Growth performance of spiny lobster *Panulirus ornatus* in land-based Integrated Multi-Trophic Aquaculture (IMTA) system

Milennie Vialantine Sumbing*, Sujjat Al-Azad, Abentin Estim & Saleem Mustafa

Borneo Marine Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, MALAYSIA.

*Corresponding author. E-Mail: milennie.bibie@yahoo.com.my; Tel: +60-88-32000; Fax: +60-88-320261

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Abstract

Aquaculture waste in the form of particulate organic matter and inorganic nutrients produces negative impacts when released to the environment. Integrated Multi-Trophic Aquaculture (IMTA) system is gaining importance for reasons of its environmental compatibility and quality of yield. The purpose of this study is to compare growth performance of a popular specis of spiny lobster in two different rearing systems. These were modeled based on recirculating system (RS) and flow-through system (FTS). Spiny lobster (*Panulirus ornatus*), sea cucumber (*Holothuria scabra*) and seaweed (*Kappaphycus alvarezii*) were used in the trials in both these systems. Water flow rate was maintained at 0.08 ± 0.1 L/sec. The stocking rate was 5 specimens / tank for spiny lobster (mean weight of 151.44 ± 7.14 g) and sea cucumber (mean weight of 32.16 ± 1.40 g), while mean initial biomass for seaweed was 500.65 ± 1.76 g/tank. Trials were conducted for 10 weeks. The results indicated that the SGR of lobster was not significantly different ($p>0.05$) in FTS (0.125 % day^{-1}) and in RS (0.096 % day^{-1}). There was no significant difference ($p>0.05$) in the survival of spiny lobster in FTS and RS. The survival rate of spiny lobster was 93.3 % and 80.0 % in FTS and RS, respectively. The inorganic nutrients, namely ammonia (NH_3), nitrite (NO_2), nitrate (NO_3) and phosphate (PO_4) were significantly higher ($p<0.05$) in RS than in FTS. Evidently, the FTS is the better option for culture in terms of efficiency of water quality remediation and growth of the stocked species.

Introduction

Integrated Multi-Trophic Aquaculture (IMTA) refers to farming of different aquaculture species together in a way that the system comprises fed aquaculture, organic extractive and inorganic extractive species in the same production module to reduce organic and inorganic wastes (Neori *et al*., 2004). In an IMTA system, the organic matter comprising uneaten feed and faeces from fed aquaculture (for example, fish or shrimp) is consumed by the deposit feeders (for example, sea cucumber). In addition, the inorganic nutrients, mainly nitrogen and phosphorus are absorbed by seaweed. Incorporation of species from different trophic levels helped in utilizing the waste from one species as a feed or fertilizer for other species, and this balance system ensures better water quality within the environment. The aim of IMTA system is to approach long-term environmental sustainability and profitability. There is a growing number of publications suggesting the feasibility of

IMTA modules in different regions. Interesting findings on Gilt-head bream (*Sparus aurata*), abalone (*Haliotis discus hannai*) and seaweed (*Ulva lactuca*) published by Neori *et al*. (2000) emphasized the sustainability element in the IMTA.

Spiny lobster was selected because it is one of the most valuable seafood and marketable species in Sabah. This species is marketed locally and is also exported to other countries such as Hong Kong and Taiwan. The price of this species averages RM70/kg in the wholesale local market and is as high as RM115/kg in the export trade to Hong Kong (Biunsing and Lin, 2004). Among the various spiny lobster species in the Indo-west Pacific region, *Panulirus ornatus* and *Panulirus homarus* are the most preferred ones for aquaculture because of high demand, market value and availability of wild seeds (Clive, 2010). Spiny lobster fed trash fish grows fast. Lobster waste comprising uneaten feed and excrement, can adversely affect water quality, especially when ammonia concentration is high (Vinh and Huong, 2009). To address this problem, spiny lobster was chosen as the first trophic level in IMTA system. The study was designed to compare the growth and survival of spiny lobster, *P. ornatus*, in recirculating and flow-through systems, as well as to observe the dynamics of water quality parameters in the two systems.

Methodology

Three aquaculture species (spiny lobster, sea cucumber and seaweed) formed the basis of trial modeled on IMTA concept. One experimental module was designed as flow-through system (FTS) and the other as recirculating water (RS) system that consisted of (1 m × 1 m × 1 m) 1000L water capacity tank for spiny lobster and two (1.3 m × 0.8 m × 0.4 m) 500L tank for both sea cucumber and seaweed. In the flow-through system (Figure 1), seawater was directly supplied to spiny lobster tank. Effluent from spiny lobster tank was drained into the sea cucumber tank through 25 mm outlet pipe. Water was pumped to seaweed tank from where it drains out. Sequence of water flow was much the same in the RS (Figure 2) except that the water from the seaweed tank was made to flow back to the spiny lobster tank. The tanks were aerated continuously to ensure adequate dissolved oxygen (DO).

Figure 1. Recirculating IMTA system

Figure 2. Flow-through IMTA system

Spiny lobster unit

Spiny lobster specimens were obtained from Pulau Banggi Kudat, Sabah. The stocking density was 5 specimens/tank (average body weight of 151.44 ± 7.14 g). PVC pipe of 10 cm diameter was provided to serve as a as shelter. Lobsters were fed trash fish with 3% of the body weight twice daily at 8:00 h and 16:00 h. Feed intake was recorded. Tanks were siphoned every morning to clean the uneaten feed.

Analysis of water sample

In-situ water quality parameters such as dissolved oxygen (mg/L), pH, temperature (°C) and salinity (ppt) recorded daily by using YSI Multi-parameter Pro Plus. *Ex-situ* water quality parameters such as total ammonium nitrogen (mg/L), nitrate (mg/L) and phosphate (mg/L) and total suspended solid (mg/L), were analysed every 15 days interval using standard analysis technique (Parson *et al*., 1984).

Collection of data

Measurement of each spiny lobster started from initial day of stocking and at 15-day interval. Body weight (g) and carapace length (mm) of spiny lobster was measured. Specific growth rate (SGR) and survival were calculated according to the following formula (Tuan, 2012):

$$\text{SGR}\ (\%\ \text{day}^{-1}) = (\ln W_e - \ln W_s)\ n \times 100$$

W_e = Final weight of targeted species

W_s = Initial weight of targeted species

n = Period of culture (days)

$$\text{Survival}\ (\%) = \frac{\text{Final number harvested}}{\text{Initial number stocked}} \times 100$$

Statistical analysis

Data pertaining to weight gain, specific growth rate (SGR), survival and all the water quality parameters were analyzed using T-test in SPSS software version 21.0 in accordance with the design of the experiment.

Results

Growth of spiny lobster was observed uniform in RS and FTS during first two weeks. Growth gradually increased in FTS (Figure 3). Finally, at the end of the experiment the average weight of 164.731 g was observed in FTS, which was not significantly different (P>0.05) from the average weight of 161.04 g obtained in RS.

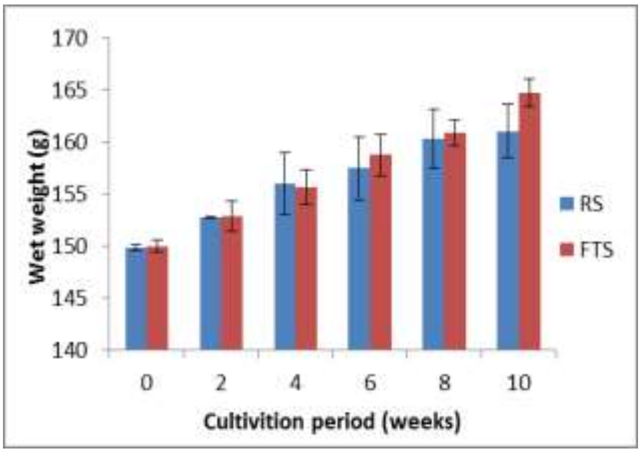

Figure 3. Mean body weight of *Panulirus ornatus* lobster in recirculating system and flow-through system

Consequently, the specific growth rate of 0.125 % day^{-1} of spiny lobster in FTS was not significantly different (P>0.05) than the specific growth rate of 0.096 % day^{-1} in RS (Figure 4)

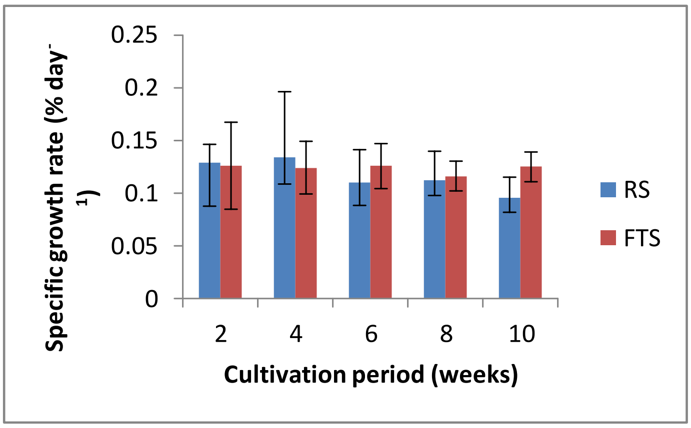

Figure 4. Specific growth rate of spiny lobster in recirculating system and flow-through system within 10 weeks cultivation.

The percentage survival of 93.3 % and 80.0 % was observed in FTS and RS respectively (Figure 5), which was not significantly different (P>0.05).

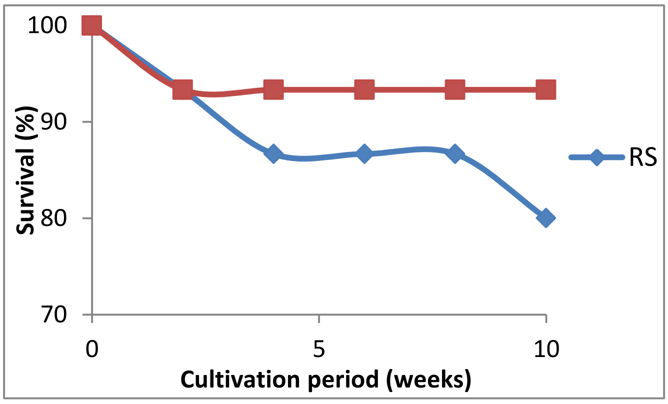

Figure 5. Survival rate of spiny lobster in recirculating system and flow-through system

Range of water quality parameters in the spiny lobster tank from both FTS and RS were shown in Table 1 and 2. Little variations were observed in *In-situ* water quality parameters (Table 1).

Table 1. Range of *In-situ* water quality parameters recorded in spiny lobster tank during the experiment period

Systems	DO (mg/L)	pH	Temperature (°C)	Salinity (psu)
Recirculating	5.25 – 7.54	8.05 – 8.27	28.00 – 30.70	31.12 – 32.92
Flow-through	5.12 – 7.32	7.92 – 8.15	30.00 – 31.20	30.60 – 31.42

The T- test analysis showed that the concentrations of $NH_3 + NH_4$, NO_2^-, NO_3^- and PO_4^- in both the culture systems were significantly different ($P<0.05$). RS recorded the highest concentration of $NH_3 + NH_4$, NO_2^-, NO_3^- and PO_4^- during the experimental period.

Table 2: Mean (± SD) concentration of $NH_3 + NH_4$, NO_2^-, NO_3^- and PO_4^- in the two culture systems during 10 weeks experiment

Systems	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
Recirculating	0.401 ± 0.209	3.639 ± 1.499	2.836 ± 1.220	0.089 ± 0.331
Flow-through	0.120 ± 0.050	0.201 ± 0.037	0.347 ± 0.112	0.024 ± 0.005

Discussion

Growth performance and specific growth rate of spiny lobster and survival rate were better in FTS compared to RS. However, there were no significant differences in both growth and survival between the two systems. Although FTS appeared to provide better growth performance compared to RS, *P. ornatus* appears to have advantages in aquaculture with regard to its tolerance to environmental fluctuations (Dennis *et al.*, 1997). Appropriate husbandry, type of rearing system and feeding are the required parameters in the culture of spiny lobster (Tuan, 2012). Mortality was relatively high in RS and this could be due to cannibalism that occurs just after the lobster molting. The requirement for type of shelter required by juvenile lobsters may be different and change with age (Kittaka and Booth, 1994). The provision of shelter can minimize the interaction during molting. Observations made on the effect of stocking density and shelter in rearing system of spiny lobster were earlier carried out by Tuan (2012). The off-bottom shelter (hanging plastic table) setting resulted in significant differences in survival that was 86.2 % compared to on-bottom shelter (plastic pipes) in which survival of 76.7%, during 60 days of the experiment. The type of shelter does not affect the specific growth rate of spiny lobster which was 0.48 % day^{-1} and 0.47 % day^{-1} using shelter of hanging plastic table and plastic pipes respectively. This was substantially higher than that observed in the present study.

In-situ water quality problems were not observed during this experiment. Lobsters are poikilotherm (cold blooded) animals and their growth rate is directly correlated with the temperature of the environment (Hartnoll, 2001). Jones and Shanks (2009) conducted an experiment on juvenile *P.*

ornatus where specimens were grown in tanks at five different temperatures (19, 22, 25 and 28 and 31°C). Growth was found to be significantly affected by temperature (P<0.01), and maximal growth occurred at 25–31 °C (Jones and Shanks, 2009). In the present study, temperatures recorded in RS (28.00–30.70 °C) and FTS (30.00–31.20 °C) were in range of 25–31 °C.

The concentration of NH_3 + NH_4^-, NO_2^-, NO_3^- and PO_4^- were lower in flow-through system compared to recirculating system. Flow-through system received continuous seawater supply through the tank and effluents drain out to the environment after it is filtered by seaweed. A study has been conducted for spiny lobster grown in shrimp pond water in northern Australia and the data were compared with the tank system with filtered sea water. The spiny lobster was noticed to be tolerant of turbid water with elevated levels of suspended solids and nutrient loading including high productivity of both phytoplankton and zooplankton species (Jones and Shanks, 2008). In a recirculation system, high level of ammonia may be acceptable to the spiny lobster (0.401 ± 0.209 mg/L). Ammonia levels more than 10 mg/L have been shown to inhibit growth in crustaceans (Chen and Lin, 1992). In this system, the water is recirculating, thus allowing the operation of seaweed as a biofilter for removal of dissolved inorganic nutrients such as ammonia that are harmful to the cultured species. Seaweed can function as a biological filter by virtue of its ability to absorb and utilize the nitrogenous during photosynthesis which can minimize the water consumption and pollution impact on the environment (Chopin *et al*., 2001). Recirculating IMTA system allows limitation of water consumption in land-based aquaculture.

Conclusion

Growth performance of *P.ornatus* was not significantly different in flow-through system and recirculating system, but survival was higher in FTS, suggesting the preference of the lobster for flowing water or favorable water quality parameters. The concentrations of total ammonium nitrogen, nitrite, nitrate and phosphate in FTS were significantly lower than the water quality parameters observed in RS. With further investigations it will be possible to design better systems, including the types of species and their biomass, for still better yield.

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