Effects of Feed Type, Temperature and Light Conditions on Rearing Performance of Ornate Spiny Lobster (*Panulirus ornatus*) Phyllosoma Larvae in Thailand

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ABSTRACT

The ornate spiny lobster *Panulirus ornatus* is a valuable but challenging aquaculture species, with larval survival—particularly of the phyllosoma stage—being a primary constraint. This study evaluated the effects of feed types and environmental conditions (light and temperature) on feeding performance and survival of primary phyllosoma larvae. Results show that providing appropriate live feed significantly enhances nursery performance ($p<0.05$). Larvae in the 1st P stage fed *Artemia* nauplii (AN) exhibited the highest mean survival from day 3, surpassing those fed with S-type rotifer (SR) or a mixed AN+SR regime. In the absence of feeding, survival dropped with complete mortality by day 7. Notably, 1st P larvae fed exclusively on AN demonstrated the longest survival duration. In contrast, artificial feed (AF) yielded a lower survival, with all individuals dying within 7 days, and combined AN+AF survival remaining below 15 days. Temperature profoundly affected feeding and mortality: at 30 °C, *Artemia* intake peaked (9.9 individuals·day^{-1}) with the lowest mortality (12.56 %·day^{-1}), whereas 33 °C produced the highest daily mortality. Light conditions did not significantly influence daily feeding or mortality rates. Collectively, these findings advance understanding of factors governing 1st P survival and offer evidence-based guidelines to optimize larval rearing and future productivity of *P. ornatus*.

Keywords: Live feed, Lobster larval rearing, Optimal rearing conditions, Spiny lobster

INTRODUCTION

The spiny lobster (*Panulirus* spp.) is a valuable resource in fisheries and a highly sought-after commodity in markets and is exported in various forms, including live, chilled, frozen, and processed products tailored for the food industry (FAO, 2022; Oniam *et al*., 2024). Almost all of the spiny lobster resources come from wild capture of young-to-adult individuals, subsequently used for various purposes, including cage farming (Tuffley *et al*., 2021; Arkronrat *et al*., 2025). Global spiny lobster fisheries have been experiencing increased pressure for resource extraction, resulting in declines in both catch volume and size. This trend had exceeded the sustainable capacity of the natural populations, leading to overfishing and indicating an unsustainable status of this fishery resource (Tirtadanu *et al*., 2024). As a result, lobster breeds have been imported to supplement domestic resources (Chamnina *et al*., 2022; Oniam *et al*., 2024). Therefore, efforts to breed lobsters to produce offspring and utilize the offspring as a substitute for natural resources are an important goal for aquarists in many countries (Ma *et al*., 2021; Utama *et al*., 2021; Yeap *et al*., 2022; Kembaren and Suman, 2023), including Thailand (Oniam *et al*., 2021; Sawaddee *et al*., 2021; Arkronrat *et al*., 2024).

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In Southeast Asian countries, the ornate spiny lobster (*Panulirus ornatus* Fabricius, 1798) is considered a high-value species with greater demand than other spiny lobsters, especially in coastal tourism areas (Utama *et al*., 2021; Chamnina *et al*., 2022; Oniam *et al*., 2024). Consequently, over 90% of lobster farming in some countries are based on juvenile lobsters from abroad, resulting in variability in quantity, size, and quality, which affects continuous production from lobster farming operations (Petersen *et al*., 2020). In Thailand, farmers in many inland cage aquaculture groups facing such issues have ceased their spiny lobster farming activities (Chamnina *et al*., 2022; Arkronrat *et al*., 2024; Oniam *et al*., 2024). The industry has remained underdeveloped due to constraints, such as a shortage of broodstock, hindering ongoing operations and expansion. No organization in Southeast Asian countries, including Thailand, has successfully established commercial breeding of *P. ornatus* juveniles, due to challenges including limitations in hatchery and nursery operations that have restricted commercial-scale production, owing to high mortality rates of phyllosoma and the lengthy nursing period (Utama *et al*., 2021; Genodepa *et al*., 2022).

P. ornatus is an economically important species for Thailand's fishing sector, especially in Phuket province in the southern region of the country, where genetic studies showed that it possessed genetic characteristics distinct from those in other areas. It is also known by another name, Phuket lobster. Additionally, it played a significant economic role at local and national levels, generating income and employment opportunities for many stakeholders (Chamnina *et al*., 2022). Understanding the primary phyllosoma larval rearing of *P. ornatus* in each region was crucial, because *P. ornatus* inhabited different environments in each region, which led to adaptations to varying environmental conditions and potentially different dietary requirements. It also reflected genetic diversity due to the different environmental factors of their respective habitats, even though they belonged to the same species (Farhadi *et al*., 2022; Yellapu *et al*., 2025). Therefore, it is critical to understand the patterns and guidelines for the initial rearing of *P. ornatus* larvae to ensure the success of the subsequent nursery stages. Consequently, the main focus of the current study was to investigate the diet used during the nursing of primary phyllosoma lobster larvae, as well as the environmental factors influencing their feeding behavior and mortality rates during this stage. Although extensive research had been conducted on the use of *Artemia* for the early phyllosoma stage of *Panulirus* spp. larvae, including the nutritional and environmental requirements of larval spiny lobsters such as *P. cygnus* (Takeuchi and Murakami, 2007), *P. echinatus* (Abrunhosa *et al*., 2008), *P. homarus* (Radhakrishnan, 2012), and *P. pelagicus* (Oniam *et al*., 2021), the optimal diet and environment for the survival of larvae at this stage remained unknown, as had been reported recently for *P. ornatus* (Genodepa *et al*., 2022).

Therefore, this study elucidates the live feed requirements of newly hatched phyllosoma larvae of *P. ornatus* and examines how environmental factors—specifically temperature and light—influence their feeding success and survivorship. The objectives of this study were to: 1) investigate the effects of live feed type on the rearing of primary phyllosoma larvae of *P. ornatus*; 2) compare the impacts of live feed versus artificial feed; and 3) examine the influence of light and temperature on feeding behavior and daily mortality rates. The findings should benefit academia, lobster farmers, and relevant agencies by providing valuable data and insights to support the advancement of lobster aquaculture. Additionally, the study sought to establish a comprehensive database to facilitate future research on the cultivation of *P. ornatus*.

MATERIALS AND METHODS

Experimental design and setup

The experiment was conducted at the Klongwan Fisheries Research Station (KFRS) in Prachuap Khiri Khan province, Thailand. Samples of the ovigerous female ornate spiny lobster, *Panulirus ornatus*, carrying eggs on their abdomen, were collected by lobster farmers from offshore cage aquaculture in Mueang Phuket district, Phuket province, Thailand. The sample females were transported to the hatchery of KFRS. The risk of

disease transmission to the hatchery system was addressed by immersing the females in formalin at a concentration of 100 ppm for 10 minutes, then transferring to an oxytetracycline solution at 50 ppm for 1 hour before being released into the tanks (Sawaddee *et al*., 2021).

The female *P. ornatus* (a carapace length of 124–148 mm and a weight of 1,967–2,740 g, n = 5) were kept in 500 L fiberglass incubation tanks (0.8 m × 1.65 m × 0.6 m), with one female per tank. The water was prepared with a salinity of 30‰, a pH ranging from 8.1 to 8.3, a dissolved oxygen level of at least 4.0 mg·L^{-1}, and an ammonia concentration of ≤0.1 mg-N·L^{-1} (Oniam *et al*., 2021). They were fed a mixed diet of green mussels (*Perna viridis*), yellowfin bream (*Selaroides leptolepis*), and squid (*Loligo* spp.), alternated daily at about 5% of their body weight, at 5:00 p.m. Additionally, sediment was siphoned out and 50% of the water was exchanged regularly. Water quality was monitored and analyzed every 3 days to ensure proper care and to maintain the environmental conditions according to animal welfare standards (Johnston and Jungalwalla, 2000). Once all the eggs attached to each female's abdomen had hatched into primary phyllosoma larva, a random sample of the larvae was collected for further study.

The experimental groups are listed in Table 1, corresponding to studies I, II, and III, each with three replications (n = 3).

Live feed preparation

For zooplankton, the S-type rotifer *Brachionus rotundiformis* was mass-cultured. The green microalga *Nannochloropsis* sp. from the KFRS laboratory was propagated in 200 L tanks with salinity of 15‰ and added fertilizer, then transferred to circular fiber tanks (2.5 m diameter, 1 m high, 2,000 L volume) and cultured for 2–3 days until the cell density reached 1–2×10^{6} cells·mL^{-1}. The rotifers were added at 10–20 individuals·mL^{-1} and cultured for about 3 days. Then, harvesting involved using a 75 µm mesh net and a filter bag (>200 µm) to trap sediments. The rotifers were collected and stored in 5 L containers (Arkronrat and Oniam, 2021). Then, these stored rotifers were used as prey for the primary phyllosoma. For *Artemia* nauplii, eggs from commercial sources were hatched in seawater (28‰) with aeration, kept under light for 24 h, then harvested for larval feeding.

Phyllosoma rearing experiment

(I) The effects of live feeding and starvation on primary phyllosoma were evaluated across four treatment groups: *Artemia* nauplii (AN), S-type rotifer (SR), *Artemia* nauplii plus S-type rotifer (AR + SR), and starvation as a control treatment for comparing the impacts of feeding and on survival. The primary phyllosoma (1st P) at 1 day post-hatch (dph) were reared in fiberglass tanks measuring

Table 1. Experimental groups for reared primary phyllosoma of ornate spiny lobster, *Panulirus ornatus*.

Subject	Treatment
(I) Effects of live feed and starvation	*Artemia* nauplii (AN)
	S-type rotifer (SR)
	Artemia nauplii + S-type rotifer: AN + SR
	Starvation
(II) Comparison of live feed versus artificial feed	Live feed
	Artificial feed (AF)
	Live feed + Artificial feed (live feed + AF)
(III) Interaction of light and temperature on feeding behavior and daily mortality rates	2-Factor experimental design: Light conditions (12 h light:12 h dark, or continuous dark condition) × Temperature levels (27 °C, 30 °C, or 33 °C)

0.30 m wide × 0.45 m long × 0.30 m high, with a water volume of 35 L. They were stocked at a density of 4 individuals·L^{-1} (Kittaka, 1994). The larvae were fed twice daily at approximately 09:00 a.m. and 9:00 p.m., at a rate of 1 g·day^{-1} (5–7 individual·mL^{-1}). The rearing period lasted for 15 days. On days 1, 3, 5, 7, and 15, the number of 1st P was randomly counted to determine survival rate.

(II) Effects of live feeding versus artificial feed were evaluated across three treatment groups: 1st P reared with the optimal live feed (control treatment) identified from study I; artificial feed (AF) (Commercial Feed®, micro-encapsulated form, containing 52% protein and 14.5% fat, semi-floating, 100–200 μm size; and a mixed diet of live feed and artificial feed (live feed + AF). The 1st P at 1 dph were reared in 35 L fiberglass tanks at a density of 4 individuals·L^{-1}. They were fed twice daily at approximately 09:00 a.m. and 9:00 p.m., at a rate of 1 g·day^{-1}. The rearing lasted 15 days, and the number of 1st P was randomly counted on days 1, 3, 5, 7, and 15 to determine survival rates.

(III) Interaction of light and temperature on daily feeding and mortality rates of 1st P was studied in a controlled chamber (Incubator Smart i-250S; Accuplus; Thailand) set to standard light conditions (12 h light:12 h dark), or continuous darkness. Temperatures were maintained at three levels: 27 °C, 30 °C, or 33 °C. The 1st P at 1 dph were placed individually into test tubes with a diameter of 1.5 cm, a height of 14.8 cm, and containing 12 mL seawater (30‰). Data were collected from 15 larvae per replicate. Larvae were fed the optimal live feed identified from study I, with feeding starting each day around 6:00 a.m. The amount of live feed consumed was counted, and larval mortality was monitored every 12 h during 72 h. Daily records included the amount of live feed eaten and the mortality rate of the 1st P larvae.

Data collection

In studies I and II, the survival rate of the 1st P was calculated, while in study III, the daily feeding and mortality rates of the 1st P were determined. These rates were calculated using the equations:

$$\text{Survival rate (\%)} = (\text{Final 1st P number} \times 100) / \text{Initial 1st P number}$$

$$\text{Feeding rate (individuals·day}^{-1}) = \sum \text{Number of live feed consumed by 1st P at t / Total t}$$

$$\text{Mortality rate (\%·day}^{-1}) = [\sum (\text{Number of 1st P dead at t} \times 100) / t] / \text{Total t}$$

where 1st P = primary phyllosoma stage, and t = time period (days).

Additionally, water quality was monitored and analyzed twice weekly throughout the rearing periods of studies I and II. Salinity was measured using a refractometer (Master-S10 alpha; Atago; Japan), pH using a portable pH meter (pH Testr30; Eutech; Singapore), dissolved oxygen (DO) and temperature using an oxygen probe (Pro20i; YSI; USA), and total ammonia, nitrite, and alkalinity were determined using indophenol blue, colorimetric, and titration methods, respectively (APHA, AWWA, and WEF, 2023).

Statistical analysis

Data from studies I and II were analyzed using one-way ANOVA, with mean comparisons conducted based on DMRT at 95% confidence. Study III was examined using two-way ANOVA, with differences among means tested based on Tukey's honestly significant difference at the 95% confidence level ($p<0.05$). All analyses were performed using the IBM SPSS Statistics for Windows (Version 24.0). Results were presented as mean ± standard deviation (SD).

RESULTS

Effects of live feed and starvation

There were no significant differences in the water quality parameters during *P. ornatus* larval rearing. The measured ranges were: salinity 30.00–30.33‰, DO 3.89–4.06 mg·L^{-1}, temperature 25.80–25.96 °C, pH 7.54–7.68, total ammonia 0.07–0.13 mg-N·L^{-1}, nitrite 0.00–0.02 mg-N·L^{-1},

and alkalinity 180.33–184.67 mg·L^{-1} $CaCO_3$. The study demonstrated that providing an appropriate live feed had a significant impact on the nursery performance of the 1st P ornate spiny lobster larvae during the initial 15 days. Larvae reared with AN had a significantly higher survival rate (85.00±13.22%) than those reared with SR (58.33±17.59%) and the combined AN+SR treatment (76.67±2.88%) from day 3 onward. The absence of feeding in 1st P resulted in a markedly low survival rate from the very first day of the nursery stage (55.00±18.02%), with the larvae unable to survive beyond 7 days (0.00±0.00%). In contrast, by day 7, the 1st P larvae fed AN, SR, or the AN+SR combination had survival rates of 55.00±18.02%, 15.00±13.22%, and 21.67±20.20%, respectively. Nevertheless, the 1st P reared solely with AN survived the longest (Figure 1).

Comparison of live feed versus artificial feed

Based on the results of study I, *Artemia* nauplii (AN) were selected as the most suitable live feed for rearing. Furthermore, the mean survival rates of the 1st P ornate spiny larvae differed significantly among the treatment groups. Larvae in the group fed with AF had a lower survival rate (46.67±25.65%) than those fed solely with AN (85.00±13.22%) from the first day of rearing. All larvae died within 7 days after rearing exclusively with commercial feed. In addition, larvae in AN+AF group survived less than 15 days. In contrast, the group fed with only AN had a mean survival rate of 31.67±16.07% on day 15 of rearing (Figure 2).

Some water quality parameters varied significantly among the treatments; in particular, the AF-nursing treatment had higher mean concentrations of total ammonia (0.36±0.05 mg-N·L^{-1}) and nitrite (0.30±0.08 mg-N·L^{-1}) than the AN (0.15±0.05 mg-N·L^{-1} ammonia and 0.07±0.02 mg-N·L^{-1} nitrite) and AN+AF (0.20±0.06 mg-N·L^{-1} ammonia and 0.16±0.05 mg-N·L^{-1} nitrite) treatments. However, these differences in water quality parameters remained within levels that did not affect the mortality rate of spiny lobster larvae. Additionally, other water quality parameters in each treatment were within the optimal ranges for nursery conditions, with no significant differences observed. These parameters included DO (3.84–4.17 mg·L^{-1}), temperature (25.50–25.63 °C), pH (7.54–7.62), and alkalinity (173.33–181.67 mg·L^{-1} $CaCO_3$).

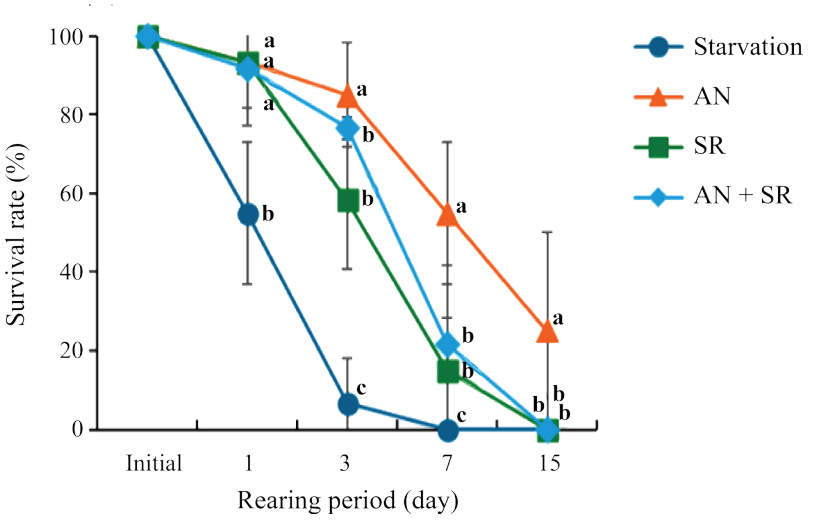


Figure 1. Mean survival rate of primary phyllosoma larvae (1st P) of ornate spiny lobster *Panulirus ornatus* reared: starvation and live feed test, *Artemia* nauplii (AN), S-type rotifer (SR), and *Artemia* nauplii + S-type rotifer (AN + SR). Error bars represent ± SD, and different lowercase letters indicate significant differences ($p<0.05$) among treatments within each time point.

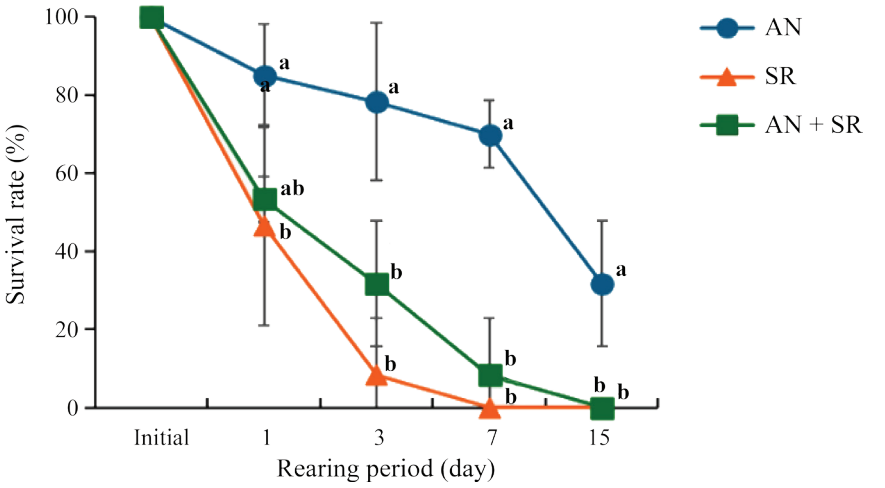


Figure 2. Mean survival rate of primary phyllosoma larvae (1st P) of ornate spiny lobster *Panulirus ornatus* reared with *Artemia* nauplii (AN), artificial feed (AF), and *Artemia* nauplii + artificial feed (AN+AF). Error bars represent ±SD, and different lowercase letters indicate significant differences ($p<0.05$) among treatments within each time point.

Influence of light and temperature on feeding behavior and daily mortality rates

Based on the results from study I, *Artemia* nauplii (AN) were selected as the most suitable live feed for rearing. A two-way ANOVA was conducted to examine the interaction between light and temperature, revealing that light and temperature did not interact to affect the feeding rate and mortality rate of 1st P ornate spiny lobster larvae (Table 2). However, temperature significantly influenced the feeding rate and mortality of the larvae. Specifically, at 30 °C, the larvae had a higher mean daily *Artemia* feeding rate (9.9±1.4 individuals·day^{-1}) and a lower mean daily mortality rate (12.56±3.60%) than those maintained at 27 °C or at 33 °C. The highest mean daily mortality rate (30.00±1.21%) was at 33 °C. Nonetheless, the *Artemia* feeding rates at 27 °C (4.5±1.1 individuals·day^{-1}) and at 33 °C (6.2±1.6 individuals·day^{-1}) did not differ significantly (Figure 3). Under the light versus the continuous dark conditions, the feeding rate of *Artemia* and the daily mortality of 1st P larvae did not differ significantly. The larvae had values for the mean *Artemia* intake of 10.1±1.9 and 9.6±1.1 individuals·day^{-1}, and for the mean mortality rate of 14.07±3.39% and 11.11±3.84% day^{-1}, under the normal light and dark conditions, respectively.

Table 2. Effect of combined effect of light and temperature on feeding and mortality rates of primary phyllosoma stage of ornate spiny lobster larvae.

Two-way ANOVA	SS	DF	MS	F	p-value
Intercept	573.459	1	573.459	243.278	0.000
Temperature on feeding rate (1)	88.821	3	29.607	12.560	0.001
Light on feeding rate (2)	0.123	1	0.123	0.052	0.823
(1) × (2)	1.864	2	0.932	0.395	0.682
Error	28.287	12	2.357		
Intercept	69,690.133	1	69,690.133	705.780	0.000
Temperature on mortality rate (1)	8,281.274	2	4,140.637	41.934	0.000
Light on mortality rate (2)	39.398	1	39.398	0.399	0.539
(1) × (2)	93.802	2	46.901	0.475	0.633
Error	1,181.904	12	98.742		

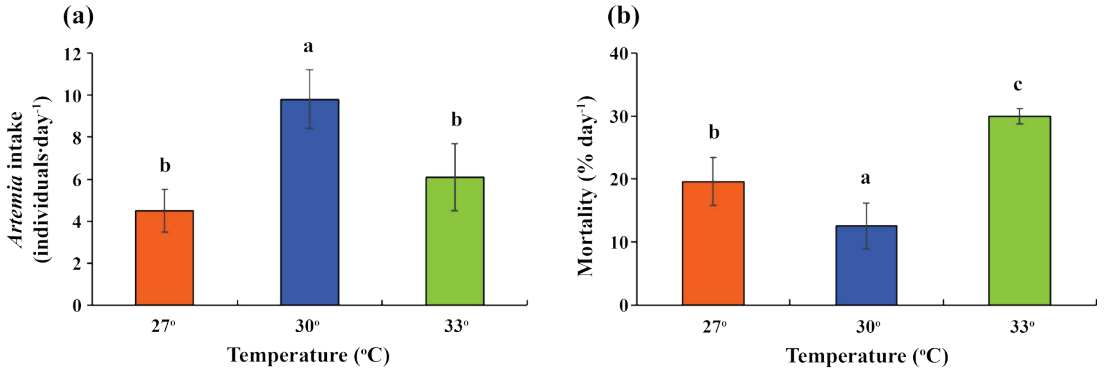


Figure 3. Influence of temperature on feeding behavior and daily mortality rates of primary phyllosoma larvae (1st P) during rearing of ornate spiny lobster *Panulirus ornatus*. Error bars represent ±SD and different lowercase letters indicate significant differences among treatments ($p<0.05$).

DISCUSSION

Although numerous factors influence the rearing of aquatic larvae, with each playing a vital role in crustacean larval development, the emphasis in the current study was primarily on the positive effects of live feeding options. Specifically, feeding *Artemia* nauplii to the primary phyllosoma stage of ornate spiny lobster *P. ornatus* larvae demonstrated a clear beneficial impact, supporting the hypothesis that selecting the optimal live feed type is crucial for successful larval rearing, as reported elsewhere (Radhakrishnan *et al*., 2020). Selecting an appropriate diet for larvae was a critical step that influenced their development and survival. *Artemia* nauplii have been widely accepted as a primary diet during the early larval stages of crustaceans, including crabs and shrimps (Zhang *et al*., 2022; Kahfi *et al*., 2023). In lobsters, essential fatty acids (e.g., EPA and DHA) are required and must be supplied via diet, supporting the common use of Artemia as a key live feed during early larval stages (Takeuchi and Murakami, 2007).

In the larval rearing of several lobster species, reports indicated that during the primary phyllosoma stage, newly hatched *Artemia* served as suitable feed alongside other live feeds (Oniam *et al*., 2021; Utama *et al*., 2021). This aligned with the present study, in which feeding *P. ornatus* during the primary phyllosoma stage exclusively with live *Artemia* yielded a higher survival rate than feeding with live rotifer or *Artemia* nauplii + rotifer. This difference was attributed to phyllosoma digestive mechanisms that were specific to the feeds they consumed, and *Artemia* represented another food source with enzymes that were specific or compatible with their digestive processes (Nankervis and Jones, 2022; Hammel *et al*., 2024). In addition, a functional-feeding explanation is plausible: phyllosoma larvae generally rely on prey detectability and capture success, and *Artemia* nauplii typically provide a more suitable prey size/shape and stronger movement cues than rotifers, which may increase encounter rate and handling success during early feeding. Recent findings indicated that although digestive enzyme activities in *P. ornatus* phyllosoma varied among sample groups, continuous exposure to *Artemia* from the first instar after hatching produced a relatively stable enzyme response that benefited survival, with this response significantly different from that observed when phyllosoma were starved (Genodepa *et al*., 2022). In contrast, commercial diets have gained popularity due to their convenience in culturing various aquaculture species that required rapid growth and simplified feed management. However, the nutritional quality and balance of these diets remained critical issues, as many often lacked the essential amino acids or fats necessary to meet the specific needs of each species, potentially affecting larval survival (Boyd *et al*., 2020). Similar to the current study, *P. ornatus* larvae exhibited

shorter survival periods when fed exclusively on commercial diets than those fed *Artemia* nauplii or *Artemia* nauplii combined with a commercial diet. The artificial feed (micro-encapsulated form, 100–200 μm size) used in this study did not induce feeding by phyllosoma, as evidenced by non-consumption and concurrent accumulation of ammonia and nitrite in the culture system. The lack of response may have resulted from factors such as unattractive appearance, odor, or movement of the food, or failure to digest post-ingestion. More specifically, non-ingestion is consistent with the feeding behaviour of phyllosoma, which often requires moving prey and appropriate particle size/buoyancy to trigger capture; microdiet particles may lack motion cues and may not match the preferred prey size/handling properties, even when nutritionally adequate. This study constitutes the first report of using artificial feed in the phyllosoma-nursery stage of lobster. The findings highlight the importance of selecting appropriate live feed for *P. ornatus* phyllosomal stage.

Consistent with previous reports that early phyllosoma stages represent a critical bottleneck for survival (Yeap *et al*., 2022), the present findings help narrow key constraints during the primary phyllosoma stage in *P. ornatus*, particularly feed type and temperature. For optimal rearing conditions, particularly regarding light and temperature, light conditions were not considered the primary environmental factors influencing food consumption and daily mortality of *P. ornatus* phyllosoma larvae. Conversely, in other economically important crustacean species, light was regarded as a significant factor affecting survival rates and developmental stages during early larval periods, such as in white shrimp, *Penaeus vannamei* (Sanudin *et al*., 2015) and the mud crab, *Scylla paramamosain* (Zhang *et al*., 2022). The present study diverged from prevailing findings in other crustacean larval systems by showing that light conditions did not constitute a primary determinant of feeding or daily mortality in *P. ornatus* phyllosoma larvae. This contrasts with the broader pattern reported for economically important crustaceans, where illumination frequently modulates survival and early ontogeny. This "no light effect" outcome appears to be a new observation for *P. ornatus* at the primary phyllosoma stage and should be highlighted as a species-specific finding. A possible biological explanation is that early phyllosoma may rely more on non-visual cues (e.g., mechanosensory/chemical cues from moving prey) than on photic cues for initiating feeding, thereby reducing sensitivity to illumination under the tested conditions. This finding also indicates that, for *P. ornatus* under the present rearing system, optimizing diet and temperature may be more critical than modifying light regime.

In terms of temperature, the current study results indicated that 30 °C yielded optimal feed intake and reduced daily mortality rates in *P. ornatus* larvae compared with 27 °C and 33 °C. These findings suggested that for phyllosoma of *P. ornatus*, live-feed availability alone was insufficient as a predictor of survival, and temperature emerged as a key environmental factor influencing its performance.

For phyllosoma of *P. ornatus*, temperatures below 30 °C and above 30 °C reduced feed intake and elevated mortality. These results are consistent with Uy *et al*. (2023), who observed that reared *P. ornatus* juveniles at 28 and 30 °C demonstrated significantly greater growth efficiency than cohorts cultured at 24 and 32 °C. Simultaneously, rearing temperatures affected their biochemical processes. In line with Sánchez-Ovando *et al*. (2023), higher temperatures were associated with decreased survival in several marine larvae, including *P. ornatus*, which may encounter similar challenges under elevated temperature conditions. Overall, the present data support careful regulation of rearing temperature to match the species- and stage-specific thermal window.

In the larval rearing of *P. ornatus*, the present study supports the conclusion that live-feed intake and daily mortality rates are the primary factors constraining performance at the optimal temperature. Regarding rearing environmental factors, this study represents the first report to clearly demonstrate how temperature influences both the feeding rate and the daily mortality rate of lobster larvae at this developmental stage. Importantly, the study also provides (i) a species-

specific finding that light did not affect feeding and mortality in primary phyllosoma of *P. ornatus*, and (ii) the first evidence that a commercial microdiet (100–200 μm) failed to elicit feeding, likely due to inadequate behavioural/physical feeding cues. The findings provide a crucial foundation for the aquaculture of this species, particularly in terms of nursery technologies aimed at increasing the survival of lobster larvae during the primary phyllosoma stage.

CONCLUSIONS

Based on the findings from the current study, the type of live feed was the primary factor influencing larval rearing of the ornate spiny lobster (*Panulirus ornatus*) at the primary phyllosoma stage. Larvae fed with *Artemia* nauplii had longer survival periods in the hatchery than those fed with S-type rotifers or *Artemia* combined with rotifers. Additionally, commercial feed was unsuitable for phyllosoma larval rearing. The environmental factors of light and temperature showed no significant interaction affecting rearing efficiency; however, the temperature directly impacted live feed intake and daily mortality rates. Furthermore, 30°C produced better outcomes than either 27 °C or 33 °C, while the light conditions had no significant effect on rearing performance. Overall, the findings suggest that optimizing live feed selection and maintaining appropriate temperature conditions are fundamental requirements for improving the survival and development of early-stage *P. ornatus* larvae.

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