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Comparison of Growth Rate of Olive Ridley Turtle Hatchlings (*Lepidochelys olivacea*) Based on Various Food Types

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Abstract

The success of sea turtle hatchling (“tukik”) release into the wild depends heavily on pre-release rearing quality, particularly feeding management. This study evaluated the effects of four feed types on the growth performance of Olive Ridley turtle hatchlings (*Lepidochelys olivacea*) during captive rearing. A Completely Randomized Design (CRD) was applied with four treatments i.e. vannamei shrimp (control), acetes shrimp, mackerel tuna, and commercial fish pellets, each with five replicates over 35 days. Observed parameters included i.e. weight gain, carapace length and width, specific growth rate (SGR), feed conversion ratio (FCR), feed utilization efficiency (FUE), and survival rate (SR). The combination of weight gain, carapace length increase, carapace width increase, and SGR was not grammatically parallel. ANOVA revealed that feed type had no significant effect on weight gain ($F=2.59$, $p=0.086$), but significantly affected carapace length ($F=6.57$, $p=0.003$) and width ($F=6.21$, $p=0.005$). Post-hoc LSD tests confirmed that mackerel tuna significantly outperformed all other treatments in carapace dimensions. Despite having lower crude protein content (23.33%) than pellets (45%), mackerel tuna yielded superior growth outcomes, likely due to higher palatability, digestibility, and lipid content (8.6%) favouring tissue development. Pellets showed comparable weight gain (15.23 g) and SGR (1.84%/day), yet the lowest survival rate was 80%. All natural-feed treatments achieved 100% SR. Mackerel tuna is recommended as the optimal feed for *L. olivacea* hatchlings during pre-release rearing.

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1. Introduction

Indonesia is an archipelagic nation nowadays comprising 17,380 islands with a coastline of approximately 95,181 km and marine territory covering roughly two-thirds of its total land area (BPS, 2026; Suryono and Taufiq-Spj, 2026). These waters represent one of the most biodiverse marine ecosystems globally, serving as critical habitat for numerous protected species, including all six sea turtle species found in the country: *Chelonia mydas*, *Lepidochelys olivacea*, *Caretta caretta*, *Eretmochelys imbricata*, *Dermochelys coriacea*, and *Natator depressus* (Kartono *et al.*, 2024; Suryono and Taufiq-Spj, 2026). All species are listed on the IUCN Red List and Appendix I of CITES,

reflecting their threatened status globally (Harnino *et al.*, 2021). The Indonesian government has regulated the protection of sea turtles since 1999, with subsequent provisions strengthened through Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.92/MENLHK/SETJEN/KUM.1/8/2018 (ProLifik, 2022).

Sea turtle populations in Indonesia continue to decline due to illegal trade of eggs, meat, and body parts, as well as habitat degradation and marine pollution (Kartono *et al.*, 2024). In response, conservation programs including beach protection, mangrove ecosystem, egg incubation management, and hatchling release programs have been established at various coastal sites (Daffa, *et al.*, 2026). The

Wana Tirta Mangrove and Coastal Conservation Area in Kulon Progo, Yogyakarta, is one such facility where *L. olivacea* hatchlings are reared prior to release into the Indian Ocean. Hatchling release programs bring educational and ecological value, encourage community conservation awareness and simultaneously increase turtle populations in the nature (Mulyani *et al.*, 2025).

The success of hatchling release is critically dependent on pre-release rearing quality. Adequate nutrition during captive rearing is essential to ensure hatchlings attain sufficient body condition for survival in the wild. Protein-rich feeds are known to accelerate growth and improve physiological resilience prior to release (Sitorus *et al.*, 2022). Natural feeds such as vannamei shrimp are commonly used in conservation facilities due to their availability and nutritional profile. However, due to inconsistent supply of life feed either their short shelf life pose in practical challenges. Artificial feeds (pellets) offer stable nutritional composition and longer shelf life, making them attractive alternatives (Darmawiyanti & Baidhowi, 2015), although their digestibility and palatability for hatchling sea turtles remain insufficiently evaluated.

Previous studies on sea turtle hatchling nutrition have yielded variable results depending on species and feed composition. Hanipa *et al.* (2017) reported that dried shrimp produced superior growth in *Chelonia mydas* hatchlings compared to pellets and dried anchovies. Ginting *et al.* (2020) found that 100% mackerel tuna produced optimal growth in *L. olivacea* compared to shellfish-based diets. In addition, Suraeda *et al.* (2018) demonstrated that artificial feeds with 40% fishmeal inclusion achieved significant Specific Growth Rate in *L. olivacea*. However, no study has systematically compared multiple natural feeds against artificial diets across weight gain, morphometric growth, and feed efficiency parameters within the same experimental design for *L. olivacea*.

This study addresses this research gap by comparing the growth performance of *L. olivacea* hatchlings fed four different diets; vannamei shrimp, acetes shrimp, mackerel tuna, and commercial fish pellets. The objective was to identify the most effective and accessible feed to optimize hatchling condition before release. Thus, this can be a contribution to the management of turtles listed in the IUCN red-list, based on evidence in the *L. olivacea* conservation programs in Indonesia.

2. Material and methods

2.1. Experimental Animals and Design

Twenty healthy *L. olivacea* hatchlings (mean initial weight: 16.87 ± 0.40 g; carapace length: 42.12 ± 0.62 mm; carapace width: 34.57 ± 0.48 mm), freshly emerged from semi-natural incubation nests, were obtained from the Wanatirta Conservation Area, Kulon Progo, Yogyakarta. Only hatchlings that were physically intact, actively mobile, and with no visible deformities were selected to minimize individual variation. Hatchlings were acclimated to rearing containers for 48 hours prior to the experiment, during which no supplemental feed was provided.

A Completely Randomized Design (CRD) was employed with four treatment groups ($n = 5$ each): P1 - vannamei shrimp (*Litopenaeus vannamei*, control); P2 - acetes shrimp (*Acetes* sp.); P3 - mackerel tuna (*Euthynnus affinis*); and P4 - commercial fish pellets (3 mm diameter, protein $\geq 45\%$ as per label). The experiment was conducted from 4 October to 7 November 2025 (35 days). All natural feeds were freshly minced to appropriate bite sizes before

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feeding. Statistical analysis was performed at the 5% significance level ($\alpha = 0.05$).

2.2 Rearing Conditions

Each hatchling was individually housed in a plastic container ($30 \times 22.5 \times 10$ cm) filled with 4 cm of filtered natural seawater ($\sim 2,700$ mL), sourced from a sand-filtered coastal aquaculture pond to ensure microbial cleanliness. Containers were arranged in a randomized layout and labeled to identify treatment and replicate. Water was replaced every two days, and containers were cleaned twice weekly. Water quality parameters (temperature, salinity, and pH) were measured daily at 09:00 using a calibrated pH meter and refractometer.

2.3 Feeding Protocol

Feeds were provided every two days following standard practice at the conservation site. Feeding amounts were calculated at 5% of hatchling body mass (wet weight). Feed was offered each morning (09:00) after water exchange. Feed residue was collected, and weighed at each exchange to calculate actual feed consumption. The remaining feed obtained should be drained with a paper towel first before weighing, hence the feed intake was monitored daily.

2.4 Proximate Analysis of Feeds

Crude protein content was determined by the Kjeldahl method ($N \times 6.25$) according to AOAC Official Method 984.13 (AOAC, 2019). While, the Crude fat analysis was performed using the Soxhlet extraction method with petroleum ether as the solvent (Jensen, 2008). Moist and ash content of each feed were determined at the Balai Besar Veterinary Wates, Yogyakarta. However, the pellet composition was additionally referenced from product labelling.

2.5 Growth and Performance Parameters

Body weight (g, digital balance ± 0.01 g), carapace length (CSL, mm), and carapace width (mm) were measured weekly using callipers (Figure 1).

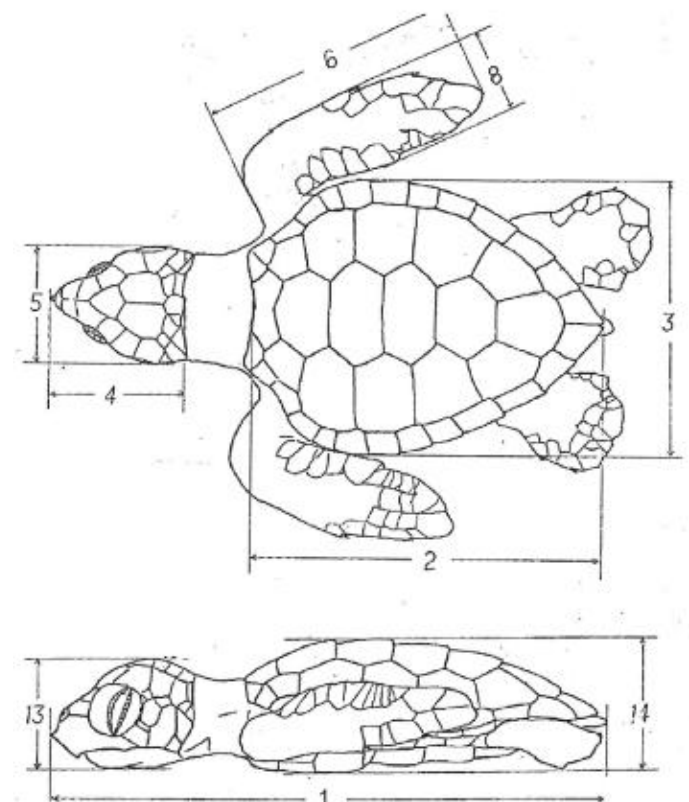


Figure 1. Turtle morphometric measurement i.e. 1. Total length, 2. Carapace length and 3. Carapace width, 4 Head length, etc. (Dermawan *et al.*, 2009)

The following formulas were used i.e.:

- *Specific Growth Rate (SGR, %/day)* (Effendie, 1997):

$$SGR = (\ln W_t - \ln W_0) / \Delta t \times 100$$

- *Feed Conversion Ratio (FCR)* (Zonneveld et al., 1991):

$$FCR = F / [(W_t + D) - W_0]$$

- *Feed Utilization Efficiency (FUE, %)* (Watanabe, 1988):

$$FUE = [(W_t + D - W_0) / F] \times 100$$

- *Survival Rate (SR, %)* (Effendie, 1997):

$$SR = (N_t / N_0) \times 100$$

where W_t = final body weight (g), W_0 = initial body weight (g), D = weight of dead hatchlings (g), F = total feed consumed (g), Δt = rearing period (days), N_t = final hatchling count, N_0 = initial hatchling count.

Table 1. Proximate composition of experimental feeds (% wet weight basis).

Feed Type	Crude Protein (%)	Crude Fat (%)	Moisture (%)	Ash (%)
Vannamei shrimp	20.81	6.06	78.56	1.45
Acetes shrimp	15.57	5.90	77.41	3.09
Mackerel tuna	23.33	8.60	72.67	1.35
Fish pellets	45.00*	4.00*	10.00*	10.00*

*As stated on product label.

3.2 Weight Gain

All treatment groups exhibited progressive weight increases throughout the 35-day rearing period (Table 2). Mackerel tuna achieved the highest total weight gain (16.54 g), followed by pellets (15.23 g), vannamei shrimp (13.59 g), and acetes shrimp (12.80 g). One-way ANOVA indicated that

2.6 Statistical Analysis

Data were tested for normality (Shapiro–Wilk test) and homogeneity of variance (Levene's test) prior to analysis. One-way ANOVA was applied to evaluate treatment effects, followed by Least Significant Difference (LSD) post-hoc tests where significant differences were detected ($p < 0.05$). All analyses were performed in SPSS v.26.

3. Results

3.1 Proximate Composition of Feeds

Proximate analysis revealed distinct nutritional profiles across feed types (Table 1). Pellets had the highest crude protein (45%) and ash content (10%), but the lowest lipid (4%) and moisture (10%). Mackerel tuna had the highest lipid content (8.6%) and the second-highest protein (23.33%), while acetes shrimp had the lowest protein content (15.57%).

feed type had no statistically significant effect on weight gain ($F = 2.59$, $p = 0.086$), suggesting that all four diets supported comparable weight accumulation. However, time (day) was highly significant ($F = 463.80$, $p < 0.001$), and the feed $\times$ time interaction was significant ($F = 4.12$, $p < 0.001$), indicating diverging growth trajectories over time across treatments.

Table 2. Mean ($\pm$ SD) body weight (g) of *L. olivacea* hatchlings across measurement days

Feed	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Gain (g)
Vannamei	17.47 $\pm$ 0.65	19.74 $\pm$ 0.41	22.28 $\pm$ 0.55	25.59 $\pm$ 0.85	28.63 $\pm$ 1.39	31.06 $\pm$ 1.70	13.59 $\pm$ 0.30
Acetes	16.93 $\pm$ 0.44	18.52 $\pm$ 0.97	21.35 $\pm$ 0.88	24.74 $\pm$ 0.91	27.55 $\pm$ 1.09	29.73 $\pm$ 1.16	12.8 $\pm$ 0.90
Mackerel tuna	16.84 $\pm$ 0.58	19.69 $\pm$ 1.33	22.32 $\pm$ 1.46	28.06 $\pm$ 2.83	30.80 $\pm$ 2.71	33.38 $\pm$ 2.72	16.54 $\pm$ 1.89
Pellets	16.56 $\pm$ 0.45	18.09 $\pm$ 0.24	21.33 $\pm$ 0.42	26.07 $\pm$ 0.96	28.80 $\pm$ 1.14	31.79 $\pm$ 1.34	15.23 $\pm$ 3.15

3.3 Carapace Length Growth

Carapace straight length increased progressively across all treatments (Table 3). Mackerel tuna yielded the greatest total length gain (11.41 mm), significantly exceeding vannamei (9.16 mm), acetes (8.74 mm), and pellets (8.79

mm). ANOVA confirmed a significant effect of feed type on carapace length ($F = 6.57$, $p = 0.003$). LSD post-hoc analysis showed that mackerel tuna differed significantly from all other treatments ($p < 0.05$), while vannamei, acetes, and pellets did not differ from each other ($p > 0.05$).

Table 3. Mean ($\pm$ SD) carapace length (mm) across measurement

Feed	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Gain (mm)
Vannamei	42.65 $\pm$ 0.34	44.07 $\pm$ 0.45	46.70 $\pm$ 0.31	49.14 $\pm$ 1.17	50.48 $\pm$ 1.30	51.81 $\pm$ 1.53	9.16 $\pm$ 0.00 ^a
Acetes	41.47 $\pm$ 1.19	42.74 $\pm$ 1.03	45.60 $\pm$ 1.09	48.13 $\pm$ 1.27	48.96 $\pm$ 1.18	50.21 $\pm$ 0.89	8.74 $\pm$ 0.28 ^a
Mackerel tuna	42.59 $\pm$ 0.59	44.08 $\pm$ 1.42	46.86 $\pm$ 0.77	50.13 $\pm$ 1.94	52.16 $\pm$ 1.47	54.00 $\pm$ 1.50	11.41 $\pm$ 1.41 ^b
Pellets	41.85 $\pm$ 0.97	42.55 $\pm$ 0.81	45.69 $\pm$ 1.00	47.29 $\pm$ 0.69	48.76 $\pm$ 1.09	50.64 $\pm$ 1.96	8.79 $\pm$ 0.78 ^a

3.4 Carapace Width Growth

Carapace width showed a similar pattern to length (Table 4). Mackerel tuna produced the highest width gain (13.40 mm), followed by vannamei (11.93 mm), acetes (11.14 mm), and pellets (10.13 mm). Feed type significantly

affected carapace width ($F = 6.21$, $p = 0.005$). LSD analysis revealed that mackerel tuna differed significantly from acetes and pellets, but not from vannamei. Pellets differed significantly from both vannamei and mackerel tuna, but not from acetes.

Table 4. Mean ($\pm$ SD) carapace width (mm) across measurement.

Feed	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Gain (mm)
Vannamei	35.39 $\pm$ 0.67	37.92 $\pm$ 0.53	41.20 $\pm$ 0.80	44.02 $\pm$ 1.26	45.63 $\pm$ 1.02	47.32 $\pm$ 1.50	11.93 $\pm$ 0.88 ^{ab}
Acetes	34.70 $\pm$ 1.52	37.28 $\pm$ 0.49	40.51 $\pm$ 1.07	43.18 $\pm$ 1.22	44.70 $\pm$ 1.38	45.84 $\pm$ 0.94	11.14 $\pm$ 0.67 ^{ac}
Mackerel tuna	34.55 $\pm$ 1.21	37.40 $\pm$ 1.42	40.38 $\pm$ 1.25	43.45 $\pm$ 1.33	45.88 $\pm$ 1.18	47.95 $\pm$ 1.67	13.40 $\pm$ 0.88 ^b
Pellets	34.22 $\pm$ 0.44	35.98 $\pm$ 0.37	38.68 $\pm$ 0.86	41.09 $\pm$ 0.50	43.06 $\pm$ 1.19	44.35 $\pm$ 1.47	10.13 $\pm$ 0.95 ^c

3.5 SGR, FCR, EPP, and Survival Rate

Feed performance indices are summarized in Table 5. Mackerel tuna yielded the highest SGR (1.95 ± 0.19 %/day) and the lowest FCR (2.44), indicating the most efficient feed utilization. Pellets showed the second-highest SGR (1.84 ± 0.16 %/day) and FCR (2.51). Vannamei and acetes shrimp had comparable, lower SGRs (1.64 and 1.61 %/day,

respectively) and higher FCRs (~2.88–2.89). EPP followed the same trend, with mackerel tuna (41.04%) and pellets (39.90%) outperforming vannamei (34.64%) and acetes (34.89%). Survival rates were 100% in vannamei, acetes, and mackerel tuna groups. One hatchling in the pellet group died on day 33, resulting in an SR of 80%. The overall mean SR was 95%.

Table 5. Growth performance and feed utilization indices of *L. olivacea* hatchlings.

Feed	SGR (%/day)	FCR	EPP (%)	SR (%)
Vannamei	1.64±0.13	2.89±0.28	34.64±3.05	100
Acetes	1.61±0.09	2.87±0.17	34.89±2.16	100
Mackerel tuna	1.95±0.19	2.44±0.44	41.04±8.58	100
Pellets	1.84±0.16	2.51±0.38	39.90±2.51	80

3.6 Water Quality Parameters

Water quality remained within acceptable ranges throughout the experiment (Table 6). Temperature ranged from 24.0 to 27.6°C, pH from 7.66 to 8.79, and salinity from 34 to 37 ppt.

Table 6. Water quality parameters recorded during the experiment.

Parameter	Minimum	Maximum
Temperature (°C)	24.0	27.6
pH	7.66	8.79
Salinity (ppt)	34	37

4. Discussion

This study showed that feed type influenced carapace development in *Lepidochelys olivacea* hatchlings, with the effects being more evident in carapace dimensions than in overall body weight during the 35-day rearing period. Mackerel tuna produced the greatest carapace length gain, while its carapace width gain was greater than that of acetes shrimp and commercial pellets but comparable to that of vannamei shrimp. These differences were supported by one-way ANOVA, which showed that feed type significantly affected carapace length ($F = 6.57$, $p = 0.003$) and carapace width ($F = 6.21$, $p = 0.005$), but not on weight gain ($F = 2.59$, $p = 0.086$). Subsequent LSD post-hoc comparisons confirmed that mackerel tuna differed significantly from all other treatments in carapace length, whereas for carapace width it differed significantly from acetes shrimp and commercial pellets but not from vannamei shrimp. Mackerel tuna also showed favorable feed utilization despite having a lower crude protein content (23.33%) than commercial pellets (45%).

The superiority of mackerel tuna in carapace growth is likely attributable to several interacting factors beyond crude protein content alone. First, mackerel tuna possesses a significantly higher lipid content (8.6%) compared to other feeds, which is critical in young reptiles for membrane development, fat-soluble vitamin absorption, and energy provision that spares dietary protein for anabolic tissue synthesis (Halver, 1989). In sea turtles, carapace growth involves active osteogenesis and keratin deposition that require both amino acids and lipid-derived structural precursors. The combination of adequate protein and high lipid in mackerel tuna likely provided a more favorable anabolic environment for carapace development. Second, fresh mackerel tuna flesh offers naturally balanced amino acid profiles including high proportions of essential amino acids such as lysine, methionine, and threonine that may align more closely with the nutritional requirements of *L. olivacea*

hatchlings than do the hydrolyzed fishmeal proteins in commercial pellets (Januarita *et al.*, 2022).

Despite the high crude protein in pellets (45%), their performance in carapace growth was comparable to that of the shrimp treatments and significantly lower than mackerel tuna. This suggests that the bioavailability of pellet protein may be limited in hatchling sea turtles. Several explanations are plausible: the digestive enzyme profile of neonatal *L. olivacea* may be poorly adapted to processed fishmeal-based feeds; pellet texture may reduce palatability and voluntary intake; and heat treatment during pellet manufacturing can cause amino acid crosslinking (Maillard reactions), reducing digestibility (Darmawiyanti & Baidhowi, 2015). The mortality observed in the pellet group (SR = 80%) warrants caution and may reflect suboptimal health maintenance, potentially linked to reduced palatability or inflammatory responses to processing by-products. This is consistent with findings by Suraeda *et al.* (2018), who emphasized that artificial feed composition requires optimization for *L. olivacea*.

The absence of a significant effect of feed type on weight gain ($p = 0.086$) contrasts with the significant effects on carapace dimensions ($p < 0.05$). This divergence may reflect the differential partitioning of nutrients between somatic mass gain and skeletal/dermal growth. In juvenile reptiles, skeletal development may be prioritized during early life stages, with carapace expansion receiving preferential nutrient allocation even under marginally differing dietary conditions. Body weight, meanwhile, may be less sensitive to feed quality differences over short experimental periods, particularly when total caloric intake is similar across groups. The significant feed $\times$ time interaction for weight ($F = 4.12$, $p < 0.001$) further confirms that growth trajectories diverged progressively, suggesting that longer rearing periods would likely reveal significant weight gain differences.

The SGR value with tuna feed (1.95%/day) was consistent or even exceeded the values reported in related studies. Ginting *et al.* (2020) reported optimal growth in *L. olivacea* fed 100% mackerel tuna. Wiguna *et al.* (2019) found vannamei shrimp yielded lower growth than mackerel in *L. olivacea* at TCEC Serangan. The SGR of shrimp-fed hatchlings (vannamei: 1.64%/day; acetes: 1.61%/day) in the present study is comparable to values for *Eretmochelys imbricata* fed similar diets (Lisandari *et al.*, 2020), suggesting consistent species-level dietary responses across chelonid hatchlings.

FCR with lower tuna feed (2.44) relative to shrimp (2.88–2.89) indicates more efficient feed-to-growth conversion, consistent with its higher FUE (41.04%). FCR values in the present study are somewhat higher than values

reported for fish species under intensive aquaculture, which is expected given that sea turtle hatchlings are not domesticated food organisms and rearing conditions (individual housing, limited water depth, intermittent feeding) may not be fully optimized. Kushartono *et al.* (2017) similarly noted that nutrient absorption efficiency in sea turtles is influenced by rearing environment quality.

Water quality parameters remained within ranges supportive of hatchling activity throughout the study. Recorded temperatures (24.0–27.6°C) were above the minimum threshold of 21°C reported by Campbell & Busack (1979), though slightly below the optimal 28°C for *L. olivacea* (Wibowo *et al.*, 2012). Lower temperatures during the study period (late rainy season transition) may have mildly suppressed metabolic rates and feed intake, potentially explaining the generally moderate weight gains observed. Salinity (34–37 ppt) was slightly above the optimal 34.2–35.75 ppt reported by Rinanda *et al.* (2022), but within tolerable ranges for this species. pH ranged from 7.66 to 8.79, encompassing the optimal pH ~8 for *L. olivacea* maintenance (Kushartono *et al.*, 2017), and did not constitute a limiting factor.

From a practical conservation standpoint, mackerel tuna is recommended as the primary feed for *L. olivacea* hatchlings during pre-release rearing. It is widely available in coastal fish markets near nesting beaches, cost-effective, and produces superior growth outcomes with 100% survival. Where supply chain reliability for fresh mackerel tuna is limited, optimized commercial pellets formulated specifically for sea turtle hatchlings with improved palatability and reduced anti-nutritional factors represent a viable future alternative, particularly for facilities managing large numbers of hatchlings.

5. Conclusions

Feed type significantly influenced carapace length and width growth ($p < 0.05$) but not weight gain ($p > 0.05$) in *L. olivacea* hatchlings over 35 days. Mackerel tuna (*Euthynnus affinis*) consistently outperformed vannamei shrimp, acetes shrimp, and commercial pellets across all growth and feed efficiency indices, achieving the highest weight gain (16.54 g), carapace length increase (11.41 mm), width increase (13.40 mm), SGR (1.95%/day), and FUE (41.04%), with 100% survival. Superior growth outcomes with mackerel tuna are attributed to its favorable lipid profile and amino acid digestibility rather than crude protein content alone. All natural-feed treatments achieved 100% survival. Mackerel tuna is recommended as the optimal primary feed for *L. olivacea* during pre-release hatchling rearing. Future research should examine longer rearing periods, larger sample sizes, and lipid and amino acid profiles specific to the nutritional requirements of *L. olivacea*.

Ethics approval

Due to no rough treatment or any specimen of organism were killed in this study, hence it doesn't have to made an "Ethical Clearance". "No permits were required for marine biota sampling."

Data availability statement

The data use is merely taken by authors which conducted during Oct – Nov 2025 in the Mangrove and Coastal Conservationist "Wana Tirta", Kulon Progo, Jogjakarta. This manuscript is part of student dissertation hence the second and third authors were actively involved in this study.

Author contributions

The second author conduct as corresponding authors provide details of co-author contributions to this manuscript. The First (1st), second (2nd) and third (3rd) Authors together made and discuss conceptualization and methodology as well as role of writing. Data curation, software, is merely done by the 1st author. Formal analysis by 2nd author, while project administration and resources were done by 3rd author. For the review editing was done by corresponding (2nd) author.

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Declaration of competing Interest

No specific funding either no competing interest. Hence, Authors declaration interest is merely "none".

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