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Cage culture of the spiny lobster *Panulirus homarus* (Linnaeus) at Vizhinjam, Trivandrum along the south-west coast of India

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ABSTRACT

The potential for using floating sea cage for the aquaculture of spiny lobster, *Panulirus homarus* was assessed by rearing them in two different holding systems such as land-based FRP tanks and a large floating cage moored at Vizhinjam Bay along the south-west coast of India. Lobsters were reared for a period of 120 and 135 days in the tanks and cage, respectively and regularly fed on small/medium sized live mussels (*Perna indica*), in order to evaluate their growth, survival and feasibility for culture. Juvenile lobsters with average weight of 114.8± 25.67 g in the cage grew to an average weight of 225.95±42.7 g in 135 days. The weight increase recorded was 0.82 g day^{-1} with a percentage weight gain of 96.68 in the cage whereas juvenile lobsters in tanks with an average weight of 77.87±15.87 g attained 137.35±30.07 g with a weight increase of 0.48 g day^{-1} and percentage weight gain of 69.2%. The specific growth rates achieved in lobsters maintained in FRP tanks and in the sea cage were 0.45% and 0.50% of the body weight per day respectively. The hydrological parameters *viz.*, temperature, pH, salinity, dissolved oxygen and microbial load recorded were at the optimal levels for normal growth of lobsters. Bio-foulers on the cage unit were represented by ascidians, barnacles, sponges, polychaetes, brown mussels, oysters and seaweeds, which did not affect the performance of the lobsters as indicated by the significant growth advantages and better survival (75%) of juvenile spiny lobsters in the cage over the tank systems (71%).

Keywords: Cage culture, Growth, *Panulirus homarus*, Spiny lobster, Survival

Introduction

Food production from the sea is dwindling alarmingly on a global account over the years. Spiny lobsters have unabated demand in the global market as well as in the domestic market of our country and their exploitation from the natural stock is ever increasing. Presently about 1539 t of lobsters are being commercially exploited annually from the Indian EEZ and continuation of indiscriminate exploitation of this resource can lead to severe setback on the fishery (CMFRI, 2008). The decline in the fishery can be compensated by augmenting production through aquaculture. Realizing the importance of aquaculture, significant advances were made in lobster culture in countries *viz.*, Vietnam, Taiwan, Singapore and New Zealand. In India, except for some studies conducted by Vijayakumaran *et al.* (2009) on *Panulirus homarus* and *Panulirus ornatus* and in few centres such as Bhavanagar in Gujarat, on *Panulirus polyphagus* (Suseelan *et al.,* 1992), proper attention has not been given for growing them to marketable size on a commercial scale. Prolonged larval life cycle including longer life span and lack of standardized technology for the larval rearing especially on nutritional aspects for different life stages of the lobsters, are the major reasons attributed for this scenario (Dexter, 1972; Kittaka and Eishi Kegami, 1988).

Experimental culture of spiny lobsters in tanks has proved their hardiness and high growth rate (Radhakrishnan and Vijayakumaran, 1984) although aggression and cannibalism were observed under high stocking density (Van Olst *et al*., 1980). Hatchery production of *P. ornatus* is being projected as a feasible proposition in Australia and all leading lobster producing countries except India and Vietnam have banned juvenile exploitation. However, exploitation and rearing of naturally available pueruli and 0 year early juveniles for aquaculture as an alternative to hatchery production has been suggested by several workers (Chittleborough, 1974; Serfling and Ford, 1975a, b; Jeffs and James, 2001; James, 2007). Growth response of *P. homarus* in cage culture was studied by Srikrishnadhas *et al.* (1983). Kaleemur *et al.* (1997) studied the growth patterns of different size groups of *P. homarus* in captive conditions. Illustrated accounts on cultivable species of

Indian lobsters including their distribution, biology and prospects for culture using naturally available baby lobsters in cages and trays were published by Suseelan *et al.* (1992) and Radhakrishnan (1994; 2004). Subsequently the effect of different holding systems and diets on the performance of spiny lobster juveniles of *Jasus edwardsii* was studied by Simon and James (2007).

In the south-west coast of India, *P. homarus* (Linnaeus) and the deep sea lobster, *Puerulus sewelli* (Ramadan) dominate the fishery. Colachal, Chinnamuttom, Kadiapatanam and Vizhinjam are the major centers where bottom set gill nets, traps and trammel nets are employed for lobster fishing. At Vizhinjam, the lobster fishery is mostly formed by spiny lobster *P. homarus*. Lobsters caught by traps have shown excellent survival/vigor when compared to those caught in other types of gears. The fishing is carried out along rocky coastal areas by the traditional sector, operating indigenous crafts such as canoes and catamaran. Traps specially made of coconut leaves as well as bottom set gill nets are operated within 18 m, with intensive fishing in 8 m depth. Fishing is done throughout the year, depending upon the prevalence of favorable weather conditions and resource availability. Since Vizhinjam and nearby centres have good fishery for *P. homarus*, an attempt was made to culture and evaluate the growth performance of juvenile/sub-adult spiny lobsters in two different holding systems such as land-based FRP tanks and a large floating cage anchored at Vizhinjam Bay. The present work was undertaken as part of the new initiative of CMFRI to launch sea cage farming of lobsters at its selected research centres with funding support from the Ministry of Agriculture, Government of India.

Materials and methods

Experimental animals

Juveniles of the spiny lobster (*P. homarus*) were collected from 4 lobster fishing centres *viz.*, Kadiapatanam and Chinnamuttom in Kanyakumari district of Tamil Nadu as well as from Kollam and Vizhinjam in Kerala along the south-west coast of India. Healthy lobsters were selected based on their external appearance with all appendages and exoskeleton intact and showing good pigmentation.

Packing and transportation

The lobsters were transported *via* road to the Marine Aquarium of the Research Centre of Central Marine Fisheries Research Institute (CMFRI) at Vizhinjam, Kerala under moist conditions, with least disturbance. Prior to packing, lobsters were dipped for 5 min in chilled sea water ($13 \pm 2\ ^0$C) to lower their biological activity. They were then wrapped individually in newspaper and placed inside rectangular polystyrene boxes on top of a layer of newspaper lightly sprayed with chilled sea water of about $13 \pm 2\ ^0$C. Lobsters were placed one upon the other with water soaked newspaper in between like a sandwich. In the corners of each box, two plastic bottles filled with chilled seawater was also kept to maintain low temperature. Finally a layer of wet newspaper was spread on top and the box was closed. Lobsters in this state were inactive and were transported without any mortality.

Holding systems

Indoor FRP tanks

The experiments were conducted with 100 numbers of juvenile lobsters stocked in each duplicate FRP tanks having 10 t water holding capacity and kept in the Marine aquarium complex of CMFRI, Vizhinjam. The tanks were filled with filtered seawater and provided with biological filter and aeration throughout the culture period. Plastic baskets and PVC pipes were provided as hide-outs in the tanks. Lobsers were fed on live brown mussel, *Perna indica* @ 16-20% of the body weight at 18.00 h daily. The leftover feed along with faecal matter were siphoned out in the early hours (06.00-07.00 h) and about 10% of the water was replaced with fresh, filtered seawater, daily.

Floating cage

Cage culture was conducted in an extended cylindrical net cage made of nylon netting of 20 mm mesh size having 5 m dia on top, 7 m dia at the bottom and 4 m depth with a circular frame made of HDPE pipes filled with poly-urethane foam (PUF) for floatation (Fig. 1). The cage was provided with a catwalk railing, an additional velon screen at the bottom and was protected with a predatory outer net of 50 mm mesh size. A bird net (80 mm mesh size) was fixed on the top of the cage to prevent bird attacks. The entire cage was positioned by ballast and ropes tied to the mooring chain and anchored in order to withstand and absorb the underwater pressure especially from winds and currents. The total volume of the net cage was 110 m^3. The cage was moored at a depth of 10 m, about 75 m away from the shore in the Vizhinjam Bay (N 76º 59' 30": E 8º 22' 58").

A total of 1100 juveniles/sub-adults of *P. homarus* having mean total length (TL) of 131.5 mm and mean body weight (BW) of 114.8 g (Fig. 2) were acclimatized for a week in 10 t FRP tanks filled with filtered seawater and provided with aeration as well as biological filter, prior to stocking in the cage in January 2009. Before stocking, the morphometric data such as carapace length (CL), total length (TL) and body weight (BW) of random samples of lobsters (n=50) were recorded. The lobsters stocked belonged to three size groups *i.e.*, <100 g (n = 498), 100-149 g (n = 470), >150 g (n = 132). They were fed on live brown mussel @ 16-20 % of body weight daily at

Fig. 1. A view of the floating cage launched in Vizhinjam Bay

Fig. 2. Lobsters before stocking in the cage

16.00 h throughout the culture period. On alternate days, the shells of mussel along with unconsumed feed were removed from the cage.

Periodical sampling of lobsters was carried out once in every month to ascertain health status and growth of the stocked lobsters in both FRP tanks and the cage. Important parameters *viz.*, weight gain (%), weight increase (g day^{-1}), specific growth rate, SGR (% body weight per day) and biomass production (g) were estimated using the following formulae.

Weight gain (%) = (Final mean weight - Initial mean weight) x 100 / Initial mean weight

Weight increase (g per day) = (Final mean weight - Initial mean weight) / No. of days

SGR (% body weight per day)= (ln Final mean weight – ln Initial mean weight) x 100 / No. of days

Biomass production (g) = (Final weight - Initial weight) x No. of lobsters harvested

Water quality parameters

Water quality parameters such as temperature, salinity and pH were monitored on a daily basis while, dissolved oxygen and total bacterial load were analyzed once in a week as per APHA (1981), in the indoor FRP culture tanks as well as in the floating cage.

Results and discussion

Cage design

Floating net cage of size 5 m x 7 m x 4 m, provided with an additional velon screen at the bottom (which would act as a substratum for the animals) and hide-outs (*i. e.,* PVC pipes and small meshed baskets) to prevent cannibalism was used in the present study. However, floating cages of 3 m x 3 m x 1.5 - 4 m and larger ones are used to grow lobsters (*P. ornatus*) in Vietnam (Tuan, *et al.*, 2000), whereas smaller submerged cages are used in New Zealand and Australia for culture of *Jasus edwarsii* (Bryars and Geddes, 2005). The cage deployed at Vizhinjam Bay was sturdy and durable and the growth rate of lobsters recorded was higher than that obtained in the indoor tanks.

Water quality

The details of the water quality parameters recorded during the study period in the cage as well as in the tanks are given in Table 1. The temperature, salinity, pH, dissolved oxygen, and the total microbial load recorded in the FRP tanks and the cage were in the ranges: 26.18 to 27 ^{0}C, 35.40 to 35.81 ppt, 7.49 to 7.68, 4.35 to 4.69 ml l^{-1}, 1.18 x10^5 to 1.65 x10^5 CFU ml^{-1} and 28.37 to 31.36 ^{0}C, 33.0– 34.33 ppt, 8.15 to 8.32, 4.46 to 5.05 ml l^{-1}, 1.10 x 10^4 to 1.0x10^5 CFU ml^{-1} respectively. The values obtained in the cage site for temperature and salinity were within the ranges (28 to 32 ^{o}C and the 30-34 ppt) as suggested by Phillips *et al.* (1980), Van Olst *et al.* (1980) and Vijayakumaran *et al.* (2009) for lobsters. Low dissolved oxygen may cause mortality of lobster under captive reering (Radhakrishnan and Vijayakumaran, 1984). Kittaka (1994) stated that the lethal level of dissolved oxygen for lobster culture ranged from 0.5 to 3.0 mg l^{-1}, however such a situation was not observed during the present study. The high survival rate of cultured lobsters recorded from the cage in the present study could be attributed to the favourable environmental parameters in the cage site, though cannibalism of moulted lobster was observed occasionally.

Growth and survival

Data on stocking, growth and survival of juveniles and sub-adults of *P. homarus* in the two holding systems are given in Table 2. Sub-adults of lobsters with an average weight of 114.8 ± 25.67 g in the cage attained a mean weight of 225.95 ± 42.86 g in 135 days of which about 5 % of the lobsters reached 350 g. The weight increase of lobsters was 0 .82 g day^{-1} and percentage weight gain was 96.68 in the cage. However, in the FRP tanks, juvenile lobsters with an average weight of 77.88 g reached 137.1 g, attaining a

Table 1. Water quality parameters recorded during obster rearing period in FRP tanks and in the floating cage

Sample days	Temperature (°C)	pH	Salinity (‰)	Dissolved Oxygen (ml l^{-1})	Microbial load (cfu ml^{-1})
FRP Tanks					
October '08	27.0 ± 0.21	7.44 ± 0.04	35.40 ±0.42	4.35±0.19	$1.21x10^5$ ±$1.19x10^5$
November	26.93 ± 0.13	7.49± 0.03	35.81 ±0.37	4.69±0.34	$1.18x10^5$ ±$1.53x10^5$
December	26.18 ± 0.18	7.68 ± 0.01	35.68 ±0.45	4.41±0.62	$1.65x10^5$ ±$1.20x10^5$
Cage					
January'09	27.0 ± 0.21	8.32 ± 0.09	33.75 ± 0.50	4.90 ± 0.44	1.56 x 10^4±$2x10^4$
February	26.93 ± 0.13	8.15 ± 0.05	33.75 ± 0.50	4.46 ± 0.27	$8.40x10^4$±$9.2x10^4$
March	26.18 ± 0.18	8.22 ± 0.15	34.33 ± 0.52	4.65 ± 0.75	$6.60x10^4$±$6.2x10^3$
April	27.0 ± 0.21	8.29 ± 0.13	34.33 ± 0.52	5.05 ± 0.15	1.00 x 10^5±$1.1x10^5$
May	26.93 ± 0.13	8.22 ± 0.17	33.00 ±0.00	4.87 ± 0.39	1.10 x10^4±$1.3x10^4$

weight increase of 0.48 g day^{-1} and percentage weight gain of only 69.23. The SGR recorded in lobsters maintained in the tanks and in the cage were 0.45 % and 0.50% of the body weight per day, respectively. The results (Fig. 3-6) indicated that cage culture of spiny lobsters can provide significant growth advantages and better survival (75%) over tank systems (70.65%). Overall CL and wet weight gain were higher for lobsters in cage than in the tank system (Table 2). The results of the present study showed that stocks fed at 16 to 20 % body weight exhibited good growth rate which is in compliance with the findings of Joel and Orcajada (2006) in *Palinurus longipes longipes*

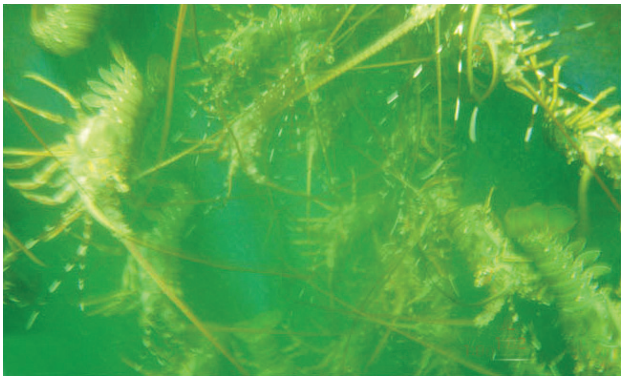

Fig. 3. Underwater view of the lobsters inside the cage

Fig. 4. A view of harvesting of spiny lobsters from the cage

Table 2. Stocking density, growth, survival and production details of *Panulirus homarus* recorded in the cage and FRP tanks

Holding system	Stocking density (no. m^{-3})	Sample Size (n)	Days	CL Initial (mm)	CL Final (mm)	Initial weight (g)	Final weight (g)	TL Initial (mm)	TL Final (mm)	Survival %	% wt increase	Wt. increase g /day	SGR (%)
Cage	10	50	135	42.08 ± 5.42	57.87 ± 6.36	114.8 ± 25.67	225.95 ± 42.86	131.15 ± 11.42	169.82 ± 14.8	75	96.86	0.82	0.50
Tank 1	10	50	120	34.45 ± 4.21	49.48 ± 4.39	83.45 ± 19.2	149 ± 28.45	117.4 ± 7.74	150.69 ± 9.71	69	65.3	0.49	0.42
Tank 2	10	50	120	32.53 ±	50.69 ± 6.07	72.3 ± 11.7	125.20 ± 31.7	113.23 ± 7.67	139.71 ± 15.95	72	73.16	0.48	0.49
Average of two tanks	10	50	120	33.49 ± 3.37	50.08 ± 5.23	77.87 ± 15.45	137.35 ± 30.07	115.31 ± 7.70	145.2 ± 12.83	70.65	69.23	0. 485	45.5

CL: carapace length; TL: Total length, SGR: specific growth rate
The values of CL, TL and weight (wet weight) given are Mean ± SD

Fig. 5. Lobsters harvested from the cage

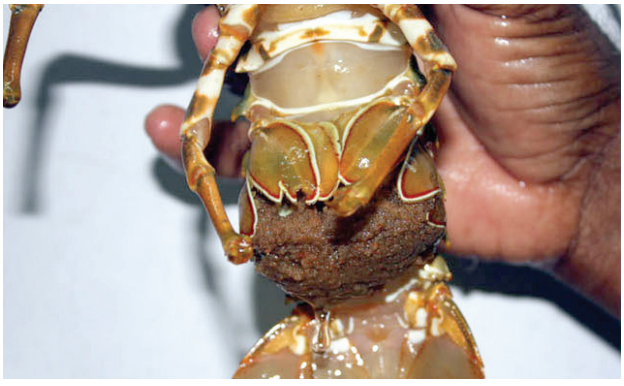

Fig. 6. Berried lobster from cage

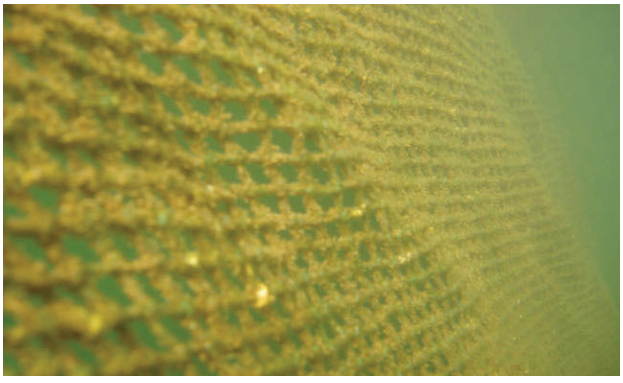

Fig. 7. Underwater view of the inner net of the cage

Fig. 8. Underwater view of outer net with ascidians

Biomass production and total production were 91.7 kg and 186 kg respectively for the cage whereas it was 4.2 kg and 9.7 kg in FRP tanks. From the 4th month of stocking, 20 - 22% of the females (in the size range of 220-350 g; CL : 53-65 mm) in the cage were observed in berried condition with developing egg mass in different stages of incubation, varying in colour from orange to dark brown. Another important observation was that, early juveniles in the weight range of 15-30 g (CL = 23 - 30 mm), which were below the initial stocking size of the lobsters were observed both inside and outside the inner net of the cage, suggesting that the cage with lobsters encouraged settlement of lobster post-larvae and early juveniles. Algae, barnacles, bryozoans, ascidians, sponges, polychaetes, pearl oysters, brown mussels and seaweeds were the main biofouling organisms recorded on the nettings of the cage (Fig. 7 and 8). Other animals commonly found associated with the net cage were brachyuran crabs and ornamental fishes.

The survival rates obtained were 75 % and 70.56 % in the cage and tanks respectively, which is comparable with the survival rates of 70- 95 % for *P. ornatus* as reported by the lobster growers in Vietnam. However, Jeffs and James (2001) recorded 67% mortality in experimental trials on sea cage farming of juvenile lobsters at the end of 6 months of stocking because of extensive cannibalism. Though, a condition of reddening was noticed in the lobsters stocked in the tanks during the initial phase, no incidence of disease was encountered in the cage.

The highest growth rate obtained in indoor culture of *P. homarus* juveniles was 0.75 g per day at a stocking density of 7 individuals per m^2 (Radhakrishnan and Vijayakumaran, 1990). Kaleemur *et al.* (1997) recorded a growth rate of 0.76 g day^{-1} with SGR of 0.58 for juvenile *P. homarus* below 100 g. In an open sea net cage experiment conducted at Thoothukkudi Harbour, Sreekrishnadas *et al.* (1983) reported 0.6 g growth per day with low survival rate (57.5%) for *P. homarus*. However, Vijayakumaran *et al.* (2009) observed growth of 0.33 - 0.97 g per day for juveniles in small FRP and mild steel floating cages at open sea sites attaining final mean weight ranging from 215 – 245 g during a period of 132 -164 days. The weight increase recorded in the present study is partly substantiated by Vijayakumaran *et al.* (2009). The SGR achieved in lobsters maintained in FRP tanks and in the cage during the present study were 0.45% and 0.50% respectively which were almost similar to that observed (0.43%) by Vijayakumaran *et al.* (2009). Weight increase per day obtained in the tanks was less than that obtained in the cage, in the present study. However, SGR was almost same in both the systems although it should have shown higher value in tanks as the initial average weight was about

70 to 80 g (Vijayakumaran *et al.*, 2009). Results of the present investigation as well as that of Jeffs and James (2001) indicate that sea cage culture is a biologically feasible way of growing juvenile lobsters to market size. Similar survival and better growth rates can be obtained in the prototype sea cages in comparison to indoor tanks even with a high biomass of animals (Simon and James, 2007). Bio-fouling as a supplementary source of nutrition is likely to have contributed to the high growth rate, although feeding a nutritionally adequate diet remains necessary to achieve optimum performance within a weight range of 220-350 g. Reduced stress, natural light levels and photoperiod are the other likely factors that may have contributed to the better performance of lobsters in the floating cage.

Vijayakumaran *et al.* (2009) estimated the size at first maturity of *P. homarus* as 150 g though lobsters below 125 – 135 g were occasionally observed carrying fertilized eggs. However, in the present study berried lobsters (Fig. 8) were observed within the weight range of 220 - 350 g (CL: 53 – 65 mm). Since more than 20% of the females were in the berried condition in the month of May, hatching of the fertilized eggs would have occurred during the culture period. This suggests that farming of lobsters in sea cages not only improves the production but also helps in enhancing the natural stock which may not be possible in captive rearing. Tamn (1980) has also reported that spiny lobster culture is an alternative to natural stock replenishment.

The present study demonstrated that good growth and survival of *P. homarus* can be obtained in floating sea cage and the performance recorded was better than the results from the tanks as well as from most of the experiments conducted in small FRP cages as reported by Vijayakumaran *et al*. (2009). Lobsters are high valued marine crustaceans and they have a commanding market value in both international and domestic markets especially in south-east Asian countries (Vijayakumaran and Radhakrishnan, 1997). Good fishery for lobsters exists along the south-east and south-west coasts of India. However, newly moulted and juvenile lobsters in the catches do not fetch good price in the local market and are used as bait for fishing cephalopods. If these can be grown in sea cages to marketable sizes >200 g (*i.e*., from 80 – 90 g to 200 - 350 g) in just over 4 ½ months, it would be an encouraging sign for this commercially important species with high export potential.

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