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RESEARCH ARTICLE

Growth and Survival of the Tapiroid Grunter, *Mesopristes cancellatus* (Cuvier, 1829) in Different Salinity Levels Under Laboratory Conditions

Jessie G. Gorospe[1], Emilie G. Tubio[2], Christina S. Nebres[2], Fernie Catienza[3], JR B. Pagalan[3], Hilbert D. Cañada[3]*, Marnelle B. Sornito[1], Jocelyn N. Gorospe[1]

[1] *School of Marine Fisheries and Technology, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*
[2] *College of Marine and Allied Sciences, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*
[3] *Research Department, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*

ABSTRACT

Increased demand for Tapiroid grunter (*Mesopristes cancellatus),* locally known as "pigek" in the market, has led to an interest in the commercial culture of this fish. However, little is known about the effect of salinity on the growth and survival of this fish. *Mesopristes cancellatus* (57.25 g ± 3.08 average body weight) used in this study were collected from the estuaries of Bayug, Iligan City. The growth and survival of this species were examined at four different salinity levels [0 ppt as control (T1), 10 ppt (T2), 20 ppt (T3), and 30 ppt (T4)] at a density of one individual 100 L^{-1} at MSU Naawan Pigek Hatchery. The results revealed that "pigek" had the highest weight gain in 20 ppt (74.67 ± 6.03 g) and the lowest in 30 ppt (55 ± 7.21g) after 120-d of culture. Throughout the sampling period, those in the 30 ppt treatment exhibited significantly lower weight gain than the other treatments. Furthermore, it had the lowest specific growth rate of -0.615% day^{-1}, while the highest rate was recorded in 20 ppt treatment at 0.45% day^{-1}. The survival rate was found to be 100% in all treatments. Although *M. cancellatus* can tolerate a wide range of salinity up to 30 ppt, this species showing the highest growth in 20 ppt salinity conditions is more suitable for brackishwater aquaculture.

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1. INTRODUCTION

Aquaculture, the farming of aquatic animals and plants, is one of the fastest-growing food producers worldwide, contributing 46% of the overall production and 52% of fish for human consumption worldwide (FAO 2020; Ahmad et al. 2021). This industry plays a crucial role in addressing the gap between supply and demand for aquatic commodities, thus enhancing food production (Subasinghe et al. 2009; Tacon 2020). In 2021, the Philippines, contributing 858.28 thousand metric tons, holds the 11th position in global aquaculture production, representing 1.01% of the world's total output of 85.34 million metric tons (DA-BFAR 2021). With the decreasing capture fisheries, aquaculture not only offers an avenue to sustain the demand in food production, especially for high-valued commodities but also provides a source of revenue to communities in the country (Palanca-Tan 2018).

One of the most promising commodities for aquaculture in Northern Mindanao is the tapiroid grunter, *Mesopristes cancellatus* (Cuvier 1829), locally known as "pigek" or "pigok" (Maralit et al. 2012). This highly-priced freshwater fish species is in high market demand, making it a lucrative option for aquaculture aside from meeting the criteria set for candidate species (Openiano et al. 2011). Its exceptional flavor, second only to the President's fish (*Cestraeus plicatilis*) or *Ludong*, makes it a sought-after delicacy, typically reserved for special occasions (Maralit et al. 2012; Cabuga Jr. et al. 2016). The tapiroid grunter can be bought for PHP 200.00–PHP 250.00 kg^{-1} (USD 3.53–USD 4.41; USD 1 = PHP 56.65) directly from the fishermen, but the buying price could reach up to PHP 450.00–PHP 500.00 kg^{-1} (USD 4.50–USD 8.83) in other cities like Cagayan de Oro and Cotabato (Openiano et al. 2011).

In the wild, *M, cancellatus* is usually found in freshwater and brackish environments in Indonesia, New Guinea, Vanuatu, Taiwan, Japan, and the Philippines, with the adults migrating to the sea to spawn as catches of breeders mostly caught in estuaries (Openiano et al. 2011; Barazona et al. 2012). Macabalang et al. (1981) reported that the fish are commonly caught by fishers operating fish corrals constructed about one kilometer upstream from the mouth of the Mandulog River. On the other hand, juveniles are sometimes found in streams within 5–10 km of the sea (Masuda et al. 1984). The fish is also present in several Mindanao River systems, including Rio Grande De Mindanao in Cotabato (Macabalang et al. 1981), Mandulog and Bayug Rivers in Iligan City (Macabalang et al. 1981; Openiano et al. 2011), Tagoloan River (Leopoldo et al. 2014), and Agusan River Basin (Cabuga Jr. et al. 2016). They are also observed in Abra River, Luzon. They are known as "Bulidao" (Maralit et al. 2012) and were recently recorded in the Talabaan River System in Naawan, Misamis Oriental (Vedra et al. 2022). Their ability to thrive in varied saline environments, attributed to their physiological resilience, classifies them as euryhaline tetrapontids (Davis et al. 2012).

Despite its potential as a promising aquaculture commodity, developing effective rearing techniques for *M. cancellatus* remains a significant challenge (Maralit et al. 2012). Primarily, the collection of this species, particularly breeders, is difficult due to its seasonal abundance, influenced by flooding patterns and lunar phases (Openiano et al. 2011). Additionally, rearing conditions are complicated by several factors, including inadequately developed hatchery protocols and various environmental conditions that can affect the growth and survival of *M. cancellatus.* Salinity is one example of the environmental factors that extensively affect fish growth (Lisboa et al. 2015), and fluctuations in salinity levels drastically affect different physiological processes resulting in mortality (Ahirwal et al. 2021). Despite *M. cancellatus* being a euryhaline species, its various life stages may exhibit differing salinity tolerances, as noted by Masuda et al. (1984) and Openiano et al. (2011). Therefore, optimizing the salinity requirements for *M. cancellatus* is a crucial step in developing effective hatchery techniques for the species, an area that remains unexplored. Furthermore, this optimization will enhance hatchery protocols for the species and provide valuable insights for expanding aquaculture production into diverse environments, including brackish waters.

In Northern Mindanao, Philippines, a Department of Agriculture-Bureau of Agricultural Research (DA-BAR) funded project on the "Breeding, Hatchery Management, Broodstock Development of Pigek *Mesopristes cancellatus*"–also called the Pigek project–was implemented at Mindanao State University at Naawan (MSUN). This project has facilitated the collection of "pigek" broodstock from the wild and their transfer to the hatchery, aiming to advance the aquaculture of this species by determining optimal hatchery conditions, including salinity requirements. However, the project has encountered challenges due to an insufficient understanding of the role of salinity in the development of collected "pigek" fish ($\bar{x}$ = 57.25 g ± 3.08). To understand the effect of salinity on the growth and survival of *M. cancellatus*, a rearing experiment was conducted on the tested fish at four salinity levels [ambient seawater at 0 (as control), 10, 20, and 30 ppt] for 120-d under laboratory conditions. The findings of this study offer significant information for advancing the culture technology of *M. cancellatus,* especially since their populations are declining. This information will also support effective resource management through artificial production systems and foster the growth of aquaculture industries in the country by introducing new aquaculture commodities.

2. MATERIALS AND METHODS

2.1 Experimental organism

The tapiroid grunter, *M. cancellatus* is characterized by a gray to grayish brown dorsal and silvery white on the ventral side when fresh (Maralit et al. 2012). The compressed body and thick and fleshy lips, with the upper one longer than the lower one, are also one of the most prominent features of the fish (Openiano et al. 2011). Initial observations show sexual dimorphism in *M. cancellatus,* usually exhibited by several fish species (Lagler et al. 1977). Fish below 100 g (the smallest was at 25 g) were males with mature testes. In comparison, those 100 g and above were all females with mature ovaries, although this observation needs further investigation (Openiano et al. 2011). The sexual dimorphism of the species was corroborated by studies conducted by Leopoldo et al. (2014) and Barazona et al. (2015), which utilized geometric and morphometric analyses to determine the variation of body shape between the sexes of "pigek".

Twelve (12) pieces of male "pigek" (*Mesopristes cancellatus*) with an average body weight (ABW) of 57.25 g ± 3.08 were caught by fishers using drift gillnet with varying mesh sizes (Nos. 6, 7 & 10) from the river mouth of Bayug, Iligan City with a salinity of approximately 25 ppt and transported to MSU-Naawan Pigek Hatchery for the experiment. Upon arrival in the hatchery, three fish were randomly distributed in each of four 1-ton capacity circular fiberglass tanks with 25 ppt water. The fish were fed *Acetes* shrimp and were monitored for a week. After seven days, the salinity of the holding tanks was gradually adjusted to attain the desired experimental salinity levels. The fish in tank 1 were acclimatized by slowly dripping seawater into the culture tank, thus gradually increasing the salinity by 2 ppt per day until 30 ppt was attained. In tanks 2, 3, and 4, salinity was reduced at 2 ppt per day by slowly dripping freshwater into the tanks until the desired salinities of 0, 10, and 20 ppt were attained, respectively. A handheld refractometer was used to monitor the changes in the salinity to conform to the target salinity of this experiment.

2.2 Experimental set-up and design

The study was conducted at MSU-Naawan Pigek Hatchery for 120 days from June 2019 to October 2019. Twelve (12) aquaria with 100 L capacity and dimensions of 59 cm L x 29 cm W x 30 cm H were used in the experiment. Four salinity levels were used for the experiment. The treatments are 0 ppt (Control; T1), 10 ppt (T2), 20 ppt (T3), and 30 ppt (T4). Each aquarium was filled with 70 L of filtered water with their desired salinity treatment. Treatment 1 was purely freshwater, which acted as the control. The desired salinities in treatments 2 to 4 were obtained by diluting seawater with freshwater. One fish was placed in each experimental tank, and each treatment with three replicates followed a Randomized Completely Block Design (RCBD). The aquaria were adequately supplied with aeration.

Before stocking, the initial weight of twelve (12) "pigek" was weighed individually using an electronic balance of up to 1 g precision (WH-B10 Electronic Scale 1-g). This was done by placing each fish into a plastic container with 1 liter freshwater (0 ppt) on the weighing scale. The weighing scale was tared before each fish weight measurement. *Pigek* were stocked randomly at one (1) fish aquarium^{-1}. The experiment was conducted with one fish per tank to mitigate the risk of mortality during its course. This is because aggressive interactions such as chasing, bumping, biting, and fin-nipping were often observed during the initial attempt at domestication.

2.3 Feeding and water management

Acetes shrimp (*uyabang)* was fed to "pigek" during the whole duration of the experiment. It was purchased from the Iligan City wet market. The shrimps were thoroughly cleaned, packed, and placed in the fridge for preservation; however, they were to be consumed no later than one week. During feeding, frozen diets were thawed and given to fish. The daily feed ratio was 12-13% of the fish's body weight and was gradually decreased to 2–3% after a month. With the initial body weight of 55 g, the amount of feed given for the first month was 7 g and was adjusted every 30 days according to the increase in the fish's body weight. Daily feed ratio (DFR) was computed using the formula (Millamena et al. 2002):

(a) $$DFR = \frac{\text{original number stocked (pcs)} \times \text{average body weight (g)} \times \text{estimated survival rate (\%)} \times \text{feeding rate (\%)}}{1000}$$

(b) $$ABW = \frac{Total\ weight\ of\ fish}{Total\ number\ of\ fish}$$

Water management was done weekly at 8:00 AM before feeding by siphoning out the unconsumed feeds and fecal waste using a small plastic tube. The entire water volume was completely drained and replaced with water adjusted to the appropriate salinity treatment. Water temperature and salinity were monitored daily using a thermometer and refractometer to ensure they were in normal range.

After 120 days of the experiment, the test organisms were not disposed of; however, they were all acclimatized to 0 ppt, same as the upper reaches of the river where most "pigek" are thriving and for further culture.

2.4 Data analysis

2.4.1 Growth determination

Sampling for the growth of "pigek" was done every thirty days. Each stock was taken using a scoop net and placed in a small container filled with their respective rearing water. The body weight was measured and recorded using a digital weighing scale in grams (g). After weighing, the fish were returned to their respective aquarium. The growth of "pigek" was calculated using the formula following Kangombe and Brown (2008):

$$(c)\ W = Wf - Wi$$

Where: *W* – is the weight gained, *Wf* – is the final weight of the fish, and *Wi* – is the initial weight of the fish.

The Specific Growth Rate (SGR) was determined using the formula (Ebrahim et al. 2007):

$$(d)\ SGR = \frac{(ln\,(W_f) - ln\,(W_i))}{(Days\ of\ culture)} X\ 100$$

Where: *SGR* – is the Specific growth rate, W_f – is the final body weight, W_i – is the initial body weight.

2.4.2 Survival rate

The survival rate was determined by checking each treatment monthly until the culture period's end. The survival rate was subjected to arcsine to avoid biases. Mortality that was observed in the treatments will not be replaced with a new fish. The following formula was used (Millamena et al. 2002):

$$(e)\ Survival\ rate = \frac{Final\ population}{Initial\ population} X\ 100$$

2.5 Statistical analysis

Average values were determined for all obtained data, and range descriptive statistics were also employed. Data were tested for homogeneity of variance using the Shapiro-Wilk Test, and the data were log-transformed when the assumption of homogeneity of variance was not met. One-way analysis of variance (ANOVA) was used to test the differences in growth and survival at a 5% significance level. When a significant difference was found, Tukey's test was performed to determine the source of variation. All analyses were performed using PAST software v.02 (Hammer et al. 2001).

3. RESULTS

The average weight gain of "pigek" reared in different salinity treatments throughout the culture period is shown in Figure 1. After 30-d of culture, the weight of the fish reared at 30 ppt was the lowest, with a significant difference from the fish reared with the other treatments (One-Way ANOVA, F = 15.4, P < 0.05). On the other hand, the fish reared at 20 ppt was heavier than those at other salinities, particularly with a significant difference from the fish reared at 30 ppt. The results showed a consistent trend throughout the culture period, with the highest weight of fish observed at 20 ppt and the lowest at 30 ppt after 60 days (One-Way ANOVA, F = 5.5, P < 0.05) and in 90 days (One-Way ANOVA, F = 9.3, P < 0.05) of culture. After 120 days of salinity trial, the highest growth of the fish was observed at 20 ppt (74.67 ± 6.03 g), followed by 10 ppt (71 ± 5.00 g), 0 ppt (65 ± 9.00 g) and lowest at 30 ppt (55 ± 7.21 g). Only 20 ppt had a significantly higher mean weight gain than 30 ppt after 120-d of culture (One-Way ANOVA, F = 4.6, P < 0.05) (Figure 1). However, no significant differences in weight gain of the fish were detected between the other treatment combinations. In addition, the weight of the fish reared at 30 ppt did not significantly increase after 120-d of culture from the beginning of the experiment. Moreover, the survival rate of *M. cancellatus* reared at different salinities after the 120-day culture period is 100%.

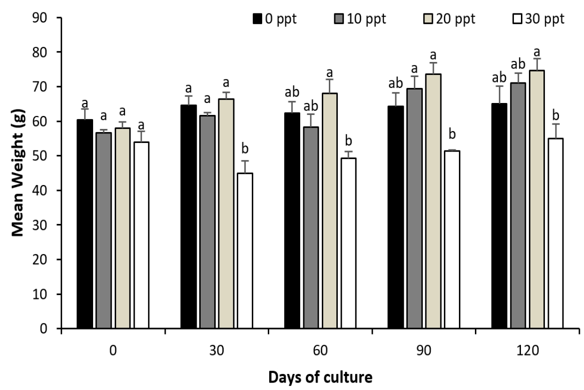

Figure 1. The mean weight gain of *Mesopristes cancellatus* in different salinity levels during the 120 days of culture. Different letters above the bar showed significant differences among treatments (Tukey's Test, P< 0.05).

The specific growth rate (SGR) of *M. cancellatus* in different salinities during the study is presented in Figure 2. After 30 days, the SGR of the fish was the highest in 20 ppt treatment with 0.45% day^{-1}, followed by 10 ppt treatment with 0.28% day^{-1}, 0 ppt treatment with 0.23% day^{-1}, and 30 ppt treatment with significant lowest - 0.61% day-^{1} (One-way ANOVA, P < 0.05, F = 12.2; Figure 2). On day 60, all treatments showed a decline in the SGR except for 30 ppt, but no significant differences in the SGR were observed among treatments. Still, the fish reared at 20 ppt had the highest growth rate, resulting in 0.27% day^{-1}, followed by 0 ppt and 10 ppt gaining 0.05% day^{-1}. Furthermore, the SGR of fish reared at 30 ppt had increased since day 60 but was still the lowest among the treatments, with 0.15% on day 1. In the 90 days of culture, the highest SGR was at 20 ppt (0.27% day^{-1}), followed by 10 ppt (0.22% day^{-1}), and 0 ppt (0.07% day^{-}

^{1}), and the lowest at 30 ppt with -0.06% day^{-1}. During the 120 days of culture, 20 ppt had the highest growth rate (0.21% day^{-1}), followed by 10 ppt, 0 ppt with 0.19% day^{-1}, and 0.06% day^{-1}, respectively, and the lowest was at 30 ppt with 0.02% day^{-1}. Moreover, the trend of SGR of T2 and T3 slightly decreased from 90 to 120 days of culture, in contrast with 30 ppt, which increased to 0.02% day^{-1} towards the end of culture. From 60 days to 120 days of culture, no significant differences were observed in the SGR of the fish among treatments.

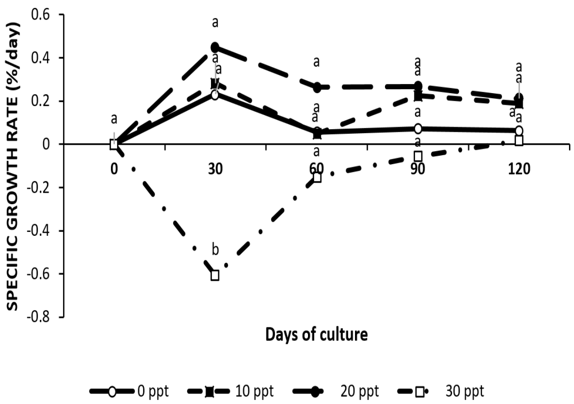

Figure 2. The specific growth rate of *Mesopristes cancellatus* in different salinities during the 120 days of culture. Differences in letters showed significant differences (Tukey's Test, P< 0.05).

4. DISCUSSION

Mesopristes cancellatus known as "pigek," is a euryhaline terapontid species (Davis et al. 2012) that can inhabit variable salinity environments since they have a wide salinity tolerance through harbor mechanisms that control dynamic changes in their osmoregulatory processes (Kultz 2015). However, the growth, metabolism, physiology, and behavioral processes of the fish species would be affected by varied salinity levels (Swanson 1998; Zhang et al. 2016) even if they are not less sensitive to salinity than stenohaline fishes, where a slight change in salinity levels affects their survival and cellular stress response (Evans, 1984; Evans and Kultz 2020). Therefore, salinity tolerance is crucial in optimizing the basic conditions for cultivating freshwater fishes with the potential for aquaculture (Dubey et al. 2016), such as *M. cancellatus.*

In the present study, the growth performance of *M. cancellatus* was best at 20 ppt, followed by 10 ppt and 0 ppt, and the lowest at 30 ppt. Although *M. cancellatus* is a freshwater fish found in several river systems in Mindanao (Openiano et al. 2011), the highest growth performance of the fish occurred in brackish waters. The optimum salinity levels of estuary-associated fishes, including freshwater fish taxa, are 8–14 ppt, encompassing many species' isosmotic state (Whitfield 2015). When environmental conditions are ideal, the energy used for routine metabolic functions (osmoregulation) is reduced to a minimum, and the energy saved is directed toward increasing growth (Perry et al. 2003; Tavares-Dias 2021). The study indicated that *M. cancellatus* collected in Bayug, Iligan City, achieves its peak growth performance at 20 ppt salinity, suggesting that this salinity level is optimal for its growth. It concurred with the other commercial fish species, such as in the study of *Trachinotus blochii*, which had the best growth performance in intermediate salinity ranging from 15 to 25 ppt and decreased in very low salinity of 5 ppt and seawater salinity of 34 ppt (Hamed et al. 2016). However, the present results differ from those of Corpuz et al. (2021), who reported that the growth of closely related fish species, silver perch *Leiopotherapon plumbeus* juveniles, is not significantly affected at different salinities (0, 10, 20, and 35 ppt salinity) at the 40-day culture period.

The lowest growth of *M. cancellatus* was observed at the highest salinity treatment, 30 ppt. Salinity influences energy budgets; when external salinity is too high or low, fish expend more energy on osmoregulation, leaving less energy for growth (Mapenzi and Mmochi 2016; Tavares-Dias 2021). Furthermore, when the salinity is raised than its normal range, it significantly boosts cortisol circulation, increases blood sugar levels, dehydrates the muscles, negatively affects feed consumption and conversion, and disrupts the cellular processes affecting physiology (Purnamawati et al. 2019; Ahirwal et al. 2021). Hence, it is possibly the reason why *M. cancellatus* had a lower growth observed at 30 ppt as it is not in its normal salinity range, and more energy is utilized for its metabolic and physiological processes under this salinity level. Furthermore, although the fish has shown a slight increase in its specific growth rate since day 60, suggesting some level of adaptation to the high salinity, its growth remains lower compared to other salinity levels. This indicates that while the fish can adapt to high salinity, its growth rate is still hindered, likely due to disrupted physiological processes. The same findings were observed in the study of Hamed et al. (2016), showing that the euryhaline fish, *Trachinotus blochii* utilizes more energy to regulate the concentration gradient at a high salinity of 34 ppt and a low salinity of 5 ppt, thereby limiting the energy available for growth. Similar results were observed for the freshwater fish *Gibelion catla*, where SGR and weight gain significantly decreased with increased salinity levels (Ahirwal et al. 2021).

The lower growth observed in *M. cancellatus* maintained in freshwater (0 ppt) may also result from high energy demands for osmoregulation, diverting energy from growth and its physiological stress to laboratory conditions. Amick and Toko (2021) recorded that juveniles and larger *M. cancellatus* naturally inhabit the inland freshwater rivers of Whiteman Range, New Britain Island, Papua New Guinea. In their natural habitat, specific adaptations and natural water chemistry allow them to optimize energy use more effectively than in laboratory settings, influencing their growth and overall health. It was also observed by the *Mugil liza* juveniles, a commercially important euryhaline fish species, which grew least quickly at 0 ppt (6.39 0.06 g/d) salinity but grew fast at 24 ppt salinity (6.78 0.07 g/d) after 40 days of culture (Lisboa et al. 2015). Accordingly, higher energy costs associated with osmoregulation were observed under this freshwater environmental condition, resulting in lower fish growth. This result supports previous research suggesting that the reduced growth of estuarine fishes in freshwater may be caused by greater gill NKA activity and, as a result, higher energy expenditure related to osmoregulation (Lisboa et al. 2015; Tavares-Dias 2021). Furthermore, if there is salinity stress, intestinal microbiota, which are factors involved in the salinity acclimation of fishes, are altered as it shows a strong correlation with salinity, leading to poorer growth of the hosts (Zhang et al. 2016).

According to the results of the current study, the "pigek," *M. cancellatus*, can tolerate a wide range of salinity when exposed to freshwater and seawater salinity levels over time. It means that the salinity variations do not significantly impact the survival rate variables among treatments and that the species can be reared up to 30 ppt. The study of Openiano et al. (2011) showed that salinity at Bayug River, where the "pigek" is collected, could reach up to 33 ppt during high tide, indicating that the fish could survive up to this salinity level. Also, the biological nature of the species to migrate to the sea for spawning enables them to adapt to the different salinity ranges. Other work by Hamed et al. (2016) found almost 100% survival of *T. blochii* when exposed to different salinity (5, 15, 25, and 34 ppt) in 56 days culture period. Varying water salinity had little impact on *M. liza* fish survival, which was about 100% in all treatments ($p > 0.05$) (Lisboa et al. 2015). *L. plumbeus*, a closely similar species, survived at a salinity of 20 ppt with an 88% survival rate, albeit mortality rose with increasing salinity (Corpuz et al. 2021). The superior salinity stress tolerance of euryhaline fishes like *Mesopristes* species has an evolutionary advantage to favor their expansion and adaptive radiation within various salinity environments (Kultz 2015).

5. CONCLUSION

The study highlighted the growth and survival of *Mesopristes cancellatus,* locally known as "pigek," in various salinity levels under laboratory conditions. The results revealed that *M. cancellatus* can tolerate a wide salinity range of up to 30 ppt. However, the best growth performance was observed at 20 ppt, and the lowest growth was observed at 30 ppt, indicating its potential as a brackishwater aquaculture commodity. The findings provide significant baseline information, contributing to the technical development of *Mesopristes cancellatus* culture to sustain its demand in the market. Further studies on the effect of drastic changes or fluctuations of salinity levels on the physiological and metabolic processes of the *M. cancellatus* are needed to understand fully how salinity works on cellular and metabolic levels for the development of the culture technology of the species. Furthermore, exploring other biological factors that could influence the salinity tolerance and rearing of the fish is also a potential area for further research.

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AUTHOR CONTRIBUTIONS

Gorospe JG: Conceptualization, Methodology, Validation, Data Curation, Writing – Review & Editing, Supervision, Project administration, Funding acquisition. **Tubio EG:** Conceptualization, Methodology, Validation, Writing – Reviewing and Editing, Supervision. **Nebres CS:** Methodology, Validation, Writing – Review & Editing.

Catienza F: Investigation, Data Curation, Writing – Review & Editing. **Pagalan JRB:** Investigation, Data Curation, Writing – Review & Editing. **Canada HD:** Investigation, Data curation, Writing – Original draft preparation, Writing – Review & Editing, Visualization. **Sornito MB:** Writing – Original draft preparation, Writing – Review & Editing, Visualization. **Gorospe JN:** Conceptualization, Methodology, Validation, Writing – Review & Editing, Supervision, Project administration.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

ETHICS STATEMENT

The researchers followed all institutional and national guidelines for the care and use of laboratory animals.

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