Impact of Low Salinity on Survival and Growth of Juvenile Mangrove Red Snapper (*Lutjanus argentimaculatus* Forsskål, 1775) in Indoor Tanks

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ABSTRACT

Mangrove red snapper (*Lutjanus argentimaculatus* Forsskål, 1775) is a high-value marine fish and an ideal mariculture species. As a euryhaline species, it requires a deeper understanding of optimal cultivation conditions. This study examined the effects of different low salinity levels [20‰, 10‰, and 0‰ (freshwater)] on fish survival (SR) and growth of juvenile red snapper in indoor tanks, with fish reared in seawater (30‰) serving as a control. Fish were fed with commercial marine fish feed (42% protein) for six weeks. Results showed no significant ($p \geq 0.05$) differences in survival rates among salinity levels (0–20‰), with survival rates ranging from 95.00–100%, similar to 30‰ (100% SR). The final total length ranged from 9.20–9.55 cm across treatments, with no significant differences. However, fish reared at 20‰ had a significantly higher final body weight (37.43 g) than those at 30‰ (25.06 g), 10‰ (32.42 g), and 0‰ (24.78 g). The highest weight gain rate and specific growth rate were observed in fish at 20‰ (442.50% and 4.02%, respectively), alongside a significantly lower FCR (2.05) than in the 30‰ (2.37), 10‰ (2.17), and 0‰ (2.44) treatments. Based on these findings, a 20‰ salinity level is recommended for nursing juvenile *L. argentimaculatus* in cultivation systems.

Keywords: Juvenile nursing, *Lutjanus argentimaculatus*, Mangrove red snapper, Salinity

INTRODUCTION

Mariculture, the rearing of aquatic organisms in brackish and saline water, is a growing industry driven by the increasing demand for marine products and the declining yields from capture fisheries (Ranjan *et al*., 2017). The mangrove red snapper (*Lutjanus argentimaculatus* Forsskål, 1775), an important commercial marine species, is an excellent candidate for mariculture. This species is distributed across coastal waters in tropical regions, ranging from the eastern Indian Ocean to the Pacific Ocean (Amorim *et al*., 2019; Spiji *et al*., 2019; Mosequera *et al*., 2023).

In 2023, fishery statistics reported that red snapper catches in the Indian Ocean and the Gulf of Thailand totaled 6,785 tonnes, representing a 20.51% increase compared to 2022 (Department of Fisheries, 2024). Currently, the demand for seafood continues to rise, while natural marine resources are decreasing due to overexploitation and habitat destruction, placing the mangrove red snapper under threat in many regions (FAO, 2022). Additionally, limited coastal ecosystems where juveniles can still be commercially harvested are facing continuous strain (Chi and True, 2018). The high market value of adult fish exacerbates local extinction risks, as both adult and juvenile populations are being overexploited to meet market demands. Furthermore, mariculture production of this species remains very limited (Philipose *et al*.,

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Received 10 March 2024 / Accepted 31 October 2024

2017; Amorim *et al*., 2019; Sookdara *et al*., 2022). Promising solutions to cope with this problem include restocking existing fisheries and advancing the mariculture of this species.

Mariculture production of mangrove red snapper concentrates in Southeast Asia, where there is high demand for this species, particularly in markets such as Hong Kong, Malaysia, Singapore, and Taiwan (De Silva and Davy, 2010). The mangrove red snapper is a euryhaline species, capable of thriving in waters with salinity levels ranging from 8 to 40‰ (Zagars *et al*., 2012; Chi and True, 2017). However, in hatchery production, larvae and juveniles are typically reared in highly saline seawater with salinity levels from 29 to 35‰ during the period from 30 to 80 days after hatching (Estudillo *et al*., 2000; Leu *et al*., 2003; Melianawati *et al*., 2019; Asiandu and Malayudha, 2022). Some studies have shown that juvenile fish achieve better survival rates at moderate salinity levels (10–17‰), compared to more saline conditions (25‰) (Chi and True, 2018). Muyot *et al*. (2021) reported that mangrove red snapper can easily adapt and grow well in freshwater environments, thriving across a range of saline levels from 35‰ to 0‰. The cultivation of marine species such as this in freshwater and brackish water areas presents an excellent opportunity for expanding mariculture practices to locations far from the sea, where abundant freshwater resources could support the growth of high-value marine species. This approach has already proven successful with species like the Pacific white shrimp, *Litopenaeus vannamei* (Supono *et al*., 2023), the Asian seabass, *Lates calcarifer* (Islam *et al*., 2023), and groupers, *Epinephelus* spp. (Ybañez and Gonzales, 2023).

The current experiment aimed to develop a nursing and management program for the early production of juvenile mangrove red snapper, *L. argentimaculatus* reared at different salinity levels. The goals were to gain a better understanding of the impacts of salinity on the survival and growth of juvenile fish. The insights from this study could provide key information for fish nursing management, ultimately contributing to improved long-term nursing practices in hatcheries and supporting the future production of this species.

MATERIALS AND METHODS

Study site and source of experimental fish

In September 2023, a sample of 500 fingerlings of mangrove red snapper, *Lutjanus argentimaculatus* approximately 55–60 days post-hatch (dph), was transferred from the hatchery of the Phang Nga Coastal Aquaculture Research and Development Center, Department of Fisheries, Phang Nga province, Thailand to the hatchery of the Klongwan Fisheries Research Station in Prachuap Khiri Khan province, Thailand. The fish were reared in an indoor concrete tank (2.0 m × 1.5 m × 1.2 m, with a water depth of 1 m) at a density of 50 fish·m^{-2}. They were fed with floating artificial feed (commercial marine fish feed: 42% protein, 6% fat, 4% fiber, 12% moisture) to satiation twice daily, at 9:00 a.m. and 3:00 p.m., for 2 weeks (age about 75–80 dph) to allow them to acclimate to the experimental environments.

Experimental design and set-up

The experiment included four treatment groups: a control at 30‰ and three others at 20‰, 10‰, and 0‰ salinity levels. Experimental fish were randomly assigned to indoor fiberglass tanks (0.7 m × 1.5 m × 0.6 m, with a 500 L capacity) filled with water at the designated salinities, with a stocking density of 40 fish·m^{-2} (Philipose *et al*., 2017). Each treatment group was replicated three times.

Low-salinity water was prepared by mixing marine water (33‰) with dechlorinated tap water (0‰) in separate 2,000 L concrete tanks for each salinity level. The tanks were aerated for several hours, and the salinity was measured using a refractometer. For 0‰ salinity, dechlorinated freshwater was used without adding marine water. Additionally, pH and alkalinity of the prepared water were measured and adjusted with liming agents, such as $Ca(OH)_2$ and/or $CaCO_3$, to ensure values were within the acceptable range for fish rearing (Boyd, 2017).

The mean initial total length (TL) and body weight (BW) of the experimental fish were approximately 5.63±0.34 cm and 6.91±1.62 g, respectively. The fish were reared in indoor tanks for 6 weeks and fed floating artificial feed to satiation at 10% of biomass per day (Suastika and Imanto, 2007). Feeding occurred twice daily at 9:00 a.m. and 3:00 p.m., with the amount of feed and fish survival recorded daily.

Water quality was closely monitored throughout the experiment, maintaining good conditions by exchanging approximately half of the water twice a week, following guidelines on fish welfare in aquaculture (Johnston and Jungalwalla, 2000).

Data collection

During the experiments, random samples of 20% of the total fish from each treatment were taken every 2 weeks for TL (in centimeters) and BW (in grams) measurement, using a set of vernier calipers and digital weighing scale, respectively. Water quality parameters were assessed twice weekly: salinity with a refractometer (Master-S10 alpha; Atago, Japan), pH with a portable pH meter (pH Testr30; Eutech; Singapore), dissolved oxygen (DO) and temperature with an oxygen probe (Pro20i; YSI; USA), and total ammonia, nitrite, and alkalinity using the indophenol blue, colorimetric, and titration method, respectively (APHA, AWWA and WEF, 2017).

At the end of the experiment, the number of surviving fish in each group was counted, and each fish was measured to assess final TL and BW. The survival rate (SR), weight gain rate (WGR), specific growth rate (SGR), and feed conversion ratio (FCR) were calculated according to the formulas (Brown, 1957):

SR (%) = 100 × (final fish number) / (initial fish number)

WGR (%) = 100 × (final BW - initial BW) / initial BW

SGR (% day-1) = 100 × [ln (final BW) - ln (initial BW)] / rearing period (days)

FCR = total feed given / fish weight gain

Statistical analysis

Descriptive statistics were calculated for all measurements. The experimental data were analyzed using one-way ANOVA, with mean differences assessed through Duncan's multiple range test at a 95% confidence level. All analyses were conducted using IBM SPSS Statistics for Windows software (version 21.0; IBM Corp.; Armonk, NY, USA), and the results were presented as mean ± standard deviation.

RESULTS

Survival

Survival rates of the juvenile *Lutjanus argentimaculatus* nursed at the different water salinity levels in indoor tanks for 6 weeks were in a range of 95.00±5.00 to 100% without statistical difference among treatments (Table 1). However, a declining trend was observed as salinity decreased to 10‰ and 0‰, while no mortality occurred in the 20‰ and 30‰ groups.

Growth performance

Growth performance was assessed at 6 weeks, with no significant differences observed in the final total length (TL) among the groups. However, the body weight (BW) of fish reared at 20‰ was significantly higher than that of the other treatment groups. Additionally, the BW of fish reared at 10‰ was significantly greater than those in 30‰ and 0‰, as shown in Table 1.

WGR and SGR followed a similar trend, decreasing in the order: 20‰ >10 ‰ > 0‰, 30‰. Additionally, the FCR was lowest in the group reared at 20‰ (2.05±0.01), followed by the 10‰ and 30‰ groups, and highest in the 0‰ group. These differences were statistically significant ($p<0.05$) (Table 1).

Water quality conditions

The water quality parameters recorded during the experiment remained within suitable

Table 1. Survival rate (SR), total length (TL), body weight (BW), weight gain rate (WGR), specific growth rate (SGR), and feed conversion ratio (FCR) of juvenile *Lutjanus argentimaculatus* reared in indoor tanks for 6 weeks under varying salinity levels: 30‰ (control), 20‰, 10‰, and 0‰.

Parameters	**Salinity levels**			
	30‰	**20‰**	**10‰**	**0‰**
SR (%)	100.00±0.00[a]	100.00±0.00[a]	98.33±2.88[a]	95.00±5.00[a]
TL (cm)	9.45±0.55[a]	9.40±0.65[a]	9.55±0.45[a]	9.20±0.51[a]
BW (g)	25.06±2.60[c]	37.43±2.88[a]	32.42±0.34[b]	24.78±0.90[c]
WGR (%)	263.26±37.73[c]	442.50±40.68[a]	369.56±5.25[b]	257.96±13.85[c]
SGR (% day^{-1})	3.06±0.25[c]	4.02±0.17[a]	3.68±0.02[b]	3.03±0.09[c]
FCR	2.37±0.04[c]	2.05±0.01[a]	2.17±0.03[b]	2.44±0.03[d]

Note: Means within each row superscripted with different lowercase letters are significantly ($p<0.05$) different.

ranges: DO levels ranged from 4.94±0.16 to 5.27±0.50 mg·L^{-1}, water temperature from 27.96±0.31 to 28.11±0.16 °C, pH from 8.08±0.14 to 8.11±0.18, total ammonia from 0.18±0.02 to 0.22±0.03 mg-N·L^{-1}, nitrite from 0.14±0.02 to 0.16±0.03 mg-N·L^{-1}, and total alkalinity from 102.10±12.17 to 117.45±5.29 mg·L^{-1} $CaCO_3$. Water conditions in the rearing tanks did not significantly differ among the treatments ($p>0.05$).

DISCUSSION

Mangrove red snapper (*Lutjanus argentimaculatus*) is a euryhaline species that in the wild inhabits waters with salinity levels ranging from 8‰ to 40‰ (Zagars *et al*., 2012; Chi and True, 2017). This adaptability enables the use of water from various sources for cultivating euryhaline fish species (Inokuchi *et al*., 2021; Mozanzadeh *et al*., 2021). In the current study, a 20‰ salinity level was highly suitable for nursing juvenile *L. argentimaculatus* in indoor tanks, as evidenced by higher mean values of BW, WGR, and SGR, as well as a lower mean FCR compared to 30‰, 10‰, and 0‰ salinity levels. On the other hand, low salinity levels (0–20‰) did not significantly affect the survivability of this fish compared with the 30‰ salinity level.

It is well known that water salinity affects the osmotic processes of aquatic animals (Edwards and Marshall, 2012; Jin *et al*., 2022). Fish maintain the ionic and osmotic balance of their bodily fluids across varying salinities through energy-intensive osmoregulatory mechanisms. Therefore, they expend more energy in hypo- and hyper-osmotic environments, which reduces their growth rate (Rahmah *et al*., 2020; Galkanda-Arachchige *et al*., 2021). Conversely, optimal growth is anticipated when fish are cultured in salinity level close to their isosmotic point, which typically aligns with intermediate salinity levels (Shaughnessy *et al*., 2022). For this reason, a salinity of 20‰ likely provides optimal conditions for juvenile *L. argentimaculatus* to maintain better ionic and osmotic balance compared to 30‰, 10‰, and 0‰, positively impacting growth and overall culture. However, the importance and ultimate utilization of the conserved energy under isosmotic conditions remain debated, as optimal salinity levels for the growth and metabolism can be influenced by factors like developmental stages of each species (Edwards and Marshall, 2012).

Juvenile *L. argentimaculatus* are typically reared at salinity levels similar to sea water, around 29–35‰ (Estudillo *et al*., 2000; Leu *et al*., 2003; Melianawati *et al*., 2019; Asiandu and Malayudha, 2022). Similar results have been reported for other juvenile snapper species, such as the spotted rose snapper (*L. guttatus*) (Ibarra-Castro *et al*., 2020), red snapper (*L. campechanus*) (Galkanda-Arachchige *et al*., 2021), and Pacific red snapper (*L. peru*) (Santamaría-Miranda *et al*., 2021). Chi and True

(2018) reported that *L. argentimaculatus* culture mainly relieson wild-caught fry due to the perception that hatchery-raised juveniles are less robust. Furthermore, hatchery rearing of larvae has not been as successful (Melianawati *et al*., 2019; Sookdara *et al*., 2022), and still requires natural juveniles for production (Asiandu and Malayudha, 2022; Mosequera *et al*., 2023). Identifying primary factors contributing to juvenile mortality during nursing remains challenging, as hatchery-reared juveniles may be raised under suboptimal conditions. The results of the current study indicate that juvenile *L. argentimaculatus* achieved the best growth performance at 20‰ salinity level, suggesting that brackish water may be preferable to seawater for maximizing growth during nursing.

Juveniles of other euryhaline species tend to achieve maximal growth in brackish water, as has been reported for cobia (*Rachycentron canadum*) at 5–15‰ (Antony *et al*., 2021), yellowfin seabream (*Acanthopagrus latus*) and Asian seabass (*Lates calcarifer*) both at 6–12‰ (Mozanzadeh *et al*., 2021), grey mullet (*Mugil cephalus*) at 15‰ (Garcés and Lara, 2023), and hybrid grouper (*Epinephelus fuscoguttatus* × *E. lanceolatus*) at 5–10‰ (Wijayanto *et al*., 2023).

The current findings, along with those from other studies, indicated that water conditions (DO, water temperature, pH, total ammonia, nitrite, and total alkalinity) in this study did not impact the growth and survival of juvenile *L. argentimaculatus* (De Silva and Davy, 2010; Coniza *et al*., 2012; Chi and True, 2018; Muyot *et al*., 2021; Asiandu and Malayudha, 2022; Mosequera *et al*., 2023). This may be because salinity is a crucial factor in regulating the growth rate of juvenile fish in this species. Growth rates observed were consistent with prior studies, showing an average SGR of 2.38–2.80% per day at a stocking density of 10–50 fish·m^{-2} and a salinity of 30–32‰ (Coniza *et al*., 2012; Philipose *et al*., 2017; Muyot *et al*., 2021; Mosequera *et al*., 2023). Indoor rearing often promotes better growth than outdoor systems, largely due to improved control over key environmental factors such as temperature, water quality, and lighting. This method also allows for continuous health monitoring of the fish. Although it requires a higher initial investment and operational costs, indoor rearing delivers better survival rates and growth outcomes (Boyd *et al*., 2020; Ibarra-Castro *et al*., 2020).

Beyond salinity, the next critical factor for enhancing *L. argentimaculatus* farming is a diet tailored to the species' specific nutritional needs. Research indicates that the optimal protein level for maximizing yield is 48–50% (Coniza *et al*., 2012). However, there is a lack of studies on developing stage-specific feeds for larvae, juveniles, and adults. Currently, commercial feeds for carnivorous marine fish provided only 38–42% protein. Implementing recirculating aquaculture systems (RAS) is also a promising strategy to boost farming efficiency, as demonstrated in other marine species (Hanif *et al*., 2021; Islam *et al*., 2023). These factors represent important areas for further study.

CONCLUSIONS

The results of this study provide evidence that better growth performance in juvenile mangrove red snapper (*Lutjanus argentimaculatus*), in terms of mean body weight, weight gain rate, specific growth rate, and feed conversion ratio, can be achieved by nursing in water at 20‰ salinity. The lowest performance was observed in the two extremes of 30‰ salinity and 0‰ (freshwater). Low salinity levels (0–20‰) did not affect fish survivability compared to the 30‰ salinity level. This study suggests that an optimum salinity level (brackish water) is a key factor in promoting growth in *L. argentimaculatus* juveniles.

ACKNOWLEDGEMENTS

This study was a part of the Project for the Development of Culturing Potential of Red Snapper (*Lutjanus argentimaculatus*) for Production as Economic Aquatic Products, supported by the Kasetsart University Research and Development Institute (KURDI), Bangkok, Thailand under research grant No. RS(KU)6.65.

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