significantly different among the treatments from freshwater to 9 ppt, but significantly lower at 12 ppt. This study proves that striped catfish can be grown in brackish water up to 9 ppt.
Key Words: digestibility, osmoregulation, *Pangasianodon hypophthalmus*, salinity.

Introduction. The Mekong River Delta (MRD) in the Southern part of Vietnam is the largest area of aquaculture in Vietnam. It has a potential of 1.37 mil. ha for aquaculture development, of which 480,181 ha freshwater and 886,249 ha brackish and marine water (Institute for Fisheries Economics and Planning 2009). There are a few species, which have been commercially produced in the MRD, of which striped catfish (*Pangasianodon hypophthalmus*) is the main species of freshwater aquaculture. The production of striped catfish reached 1.52 mil. tons in 2021 (VASEP 2022), that shared 45.2% and 31.3% of the MRD and national aquaculture production, respectively. However, the MRD of Vietnam is projected as one of three deltas in the world to be heavily affected by climate change (IPCC 2007). The increase in temperature, sea-level rise, and ocean acidification are the three main factors of concern. Seawater level rise in MRD is projected to be 75 cm (52 - 106 cm) at the end of this century causing salinity intrusion into the inland (MONRE 2016), which might impact the freshwater aquaculture systems including the striped catfish farming.

Among the ecological factors, salinity is specific to the aquatic environment (Boeuf & Payan 2001). Salinity is one of the environmental factors that influence the growth performance of many fish (Kang'ombe & Brown 2008). The effects of external salinity on growth capacities, feed conversion, and digestibility in fish have been studied for several species. Likongwe et al (1996) reported that Tilapia (*Oreochromis niloticus*) could tolerate a salinity level up to 16 ppt and the growth decreased as the salinity increased above 8 ppt. Kang'ombe & Brown (2008) found that *Tilapia rendalli* reared in 10 ppt salnity were significantly larger than those in 0, 5, and 15 ppt; and also showed better feed utilization and feed digestibility (crude protein, fat, ash, and gross energy), so that

10 ppt would be optimal for *T. rendalli*. No effects of salinity from 0 - 10 ppt were found in goldfish (*Carassius auratus*) (Canagaratnam 1959), grass carp (*Ctenopharyngodon idella*) (Kilambi 1980), or bluegill (*Lepomis macrochirus*) (Musselman et al 1995). However, the salinity tolerance of catfishes was found to depend on the size. Clay (1977) found that mature catfish (*Clarias lazera*) of 0.6-1.5 kg each were able to tolerate 10 ppt for 100 hrs. with no sign of stress. Allen and Avault (1970) found that channel catfish (*Ictalurus punctatus*) at post-larvae size was able to tolerate salinities to 10 ppt, while fish of 6 - 12 months old were able to survive 12 ppt. Growth of juvenile channel catfish (*I. punctatus*) reared in 0.85 to 4 ppt was enhanced (Allen & Avault 1970; Lewis 1972).

Little work has been reported on salinity effects on growth and feed utilization of striped catfish. Nguyen et al (2014) reported that striped catfish had higher survival rates in salinity from 2 - 10 ppt if compared to that of 0 ppt; the best growth performance, survival rate, and feed conversion ratio (FCR) were in 6 ppt; but plasma cortisol levels of fish in high salinity levels were significantly higher than those in lower salinity levels. Responses of *P. hypophthalmus* to feed utilization, digestibility, and stomach passage time reared in various salinities have not been documented.

Material and Method. Four experiments were performed to investigate the aspects of how salinity affects growth in the *P. hypophthalmus* including characterizing the effects of salinity on plasma osmolality and ion composition; investigating the effects of salinity on growth, survival, and feed conversion ratio (FCR); measuring the effect of salinity on stomach passage time, and finally investigating the effects of salinity on protein and dry matter digestibility.

Experimental animals and rearing conditions. The *Pangasianodon hypophthalmus* used in this study were hatched and nursed at the College of Aquaculture and Fisheries, Can Tho University, Vietnam. Research took place between June and December 2020. The fingerlings were acclimated to the experimental aquaria or growth tanks for 2 weeks before the experiments started. Fish were fed twice a day with a commercial pellet (38% protein, Tomboy Aquafeed, Vietnam). The average weights of fish was 16.3 ± 1.85 g (mean ± SD) for the salinity tolerance and ion composition experiment; 23.6 ± 4.43 g for the growth experiment; 23.5 ± 3.62 g for the stomach passage time and 26.4 ± 2.42 g for the digestibility measurement. The fish were kept in local de-chlorinated tap water. Brackishwater was prepared by mixing de-chlorinated tap water and high saline water (> 60 ppt), which was collected from a salt farm in Bac Lieu province, to the desired salinities.

Osmolality and ion composition. Fish were randomly divided into aquaria destined for 1, 3, 6, 9, 12, 15, 18, and 21 ppt. Thirty (30) fish were stocked into each 100 L aquarium (containing 80 L of water). These treatments were in triplicate. In all treatments, salinity was increased stepwise by 1 ppt per day until the desired salinity was reached. This salinity was then maintained for 21 days to observe the occurrence of mortality after which plasma osmolality and ion composition were measured. Fish were fed commercial pellets (38% protein, Tomboy Aquafeed, Vietnam) with a feeding rate of 3-4% of body mass daily. Tank water was exchanged 20-30% every 3 days.

Three fish in each tank were randomly collected at 6 hrs, 1, 3, 6, 14, and 21 days for blood sampling. Fish were anesthetized then blood was sampled by direct puncture of the caudal vein. Plasma was separated after centrifugation to determine osmolality and concentrations of sodium, potassium, and chloride. Plasma osmolality was measured using a Fiske 1-10 micro-osmometer (Advanced Instruments Inc, MA, USA); plasma chloride concentration ($[Cl^-]_{pl}$) measured with a Sherwood ionic meter (926 S, Sherwood scientific, Ltd., UK); while sodium and potassium ($[Na^+]_{pl}$ and $[K^+]_{pl}$, respectively) with a Sherwood flame spectrophotometer (Sherwood Scientific Ltd., UK).

Growth, survival, and feed conversion ratio. Growth was studied in three replicates at 0, 3, 6, 9, and 12 ppt over 60 days. All tanks contained 500 L of re-circulating water with a bio-filter and 30% of the water was renewed every three days. Each tank was

stocked with 50 fish. The fish were acclimated to the selected salinities by the stepwise increase of 1 ppt per day. Fish were fed commercial pellets (30% crude protein, Cargill Aquafeed, Vietnam) with a feeding rate of 3 - 4% of body mass daily. The body mass of fish (23.6 ± 4.43 g each) was not significant difference between either tanks or treatments. Body mass was determined at 30 and 60 days (30 from each tank were anesthetized in 0.1 g L^{-1} benzocaine and measured weight and length). In this experiment, growth rate, feed intake, and survival rate were measured.

The daily weight gain (DWG) and specific growth rate (SGR) were calculated as follows:

$$DWG\ (g\ day^{-1}) = (final\ weight\ (g) - initial\ weight\ (g)) / time\ interval\ (days)$$

$$SGR\ (\%\ day^{-1}) = 100 \times (LnW_t - LnW_o) / t$$

where: W_o is the initial body mass of the fish (g); W_t is the final body mass of the fish (g), and t is experimental time (day).

Feed conversion ratio (FCR) was determined using the following formula:

Feed conversion ratio (FCR) = Total feed consumed (g) / total weight gain (g)

In this experiment, the water temperature was measured several times each day and fluctuated from 26.5°C in the morning to 28.0°C in the afternoon, while pH over the same period ranged from 6.8 ± 0.4 to 7.2 ± 0.7. Dissolved oxygen ranged from 5.5 to 6.5 mg L^{-1}, corresponding to 71 to 83% saturation. Nitrogenous parameters were always within acceptable limits such as NH_4^+ levels were between 0.46 and 2.19 mg NH_4^+ L^{-1}; nitrate levels were between 2.84 and 15.01 mg NO_3^- L^{-1} in the brackish tanks and between 0.06-1.87 mg NO_3^- L^{-1} in the freshwater tanks; nitrite levels were always below 1.45 mg NO_2^- L^{-1} in freshwater and below 2.1 mg NO_2^- L^{-1} in brackishwater treatments. These measurements were conducted two times per week.

Stomach passage time. The residence time of the feed in the stomach was measured in 9 tanks for each treatment with salinities at 0, 3, 6, 9, and 12 ppt. All tanks contained 400 L of re-circulating water with a small bio-filter. All tanks were stocked with 30 equally sized fish (23.5 ± 3.62 g) and there was no initial difference in fish biomass among tanks. The fish were acclimated to the salinity treatments by a stepwise increase of 1 ppt per day and held at the goal salinity for a further week before experimentation. During this acclimation period, the fish were fed normally with commercial pellets (30% crude protein, Cargill Aquafeed, Vietnam) until satiation.

For the analysis of passage time, the fish were fed until satiation. The stomachs of 30 fish were sampled 20, 60, 120, 180, 240, 300, 360, 420, and 480 minutes after feeding. Fish were killed by anesthesia with 0.1 g L^{-1} benzocaine. The stomach was then collected, and the stomach contents were removed and placed into an aluminum cup of known weight for weight analysis after drying for 24 h at 105°C.

Protein and dry matter digestibility. This study used the dissection method described by Hien et al (2010). Thirty juveniles (26.4 ± 2.42 g in weight) were randomly placed in each 400 L tank. There were 5 salinity treatments at 0, 3, 6, 9, and 12 ppt, and each treatment was replicated 4 times. The fish were fed pellet feed containing 1% chromite oxide (Cr_2O_3) (Hien et al 2010) twice a day until satiation. Uneaten feed was removed 20 minutes after feeding. The experiment was commenced after two weeks when the fish were familiar with the tanks and the feed. Eight hours after feeding the experimental diet, all 30 fish were anesthetized in 0.1 g L^{-1} benzocaine and killed, the distal intestine dissected, and feces were expelled with gentle pressure into sample container (Hien et al 2010). Feces samples were stored at -20°C for analysis.

The feed and collected feces were analyzed for Cr_2O_3, dry matter, and crude protein according to AOAC (2000). The dry matter digestibility (DMD) and protein

digestibility (nutrient. ADC, apparent digestibility coefficients) were calculated using equations:

Equation 1: $$DMD = 1 - \left(\frac{\text{Marker}_{diet}}{\text{Marker}_{faeces}} \right)$$

Equation 2: $$Nutrient.ADC = 1 - \left(\frac{\text{Marker}_{diet} \times \text{Nutrient}_{faeces}}{\text{Marker}_{faeces} \times \text{Nutrient}_{diet}} \right)$$

where: $Marker_{diet}$ = concentration (g/100 g dry weight) of Cr_2O_3 in the diet
$Marker_{faeces}$ = concentration (g/100 g dry weight) of Cr_2O_3 in the faeces.
$Nutrient_{diet}$ = concentration (g/100 g dry weight) of nutrient in the diet
$Nutrient_{faeces}$ = concentration (g/100 g dry weight) of nutrient in the faeces

Statistical analysis. Data was analyzed using ANOVA after checking for variance homogeneity and normality and post-hoc with the Dunnett's multiple comparison test. Statistical analysis was performed in SPSS version 27 for Windows (IBM corporation, Armonk, NY, USA). The statistically significant level was set at P-values < 0.05.

Results

Plasma composition and survival at increased salinities. The fish regulated plasma osmolality at 270 - 296 mOsmol kg^{-1} at all salinities from 0 to 9 ppt, while above this salinity (from 12 to 21 ppt), the plasma osmolality increased to between 305 to 489 mOsmol kg^{-1}, which were significantly different compared to those of the control ($p<0.05$). The osmolality significantly increased in comparison with the 0 hr (or at starting) at 7 days in 12 ppt and from 6 hrs at all salinities from 15-21 ppt (Figure 1). The Na^+ and Cl^- concentrations were not significant differences if compared to the control up to 6 ppt and 12 ppt, respectively (Figure 1). However, K^+ concentrations at all salinities were not significantly different from the control. This disturbance of plasma composition above the iso-osmotic point was mirrored by an increasing lethargic behavior and the observation that mortality did not appear up to 15 ppt. On day 21, 80% and 100% mortality had occurred in the 18 and 21 ppt treatments, respectively. All fish exposed to 21 ppt died after 3 days of reaching this target salinity.

Survival and growth rate of fish reared in different salinities. Survival rate was high in the experiment and unaffected by salinities up to 12 ppt, with more than 95% (from 96.6 to 99.3%) survival in all of these tanks over the 60 days of the experiment (Figure 2).

The experiment shows clearly that in general growth is unaffected by salinity up to 12 ppt, although the highest growth ($p > 0.05$) was seen at 9 ppt. The body mass of the fish, determined at 2 measurement intervals during the growth experiment is shown in Figure 3. There was no significant difference between brackish water salinities (3, 6, and 12) and the freshwater (control), during the first 30 days, whereas at 60 days fish from the 9 ppt group had out-grown those in other salinities with an end weight of 67.2 g compared to 51.1 - 55.1 g in the other treatments.

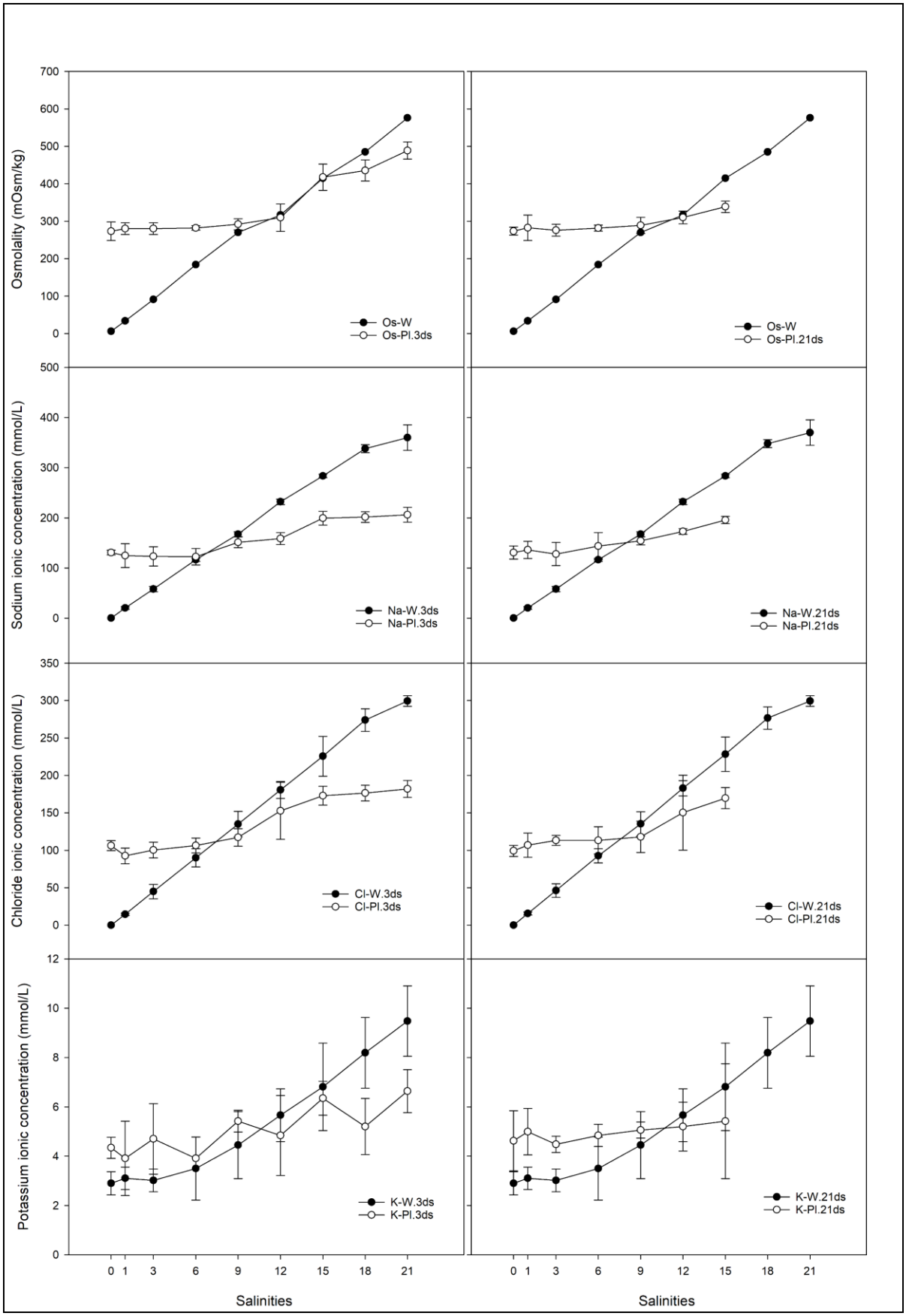

Figure 1. Osmolality, sodium, potassium, and chloride ionic concentration of *P. hypophthalmus*.

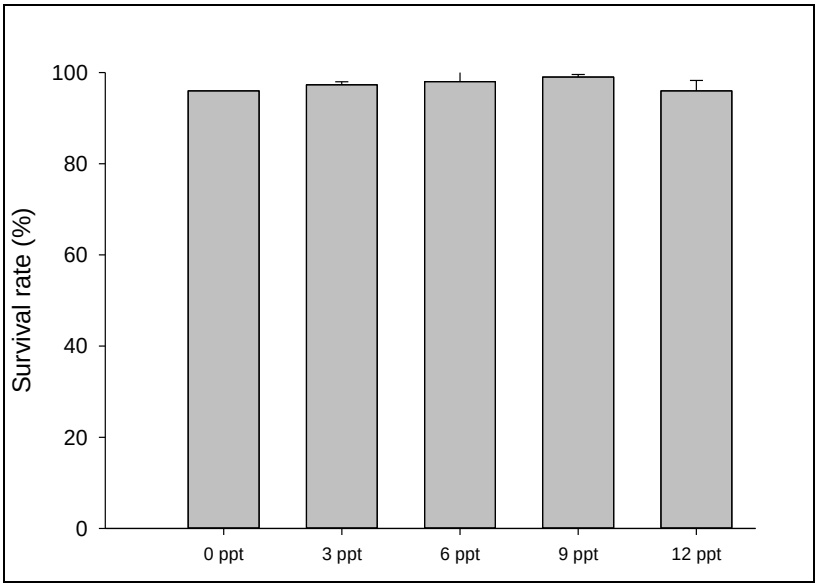

Figure 2. The survival rate of the *P. hypophthalmus* reared in different salinities (average±SE) (n=3).

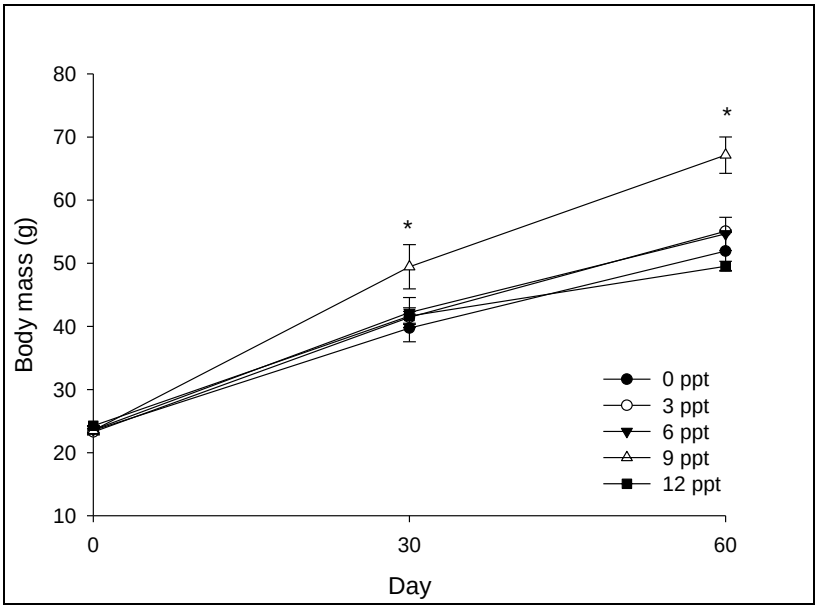

Figure 3. Body mass of *P. hypophthalmus* rearing in different salinities after 60 days. The average body mass (average±SE) of *P. hypophthalmus* was calculated with n=3 and the stars show that a significant difference was found to others of the same sampling point.

This overall picture is repeated in the other calculated growth parameters with specific growth rate, daily weight gain and food conversion ratio (Figure 4 and Figure 5) all showing the same pattern that growth is similar up to 12 ppt with the exception that the 9 ppt group consistently outperforms other treatments (Figure 3 and Figure 4).

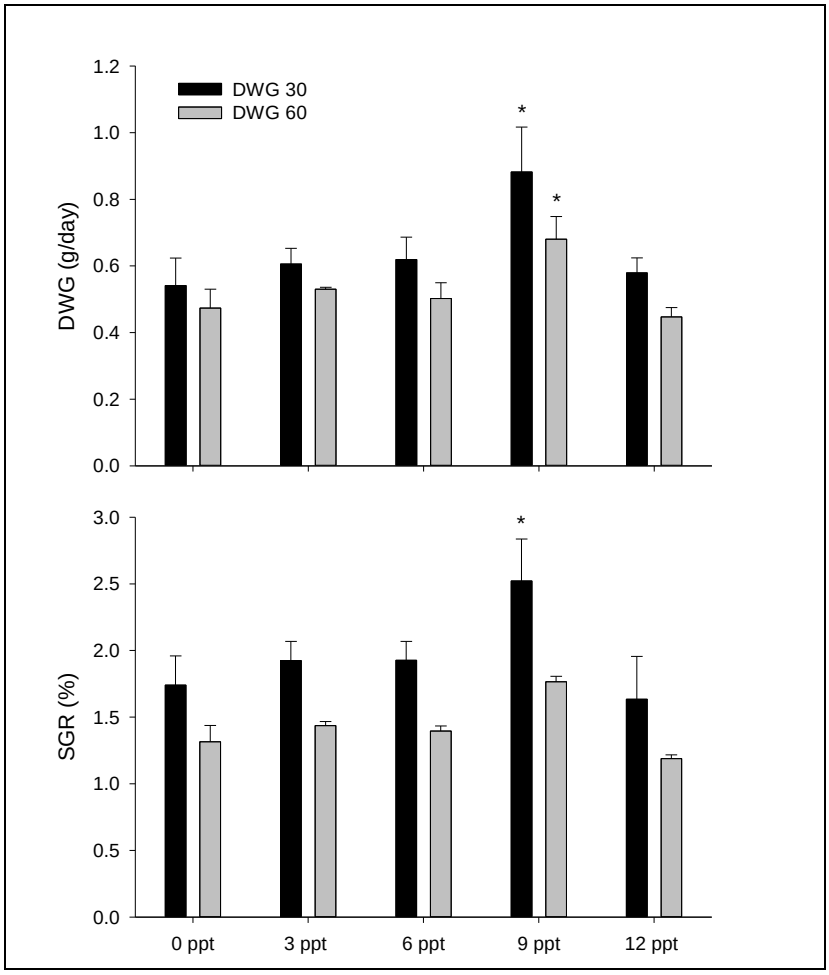

Figure 4. Daily weight gain and specific growth rate of *P. hypophthalmus* rearing in different salinities. The average DWG and SGR (average±SE) of *P. hypophthalmus* were calculated with n=3 and the stars show that the significant difference was found to others of the same sampling point.

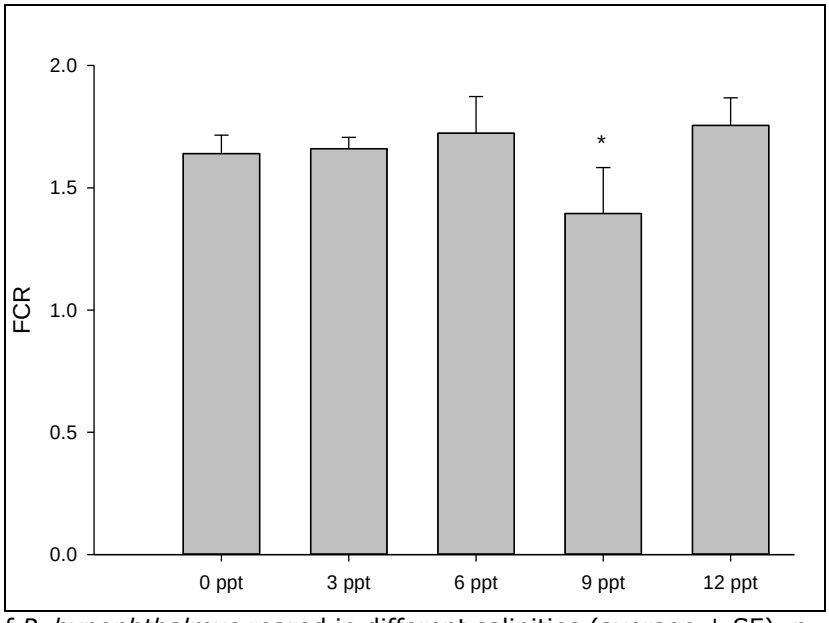

Figure 5. FCR of *P. hypophthalmus* reared in different salinities (average ± SE), n=3 and the stars show that the significant difference was found to others of the same sampling point.

Feed passage time. The time of the feed passing through the stomach of the fish in different salinities was shown in Figure 6. Stomach content across treatments was

identical up to 300 minutes after feeding. However, during the following three hours, it became evident that stomach passage time was slightly elevated in the 12 ppt group compared to the other treatments so that these animals had significantly more feed remaining at the last two measurements at 420 min (7 h) and 480 min. (8 h).

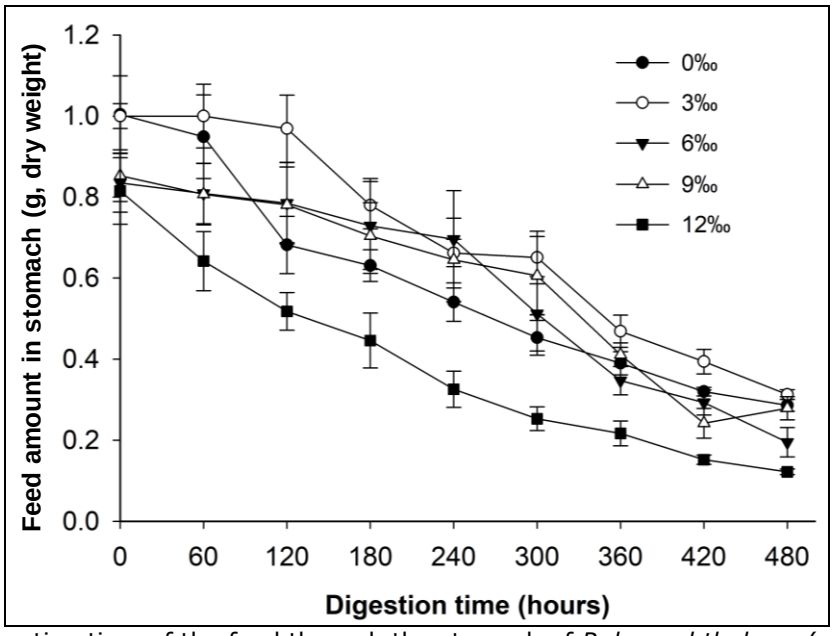

Figure 6. Evacuation time of the feed through the stomach of *P. hypophthalmus* (average ± SE), n=3.

Protein and dry matter digestibility. There was no significant difference in dry matter digestibility (DMD) in fish from salinities 0 to 9 ppt with average values in these treatments varying between 85.3 ± 0.2 and 86.2 ± 0.3%. However, DMD was significantly reduced in fish from 12 ppt at only 76.2 ± 0.4% (Table 1). The same pattern was seen in protein digestibility, with no significant difference in salinities from freshwater up to 9 ppt (90.7 - 92.7%), whereas the protein digestibility at 12 ppt was significantly reduced by more than 10% to 82.7% (Table 1).

Table 1

The dry matter and protein digestibility (%) of *P. hypophthalmus* in different salinities

Salinities	*Digestibility (%)*	
	Dry matter	*Protein*
0 ppt	85.9 ± 0.7[a]	90.7 ± 0.6[a]
3 ppt	86.2 ± 0.3[a]	90.7 ± 0.4[a]
6 ppt	85.3 ± 0.2[a]	92.2 ± 0.7[a]
9 ppt	86.0 ± 0.4[a]	92.7 ± 0.8[a]
12 ppt	76.2 ± 0.4[b]	82.7 ± 0.6[b]

Note: The values are mean ± SD. The numbers following with the different letters in the column show the significant difference from each other ($p<0.05$).

Discussion. The osmotic and ionic regulatory ability were examined in the *P. hypophthalmus* fingerlings (this size of fish is stocked in grow-out ponds) in response to different salinities. The osmolality of the fish was maintained at a stable level in freshwater to 12 ppt (varying between 270 - 300 mOsmol kg^{-1}) for 3 weeks after acclimation. The fish, in this condition, showed to be hyper-osmoregulator; and at 9 to 12 ppt, the plasma osmolality and ambient were in the same levels that mean the iso-osmotic was found between 9 and 12 ppt. The plasma osmolality of the fish was highly increased in the salinities from 15 to 21 ppt after 3 days. This species showed a hypo-osmoregulator, however, in this condition, the osmoregulatory ability of the fish was not

lengthened until the end of the experiment (21 days). The mortality occurred within 1, 2, and 3 weeks at 21, 18, and 15 ppt, respectively. Thus, it is illustrated that *P. hypophthalmus* possess freshwater and low salinities (0-9 ppt). Nguyen et al (2014) reported that *P. hypophthalmus* had the highest survival rates in salinity from 2-10 ppt if compared to that of higher salinities. Some species also show typical stenohaline groups such as the rice eel (*Monopterus albus*), sand goby (*Oxyeleotris marmorata*) (Pedersen et al 2014; Loc & Huong 2010). The other freshwater fishes also showed the same situation, such as common carp (*Cyprinus carpio*) (Wang et al 1997) and goldfish (*Carassius auratus*) (Luz et al 2008). The result from this study is summary that the mortality of *P. hypophthalmus* was found when the water salinity rises up 15 ppt. It is demonstrated that *P. hypophthalmus* belong to the stenohaline group.

The growth of *P. hypophthalmus* reared in different salinities from freshwater to 12 ppt was observed by weight gain, SGR, and DWG. These values illustrate that these species can grow well from freshwater up to 9 ppt salinity. Nguyen et al (2014) found that the best growth performance, survival rate, and FCR of *P. hypophthalmus* juveniles were in 6 ppt; but the plasma cortisol levels of fish in high salinity levels were significantly higher than those in lower salinities. Asian catfish (*Clarias batrachus*) fingerling reared above 4 ppt was found to be detrimental to fish and in turn, they lost their body weight, but without any adverse effect on growth, survivability, and biomass production was recorded at 2 ppt (Sahoo et al 2011). Enhanced growth of juvenile channel catfish (*Ictalurus punctatus*) in 0.85 to 4 ppt was reported by Allen and Avault (1970) and Lewis (1972). Several studies on the effects of salinities on the growth of other freshwater fish have been documented, the growth rate and feed efficiencies of common carp (*Cyprinus carpio*), white amur (*Ctenopharyngodon idella*), and Russian sturgeon (*Acipenser gueldenstaedtii*) juveniles increased when they were reared in 2 ppt ambient (Konstantinov & Martynova 1993). No effects of salinity from 0 to 10 ppt were found in goldfish (*Carassius auratus*) (Canagaratnam 1959), grass carp (*Ctenopharyngodon idella*) (Kilambi 1980), and bluegill (*Lepomis macrochirus*) (Musselman et al 1995). While the salinity tolerance of goldfish (*Carassius auratus*) was better than common carp, this species grows well in water salinity from 0 to 6 ppt (Luz et al 2008). The growth of snakehead fish (*Channa striata*) also was not significant different in freshwater to 6 ppt ambient (Ha et al 2021). The grass carp (*Ctenopharyngodon idella*) growth rate was higher in freshwater than in a 3 ppt saline environment (Maceina & Shireman 1980). The lowest salinity tolerant capacity was found in silver carp (*Hypophthalmichthys molitrix*) (Oertzen 1985).

The feed conversion rate is efficient by many factors, but the best response is probably related to optimizing the environmental conditions to which the fish is accustomed. It was found that the *P. hypophthalmus* growth rate was the highest and the lowest feed conversion value at 9 ppt. As the result of the feed passage time through the stomach of the *P. hypophthalmus* in freshwater and low salinities (3 to 9 ppt) was shown that the stomach was capable of storing sufficient feed in a single feed to the last about 8 h with the feed mass approximately 3% of body weight. This is consistent with the finding that the feeding frequency should be 8 h and the maximum feed will be 3% of body weight. The time of the feed passage through the stomach of the fish in 12 ppt showed significant slowing and the last traces of feed were evacuated through these tended to less digestibility ingredient of the feed. Wang et al (1997) found that in common carp (*Cyprinus carpio*) fingerling reared for 92 days in 2.5 ppt had the lowest FCR (1.11), while FCR was 1.48 in freshwater and 5.53 in 10.5 ppt.

Figure 6 shows that the components of the feed in the fish in freshwater and low salinities (3-9 ppt) environment evacuated through the stomach fit to linear model leading to indicates that the process of digestion was stable that means the nutrient would come through the intestine and absorption, while in high salinity (12 ppt) the remaining feed still is high in the stomach. It can also be presumed that digestive enzymes may be affected by water content in the gut, the pH of the drinking water was high so that the digestive enzyme activities would be decreased. The possibility of a direct physical action of salinity on digestive enzyme effectiveness remains to be elucidated, the explanation can show from the result. The activities of digestive enzymes

decreased, leading to the feed conversion rate increase which was evidenced by the result of dry matter and protein digestibility. Regarding the result on the dry matter and protein digestibility of the fish in different salinities (from 0 to 9 ppt), they were not significantly different (Table 1), however, these levels in 12 ppt were low. The protein digestibility of the fish depends on both internal (secreted enzyme capacity, body activity, and nervous system) and internal factors (feed intake, temperature, dissolved oxygen, pH, and salinity of the water). The salinity of rearing water is considered to directly affect the activity of the proteinase in the stomach. This enzyme was activated by HCl (pH ranges from 1.45 to 3). When *P. hypophthalmus* were transferred to high salinity (≥12 ppt) would drink saline water, thus, pH in the stomach was increased leading to the enzyme was inactivated. From the result, the protein digestibility of the feed decreased. Wang et al (1997) reported that the feed digestibility of *C. carpio* reached the highest at 2.5 ppt (99.6%), next highest in freshwater (95.0%) then decreased at higher salinities (64.5% at 10.5 ppt). Usher et al (1990), Ringø (1991) and Storebakken et al (1998) found that the digestibility of macro-nutrients or energy was significantly lower in Atlantic salmon (*Salmo salar*), Arctic charr (*Salvelinus alpinus*), and rainbow trout (*Oncorhynchus mykiss*) kept in seawater rather than in freshwater. Usher et al (1990) reported that the lower digestibility of feed in high salinity could cause by the interactions between the mechanisms of salt uptake and nutrient uptake in the gut. Tran-Ngoc et al (2017) found in Nile tilapia (*Oreochromis niloticus*) of 35 g individual size that the salinity of 15‰ increased the nutrient digestibility, but his enhanced digestibility diminished over time and the intestinal morphology was influenced by the salinity.

The Mekong River delta of Vietnam, where is the main farming location of *P. hypophthalmus*, has been forecasted to be highly affected by salinity intrusion. Vietnam's national scenarios for sea-level rise (SLR) showed that by the end of this century the seawater level is projected to be 75 cm (MONRE 2016) and it encompassed more than 700 km of coastline resulting in that land area with an isoline of 4 ppt salinity in the Delta could increase up to 331,168 ha (Toan 2014). This scenario shows that *P. hypophthalmus* industry in Vietnam will not be affected by climate change in terms of salinity increase.

Salt is a parasiticide and osmoregulatory aid (Seim et al 1997) and is widely used in aquaculture (Wurts 1995) for preventive treatment of freshwater fish disease (especially parasitic pathogens) by a fast bath at concentrations depending on the species (3-50 ppt) (Selosse & Rowland 1990). The farmers are therefore suggested to stock *P. hypophthalmus* species from 0-9 ppt in order to culture or remove external pathogens (e.g. the parasite, fungi, and the other organisms) developing in freshwater.

Conclusions. This *Pangasianodon hypophthalmus* showed high tolerance to salinity, the growth, dry matter and protein digestibility were not affected by salinity from freshwater up to 9 ppt. The *Pangasianodon hypophthalmus* could grow, even better at the salinity of 9 ppt. Therefore, *Pangasianodon hypophthalmus* culture can be expanded to saline water areas up to 9 ppt.

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Conflict of interest. The authors declare that there is no conflict of interest.

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