

## Capture based aquaculture of mud spiny lobster, *Panulirus polyphagus* (Herbst, 1793) in open sea floating net cages off Veraval, north-west coast of India

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### ABSTRACT

Capture based aquaculture (CBA) of the mud spiny lobster, *Panulirus polyphagus* was conducted in two cylindrical floating net cages of 6 m diameter and 4.5 m depth, made of HDPE sapphire netting of 18 mm mesh size. The cages were installed at a depth of 8 m, about 900 m away from the shore off Prabhas Patan, Veraval, India. Live lobsters were collected from lobster fishing centres of Veraval and Mahua regions of Gujarat and segregated into two groups: animals weighing 80-120 g (Group-1) and animals weighing < 80 g (Group-2). One thousand numbers of sub-adults of Group-1 with initial body weight of  $99.75 \pm 8.4$  g, were stocked in Cage-1 and 1500 juveniles of Group-2 with initial body weight of  $46.44 \pm 8.8$  g were stocked in Cage-2. The lobsters were fed twice daily with trash fish @ 8 % of the body weight by tray feeding. After the culture period of 90 days, no significant difference ( $p > 0.05$ ) was observed in the survival rate (overall survival = 93.7 %) whereas, juvenile lobsters in Cage-2 showed weight increase of  $1.49 \text{ g d}^{-1}$  and specific growth rates of  $1.51 \% \text{ d}^{-1}$  which was significantly higher ( $p < 0.05$ ) than the weight increase of  $1.17 \text{ g d}^{-1}$  and specific growth rates of  $0.80 \% \text{ d}^{-1}$  recorded from Cage-1. Results suggest that *P. polyphagus* has potential for capture based aquaculture in sea cage culture systems along Gujarat coast.

Keywords: Capture based aquaculture, *Panulirus polyphagus*, Sea cage farming, Spiny lobster, Veraval coast

### Introduction

Spiny lobsters (Family: Palinuridae) are one of the most highly priced export commodities from India fetching high prices in various international markets. They are also among the most important natural resources of Gujarat coast. Increased demand for these animals has led to their indiscriminate exploitation. Recent studies have pointed out that unless new fishing grounds are identified, the scope for improvement of fishery is limited with regard to spiny lobsters (Radhakrishnan and Manisseri, 2001). In this situation, besides fishery management and habitat restoration, augmenting the production through population enhancement, aquaculture and fattening remain the only option for sustaining export of lobsters to overseas markets (Raghavan, 2003). Gulshad *et al.* (2010) reported that, in terms of seed availability, spiny lobster pueruli as well as early post-pueruli are abundantly available in near-shore waters along the Saurashtra coast in the post-monsoon months (from September onwards). Mohanraj *et al.* (2009) observed that, in recent times the bulk of fish catch of Gujarat is comprised of low value species and juveniles.

India has lost substantial amount of foreign exchange by supplying lobster juveniles to overseas countries for farming (Charles and Peter, 2003). To avoid targeted fishing of juvenile lobsters and to protect the breeding stock, the Ministry of Commerce, Government of India has banned export of undersized (<150 g) lobsters by a Gazette notification in July 2003 (Venkatesan, 2004). Newly moulted and juvenile spiny lobsters in the catches do not fetch good price in the local market. If these can be grown in a holding system to marketable sizes >200 g within 3-4 months, it would be an encouraging sign for this commercially important group with high export potential. Hence the present study was conducted with the aim of promoting capture based aquaculture of the mud spiny lobster, *Panulirus polyphagus* (Herbst, 1793) and demonstrating the growth performance of juvenile lobsters in sea cage holding systems.

### Materials and methods

Two numbers of cages were installed in the month of February, 2012 at a depth of 8 m, about 900 m away from

the shore off Prabhas patan, Veraval. GPS marking for the two cage deployment sites are Cage-1: 20p 53' 22.78" N; 70p 23' 20.06" E and Cage-2: 20p 53' 17.95" N; 70p 23.25'.89" E. Cage culture was conducted in two single-moored, semi-submerged cylindrical floating net cages of 8 m outer and 6 m inner diameter and 4.5 m depth, made of sapphire netting of 18 mm mesh size. The circular cage frame was made of HDPE pipes of 140 mm diameter (thickness), supported by diagonal and vertical support collar pipes of 90 mm diameter (thickness). Base cage floating collar was filled with expandable polystyrene (EP). Three nets were used in the cage - inner (grow out) net, outer (predator protection) net and bird protection net. Inner and outer nets were made up of HDPE, and material was modified as per the biology of the lobster. A flexible HDPE mat of 3 mm thickness with 2 mm holes was stretched to the bottom of the inner net and 200 shelters were provided with PVC pipes of 90 mm diameter and 30 cm length at the bottom of the inner net and side wall of the net. The inner net for the sea cage was made up of HDPE Sapphire net of 18 mm mesh size and 1.5 mm twine thickness. Outer net made up of HDPE braided material having 43 mm mesh size and 3 mm twine thickness was attached to 8 m diameter ballast at the bottom of outer net. Inner net and outer net were held together with PP rope. The cages were moored with the dynamic single mooring system containing 12 mm alloy steel chain connected with a gabion box of 3.5 t dead weight. The cage was 6 m in height and was held in position by attached floats, gabion boxes and shock absorbers. It was also provided with 1.3 m catwalk to facilitate working space. An additional velon screen was provided at the bottom and a bird's net (80 mm mesh size) on top of the cage. The total area of net cage was 103.6 m<sup>2</sup>.

Juveniles of *P. polyphagus* were collected from lobster fishing centers *viz.*, Veraval and Mahua regions of Gujarat along the north-west coast of India. Based on their external appearance, healthy lobsters, showing good pigmentation and with all appendages and exoskeleton intact, were selected. The lobsters were transported *via* road to the Regional Centre of Central Marine Fisheries Research Institute (CMFRI) at Veraval, Gujarat under moist conditions, with least disturbance, and acclimatised for a period of two weeks in 400 l FRP tanks. A total of 2,500 lobsters were selected for stocking in the two cages. Before stocking, morphometric data such as carapace length (CL), total length (TL) and body weight (BW) of random samples of lobsters (n = 65) were recorded. Based on the body weight, the lobsters were divided into two size groups (Gulshad *et al.*, 2010): animals weighing 80-120 g (Group-1) and animals weighing < 80 g (Group-2). One thousand sub-adults of Group-1 with mean CL of 56.80 ± 7.5 mm and initial body weight (IBW) of 99.75 ± 8.4 g and 1500 juveniles of Group-2 with mean CL of 42.40 ± 8.1

mm, initial body weight (IBW) of 46.44 ± 8.8 g, were stocked in Cage-1 and Cage-2 respectively. The lobsters were fed daily with trash fish at 8% of the body weight. Caged lobsters were fed exclusively with fresh whole or chopped finfish and shellfish. *Saurida tumbil*, *Decapterus* spp, squid waste, shrimp waste and *Turbo* were most commonly used for feeding. Tray feeding was performed during the culture period. Feeding trays were tied at an equal distance around the handrail and chopped feed was kept in the trays. The daily ration was divided into two parts, 20% of feed was given in morning (07:00 hrs) and 80% in evening (17:00 hrs). Observations were made on the growth rate of caged lobsters by fortnightly random sampling of the population using cast net to ascertain their health status and also to adjust the feeding ration in accordance with the changes in the biomass of the caged population. The nets were cleaned every 15 days to remove clogging with silt and fouling with barnacles and exuvia. The cages were harvested in May 2012, after 90 days of culture. After harvesting, CL, and BW from random samples of lobsters (n = 65) were recorded for assessment of growth performance. Growth during the culture period was estimated using the formulae given below:

$$\text{Carapace length gain (\%)} = \frac{(\text{Mean final carapace length} - \text{Mean initial carapace length})}{\text{Mean initial carapace length}} \times 100$$

$$\text{Total length gain (\%)} = \frac{(\text{Mean final total length} - \text{Mean initial total length})}{\text{Mean initial total length}} \times 100$$

$$\text{Body weight gain (\%)} = \frac{(\text{Mean final wet weight} - \text{Mean initial wet weight})}{\text{Mean initial wet weight}} \times 100$$

$$\text{Body weight increase (g. d}^{-1}\text{)} = \frac{(\text{Mean final wet weight} - \text{Mean initial wet weight})}{\text{Culture period (in days)}}$$

$$\text{Survival (\%)} = (\text{Number of lobsters harvested} / \text{Number of lobsters stocked}) \times 100$$

$$\text{Specific growth rate (SGR)} = \frac{(\ln \text{ final weight} - \ln \text{ initial weight})}{\text{Culture duration (in days)}} \times 100$$

The water quality parameters *viz.*, temperature, salinity, pH and total suspended solids (TSS) were monitored on weekly basis. Dissolved oxygen content, total ammoniacal nitrogen, nitrate nitrogen and phosphate phosphorus were estimated fortnightly (APHA, 1998). Data from each treatment were subjected to one-way analyses of variance (ANOVA). Means were compared after analysis of

variances by Tukey's test ( $p=0.05$ ). The level of significance was chosen at  $p < 0.05$ , and the results are presented as mean  $\pm$  standard error of the mean (S.E.M.).

## Results and discussion

The water quality and nutrient parameters recorded from the cage site during the culture period were well within the optimum ranges recommended for lobster culture (Table 1). The optimal hydro-biological parameters reported for lobster farming are: temperature (26-33°C), salinity (25-35‰), pH (6.8-8.5), dissolved oxygen ( $>3.5$  ppm), ammonia ( $<0.1$  ppm) and nitrate ( $<0.1$  ppm) (Philips *et al.*, 1980; Van Olst *et al.*, 1980; Kittaka, 1994; Vijayakumaran *et al.*, 2009).

Data on stocking, growth and survival of juveniles and sub-adults of *P. polyphagus* in the holding system are given in Table 2. Lobsters grew from initial body weight (IBW) of  $99.75 \pm 8.4$  g to final body weight (FBW) of  $204.62 \pm 17.7$  g in Cage-1 showing body weight increase of  $1.17$  g  $d^{-1}$  whereas, juvenile lobsters in Cage-2 grew from

IBW of  $46.44 \pm 8.8$  g to FBW of  $180.06 \pm 24.3$  g showing body weight increase of  $1.49$  g  $d^{-1}$  in a culture period of 90 days. The specific growth rates (SGR) achieved in lobsters grown in Cage-1 and Cage-2 were 0.80 and 1.51 %  $day^{-1}$  respectively.

The growth pattern of *P. polyphagus* in the sea cages are illustrated in Fig. 1 and 2. Average growth of 30-40 g per year has been reported by George (1965) in Indian lobsters, and males have been found to grow faster than females (Mohamed and George, 1968). However, Thomas (1972) reported growth of 4 to 9 mm in carapace length (CL) in *P. homarus* after every successful moult and Vijayakumaran *et al.* (2010) recorded an increase of  $0.06$  mm  $d^{-1}$  in CL and  $0.54$  g  $d^{-1}$  weight in a communal rearing of *P. homarus*. Similarly, Kathirvel (1973) has reported increase of 2-5 mm in CL after every successful moult in the aquarium held *P. polyphagus*. Nair *et al.* (1981) reported growth increment of 6.5-9.6 mm per moult in CL of *P. homarus*, 11.3-13.8 mm per moult in CL of *P. ornatus* and 5.5 mm per moult in CL of *P. penicillatus*.

Table 1. Water quality and nutrient parameters recorded from cage site during the lobster culture period (all values are mean  $\pm$  S.E; n=20).

Water quality parameters	Feb. to Mar. 2012	Mar. to Apr. 2012	Apr. to May 2012
Temperature (°C)	23.41 $\pm$ 0.39	24.43 $\pm$ 0.46	26.41 $\pm$ 0.73
Salinity (ppt)	35.24 $\pm$ 0.20	35.74 $\pm$ 0.44	36.48 $\pm$ 0.28
pH	7.88 $\pm$ 0.05	7.99 $\pm$ 0.08	8.01 $\pm$ 0.07
Dissolved oxygen (ml $l^{-1}$ )	5.00 $\pm$ 0.11	4.77 $\pm$ 0.41	4.26 $\pm$ 0.93
Total suspended solids (mg $l^{-1}$ )	465.63 $\pm$ 10.89	462.50 $\pm$ 28.81	490.54 $\pm$ 57.62
Ammonia ( $\mu$ g at. $NH_4 - N$ $l^{-1}$ )	0.29 $\pm$ 0.05	0.34 $\pm$ 0.20	0.33 $\pm$ 0.06
Phosphate ( $\mu$ g at. $PO_4 - P$ $l^{-1}$ )	0.07 $\pm$ 0.01	0.07 $\pm$ 0.01	0.08 $\pm$ 0.01
Nitrate ( $\mu$ g at. $NO_3 - N$ $l^{-1}$ )	4.77 $\pm$ 0.46	4.93 $\pm$ 0.79	4.64 $\pm$ 0.46

Table 2. Stocking density, growth, survival and production details of *Panulirus polyphagus* recorded in the cage culture (Values in bracket are ranges observed during sampling; n=65).

	Cage-1	Cage-2
Size group	80-120 g	<80 g
Stocking density (no.)	1000	1500
Culture period (d)	90	90
Carapace length initial (mm)*	56.80 $\pm$ 7.5 (46-59)	42.40 $\pm$ 8.1(29-46)
Carapace length final (mm)*	70.73 $\pm$ 6.9 (67-76)	64.56 $\pm$ 4.3(59-71)
Wet weight initial (g)*	99.75 $\pm$ 8.4 (87-121)	46.44 $\pm$ 8.8(31-61)
Wet weight final (g)*	204.62 $\pm$ 17.7 (188-260)	180.06 $\pm$ 24.3(138-225)
Survival (%)	94.5	92.9
Carapace length gain (%)	24.52	52.26
Body weight gain (%)	105.13	287.72
Body weight increase (g. $d^{-1}$ )	1.17	1.49
Specific Growth Rate (% body weight $d^{-1}$ )	0.80	1.51

\*The values of carapace length and wet weight given are Mean  $\pm$  S.E.; n=65

From the above observations it can be concluded that the growth of lobsters varies from species to species. Kizhakudan and Patel (2011) have reported daily growth of 0.14 mm CL (0.47 g) in male and 0.12 mm CL (0.33 g) in female *P. polyphagus* fed on *Turbo* sp., in closed captive rearing. According to Radhakrishnan (2008), juvenile *P. polyphagus* (30-50 g) stocked in intertidal pits (21 x 7 x 1 m<sup>3</sup>) at 20 no. m<sup>2</sup> attained 100-125 g in 90 days, *i.e.*, 0.78-0.83 g d<sup>-1</sup>. In the present study, higher growth rates were achieved. Moreover, the smaller animals in Cage-2 showed higher growth rate than the larger animals in Cage-1 which suggests higher growth performance of smaller animals at high stocking density compared with larger animals.

Significant difference ( $p < 0.05$ ) was noticed in the growth pattern whereas, no significant difference was observed between the survival rates of two size groups of lobsters stocked in Cage-1 and Cage-2, which shows that higher stocking density with smaller animal is advisable for faster growth and also the other physiological factors are likely to influence these results, since lobsters approaching sexual maturity (in Cage 1) are likely to show suppressed growth (Figs. 1 and 2), indicating that juvenile lobsters are better candidates than sub-adults for stocking in cages. During the culture period, the overall survival rate was 93.7%, which is comparatively higher than survival recorded in the same species by Gulshad *et al.* (2010) where, survival rate of 86.1%, specific growth rate of 0.519 and total production of 308.6 kg was reported from the sea cage. Rao *et al.* (2010) have recorded survival of 75%, weight increment of 0.82 g per day and SGR of 0.50 in cage reared spiny lobsters, *P. homarus* at Vizhinjam Bay. Vijayakumaran *et al.* (2009) reported that sub-adults of *P. homarus* grew from IBW of 123.61 g to FBW of 341.25 g in 225 days at a stocking density of 21 no. m<sup>-2</sup> showing

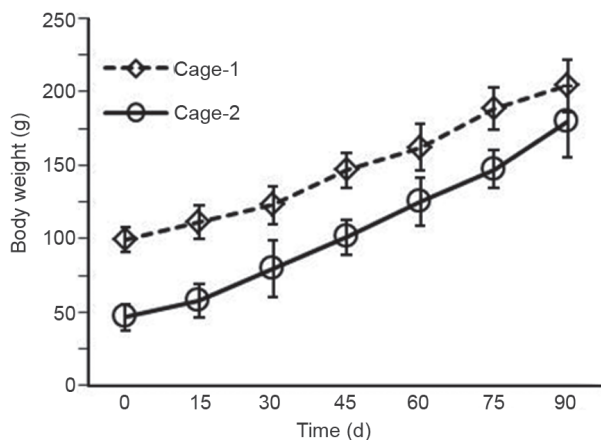


Fig. 1. Mean increase in body weight (g) of *Panulirus polyphagus* cultured in Cage-1 and Cage-2; each point represent the mean  $\pm$  S.E of about 65 individuals

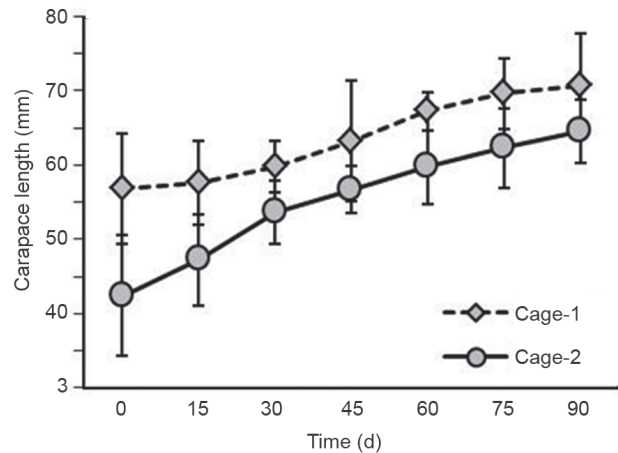


Fig.2. Mean increase in carapace length (mm) of *Panulirus polyphagus* cultured in Cage-1 and Cage-2; each point represent the mean  $\pm$  S.E of about 65 individuals

survival of 73% and growth rate of 0.97 g per day in floating sea cages along the south-east coast of India. Sreekrishnadas *et al.* (1983) recorded growth rate of 0.6 g per day with survival rate of 57.5% for *P. homarus* from open sea net cage at Tuticorin Harbour. In the present study, the survival rates recorded was similar to 70-95% recorded for *P. homarus* by lobster growers in Vietnam (Tuan and Mao, 2004).

There was no incidence of disease in cages during the culture period and no damages were noticed in tail fan. Bryars and Geddes (2005) have reported that tail fan damage was found to be a major problem with long-term live-held lobsters which reduces market value. The other main factor affecting the live trading of lobster is the coloration. The ability to maintain and improve coloration is an important consideration in live-holding of lobsters. Color change over time in the exoskeleton of captive decapod crustaceans has been reported on several occasions (D'Abramo *et al.*, 1983; Howell and Matthews, 1991; Menasveta *et al.*, 1993). These changes can usually be attributed to the level of carotenoids in the diet as carotenoids are essential for the pigmentation of the exoskeleton. In the present study, lobsters maintained their coloration, possibly by deriving carotenoids through consumption of biofouling organisms from the cage surfaces. The major biofouling organisms observed on the nettings of the cage are algae (biofilm), barnacles, bryozoans, ascidians, sponges, polychaetes, oysters and seaweeds. Brachyuran crabs and small fishes were the other animals commonly found associated with the net cage. Jeffs and James (2001) reported that, supplemental nutrition from biofouling in sea-cages could be a major factor influencing the high growth rates and darker coloration of animals compared to those grown in tanks. The more natural exoskeleton pigmentation of lobsters cultured in the sea-

cage would improve their market price and minimise the need for the inclusion of costly astaxanthin in dry formulated feeds (Barclay *et al.*, 2006).

The present study demonstrated that good growth and survival of *P. polyphagus* can be obtained in floating sea cage. The study also provided biological and husbandry information on potential survival rates, growth performance, conditioning and feeding of live-held lobsters. The results from the present study were encouraging and the performance recorded was better than the earlier results from the same region with the same species (Gulshad *et al.*, 2010) as well as from most of the experiments conducted with *P. homarus* in open sea cage (Sreekrishnadas *et al.*, 1983; Vijayakumaran *et al.*, 2009; Rao *et al.*, 2010). Results of the study suggest that *P. polyphagus* is a potential lobster species for capture based aquaculture in sea cage culture systems along Gujarat coast.

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## Fishery of elasmobranchs with some observations on the biology and stock assessment of *Carcharhinus limbatus* (P. Muller & Henle, 1839) exploited along Malabar coast

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### ABSTRACT

Elasmobranchs are caught in trawls, gillnets and longlines along the Malabar region of Kerala and they are landed almost round the year, accounting less than 1% of the total catch. The catch of elasmobranchs during the period 2001-2011 has shown a declining trend, but towards the end of this period the fishery has improved marginally. The contribution of trawl, gillnets, longlines and other gears were 43.1%, 31.3%, 21.1%, and 4.5 % respectively. The contribution of sharks, rays and skates were 70.8%, 24.2% and 5.0% respectively. Twenty four species of sharks, 8 species of rays and 2 species of skates were recorded in the catch. Length-weight relationship was estimated for *Carcharhinus limbatus* and the regression equation for both the sexes was  $W = 0.00001486L^{2.80214}$  ( $r=0.9661$ ). The overall F: M ratio was estimated as 1:1.59; females predominated the catches in almost all months. The growth of this species is described by the equation  $L_t = 302(1 - e^{-(0.45)(t-1.2)})$ . The species grows fast during the early stages of its life. The annual average exploitation ratio (E) is estimated as 0.74 which is higher than the optimum exploitation rate estimated. The present study showed that *C. limbatus* is heavily targeted, hence this species is at risk of being overexploited and is in need of immediate management.

Keywords: Elasmobranchs, Fishery, Malabar, Mortality, Stock assessment

### Introduction

Elasmobranchs are an important demersal resource exploited along the Malabar coast. They are caught throughout the year by trawl, gillnet and longlines. Among the elasmobranchs, sharks form the dominant resource followed by rays and skates. There is very good demand for this resource in fresh and dried condition. Information on the elasmobranchs of Malabar region is scanty except for works by Devadoss (1984, 1998), Devadoss *et al.* (2000) and Raje *et al.* (2002, 2007). Based on exploratory surveys, Sudarsan *et al.* (1989) and Ninan *et al.* (1992) gave quantitative assessment of elasmobranchs along the outer continental shelf and slope of the south-west coast. In the present study, an attempt has been made to put together detailed information on the fishery of elasmobranchs along this coast, with some information on the biology and stock assessment of *Carcharhinus limbatus*.

### Materials and methods

The data on the landing of elasmobranchs along the Malabar region by trawls, gillnets, longlines and other gears for the period 2001-2011 collected by the Central Marine Fisheries Research Institute (CMFRI) from Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala were

used for this study. The length frequency data of *C. limbatus* collected from the landing centers at weekly intervals during 2005-2011 were used for estimation of growth and population parameters. A total of 2088 specimens in the length (total length, TL) range of 62-238.2 cm were used for the study. The data on length was grouped into 5 cm class intervals and the raised monthly frequency distribution was used for the growth studies following Sekharan (1962). Length-weight relationship was studied following Le Cren (1951). A total of 1,151 males in the range of 65.1-211.2 cm (2.6 - 76.8 kg weight) and 1,100 females in the range of 75.8-238.2 cm (2.3-82.5 kg weight) were used for determining the length-weight relationship of *C. limbatus*. The relationship was estimated by the least square method. Growth and mortality parameters were estimated using FiSAT programme (Gayanilo Jr. *et al.*, 1996) after pooling the annual data for the period 2005-2011. Natural mortality (M) was estimated from the empirical formula as in Pauly (1980), by taking the mean seawater temperature as 28°C and the total mortality (Z) from the catch curve as in Pauly (1983). The exploitation ratio (E) was estimated by the ratio of fishing mortality to total mortality. The exploitation rate 'U' was estimated by the formula  $U = F/Z * (1 - e^{-Z})$ . The average exploitation rate over the period of study was estimated by pooling data for the period 2005-2011. The