Indian J. Fish., 59(1) : 113-118, 2012

Effect of salinity on growth and survival of juvenile Indian spiny lobster, *Panulirus homarus* (Linnaeus)

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ABSTRACT

The spiny lobster, *Panulirus homarus* has recently captured much attention in India for fattening in marine cages due to its high demand in the international market. Water quality parameters play an important role in the production rate of commercial lobster mariculture. In the present study, juvenile lobsters (93.63 ± 0.4 g, mean ± SD; 41.66 ± 0.57 mm CL, mean ± SD) were grown in four different salinities (20, 25, 30 and 35 ppt) over a period of 80 d and significant differences ($p<0.01$) were observed in survival and growth. Growth was highest in 35 ppt salinity and progressively reduced at lower salinities. Although rearing in seawater of 35 ppt salinity has resulted in the best performance for *P. homarus*, its capacity to tolerate lower salinities would provide greater opportunity to develop commercial aquaculture.

Keywords: Cannibalism, Growth, Salinity, Spiny lobster, Survival, Water quality parameters

Introduction

Lobsters are one of the most attractive, economically important premium seafood items marked for its delicacy. It forms one of the most valuable low volume fisheries in the coastal waters of India. Current production of lobsters in India, is around 2000 t, most being exported alive and in whole cooked form to the south-east Asian market (Radhakrishnan *et al*., 2000). *Panulirus homarus,* a species of spiny lobster, is distributed in India along the south-east and south-west coasts and major fishery is from Tamil Nadu and Kerala.

Development of lobster culture has been actively pursued for many decades in the world as well as in India. Several species, well established in the market have been the subject of intensive research and development aimed at establishing commercial aquaculture to supplement wild catches, and to meet the ever increasing demand. The most prominent of these are the two clawed lobster species *Homarus americanus* and *Homarus gammarus* from the north-west and north-east Atlantic. Aquaculture technology for these two species was ardently pursued, but was unsuccessful due to biological constraints primarily the aggressive behaviour (Aiken, 1988; Waddy *et al*., 1998; Tlusty, 2004). Adverse environmental conditions have been suspected to cause heavy mortalities among the cultured homarid lobsters (McLeese, 1956). In the case of marine organisms, among the water quality parameters, temperature and salinity are the two important parameters which are examined through individual experiments to determine the optimum levels and tolerances (Chaisson, 1932; McLeese, 1956; Jones, 2009). Following preliminary investigations by Chaisson (1932), a comprehensive study was conducted by McLeese (1956) on the combined effects of temperature, salinity and oxygen levels on the survival of adult *H. americanus*.

In India, the Central Maine Fisheries Research Institute (CMFRI) has successfully cultured the lobsters in sea cages from the wild-caught juveniles (Syda Rao *et al*., 2010). Success of cage culture could be further enhanced by adopting more intensive culture methods, *i.e.,* using managed environmental conditions. The cage culture experiments revealed maturation and spawning of lobsters in the cages when the environmental conditions were suitable. This can lead to the propagation of the larvae which could supplement and enrich the wild population against juveniles caught for culture. A sound understanding of the environmental requirements and biological conditions of the species is essential for the identification of optimal conditions which maximize growth and survival as well as to enable captive breeding of lobsters. Salinity tolerance studies are inevitable as it is the basic requirement in the case of marine animals like lobsters to identify the capacity of the species to withstand fluctuations in salinity which enables a significant expansion of potential sites and system requirements for commercial cultivation.

Materials and methods

Experiments were conducted at the Marine Hatchery of CMFRI, Kochi. Experimental lobsters were collected from the wild using traps from various locations at Vizhinjam. All lobsters were acclimated to captive conditions in flow-through seawater for a minimum period of 7 days prior to the commencement of experiments. A 3×4 randomized block design was applied to assess the effect of salinity on growth and survival of juvenile spiny lobster. The salinity treatments applied were 20, 25, 30 and 35 ppt with an individual recirculation system for each with three replicates. Experimental tanks were cylindrical in shape and made of fibre glass of 500 l capacity. The tanks were filled with 400 l of water and the experimental animals were stocked.

Eight lobsters (93.63 ± 0.4 g, mean ± SD; 41.66 ± 0.57 mm CL, mean ± SD) were allocated to each tank. Lobsters were acclimated for a minimum of 24 h at each intermediate salinity levels prior to the salinity treatment experiment. Individual weight, carapace length, and sex were recorded at stocking. To distinguish moults, the lobsters were tagged with a 5 mm diameter disc of water proof alphabetic label, super glued to the dorsal carapace between the orbital horns.

For each salinity treatment, filtered seawater was diluted at 5 ppt d^{-1} with freshwater until the required salinity was achieved. Periodic replacement of water was done by mixing water from reservoir tank of required salinity and flushing the recirculation system with approximately 50% of its volume. This was carried out at fortnightly intervals for each treatment. Prawn flesh was provided once in a day after 1500 hrs at the rate of 5% of biomass adjusted according to observation. Feeding rate was consistent for all tanks and was recorded daily. Water quality parameters were analysed at weekly intervals prior to replacement of water.

Moulted lobsters were identified daily and retagged. Weight and carapace length were measured after 3 days from the date of their moult, when the soft shell of the newly moulted lobsters hardened. The corresponding exuviae's were measured for carapace length to determine moult increment. The experiment was carried out for 80 days.

Moult increment and intermoult period were determined from all lobsters which moulted more than once by calculating the size increase between successive moults and the period. Daily growth coefficient (DGC) (% g d^{-1}) was calculated as per Cho (1992) and Bureau *et al.* (2000).

$$DGC = 100 \times (BWf^{1/3} - BWi^{1/3}) / t$$

where BWf is the final body weight (g); BWi is the initial body weight (g); and t is the duration of the growth period in days.

Food consumption was calculated by subtracting the wet weight of uneaten food remaining in each tank in the morning from the wet weight of food provided the previous afternoon. Apparent feed intake (AFI) was expressed as food consumed divided by the number of lobsters in each tank on a daily basis.

Statistical analysis

Statistical analysis was performed using Microsoft Excel and SPSS. One-way analysis of variance was employed to analyse the data. Least significant difference was applied to compare treatment means.

Results

Water quality parameters remained within the acceptable limits during the experimental period (Table 1). Occasional elevated ammonia levels were observed in the 20 ppt and 35 ppt treatments (Fig. 1). On six occasions, ammonia levels exceeded 0.5 mg l^{-1}, although during the intervening periods it was less than 0.1 mg l^{-1}. Some of the

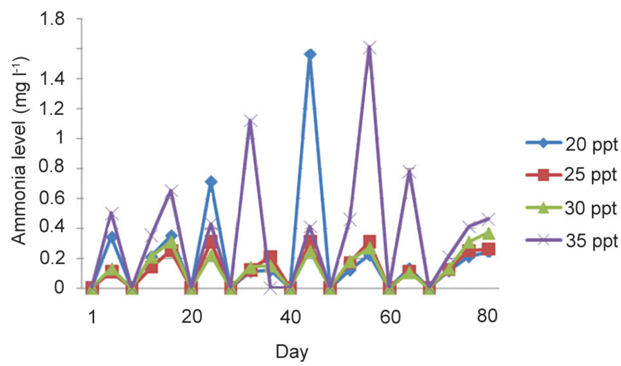

Fig. 1. Ammonia levels of seawater in the experimental tanks at four salinities during 80 d experiment.

Table 1. Water quality parameters in the experimental tanks

Treatment	pH			Salinity (ppt.)			Temperature (°C)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
20	7.46	8.56	8.01	19.6	20.5	20.05	25	31.7	28.35
25	7.3	8.7	8.0	24	26.5	25.25	25	31.6	28.3
30	7.49	8.12	7.80	29	33	31	25.1	31.6	28.35
35	7.41	8.17	7.79	34.5	36	35.25	24.7	30.4	27.55

observed mortalities for this treatment may be attributable to the high ammonia level. Temperature averaged at 28.13 ºC and pH at 7.9 for all the tanks.

Summary statistics for lobster size, survival and growth are presented in Table 2. Survival was significantly less ($p<0.01$) for lobsters at 35 ppt salinity treatment than at the lower salinities. Survival percentage observed for 80 d experiment at 35 ppt salinity was only 66.6%, while for 20 ppt, it was 82.5%. Cent percent survival was observed at 25 ppt and 30 ppt salinities (Fig. 2). Growth was significantly, positively affected by salinity ($p<0.001$) (Table 2; Fig. 3). After 80 d, lobsters grown at 35 ppt were 90% larger than those grown at 20 ppt, but were only 57% larger than those at 25 ppt and only 17% larger than those at 30 ppt. Growth rates were strong for salinities above 30 ppt but relatively weak at 20 ppt. DGC (0.9% g d^{-1}) was significantly higher at 35 ppt and there was a gradual decline at lower salinities (Table 2).

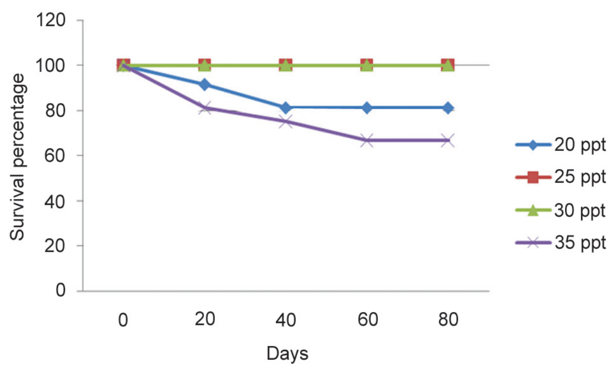

Fig. 2. Survival of *P. homarus* juveniles grown in four salinities during 80 d. (mean survival %)

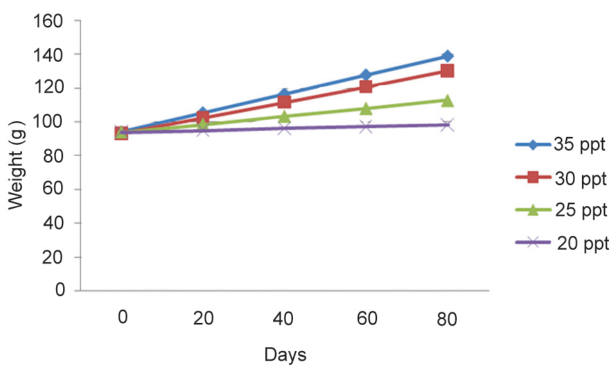

Fig. 3. Growth of *P. homarus* juveniles at four different salinities during 80 d culture period.

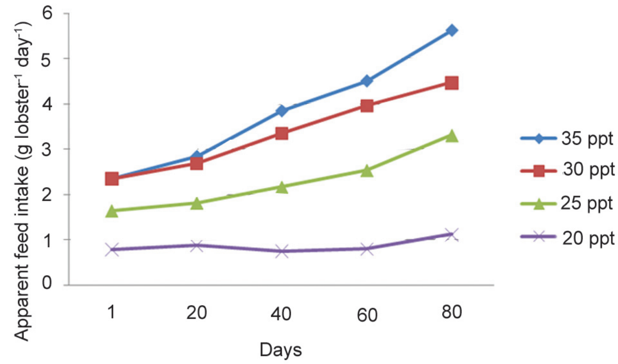

Fig. 4. Apparent Feed Intake (g $lobster^{-1}$ day^{-1}) of *P. homarus* at four different salinities

Apparent feed intake during the experiment is illustrated in Fig. 4. Food intake increased over time at all salinities, with increasing rates at higher salinities. Significant positive correlation was observed in the case of salinity ($p<0.01$) and food consumption in captivity.

Discussion

The spiny lobsters have recently captured more attention in India due to their fattening possibilities in cages and high demand in the international market (Vijayakumaran *et al.,* 2009). As the seed production of spiny lobsters in the hatchery is still a distant possibility, the lobster aquaculture relies on wild caught undersized juveniles for fattening (Varghese *et al.,* 2007; Vijayakumaran *et al*., 2009). Similarly, disease outbreaks in spiny lobster culture are rare but recent instances in Vietnam (Anon, 2009a, b) and India (Jayagopal and Vijayakumaran, 2010) suggest that commercial ventures may confront water quality problems and disease outbreaks. Therefore, adequate knowledge of environmental factors like salinity, affecting the growth and survival is essential.

Table 2. Growth of *P. homarus* grown at four different salinities for a period of 80 d

Salinity	20 ppt	25 ppt	30 ppt	35 ppt
Initial CL (mm)	40.9 ± 0.49	41.9 ± 0.51	41.6 ± 0.88	42.3 ± 0.34
Final CL (mm)	42.7 ± 1.05^{b}	50.8 ± 2.98^{b}	53.7 ± 0.40^{b}	56.1 ± 6.47^{b}
Initial weight (g)	93.7 ± 1.27	93.8 ± 0.60	93.1 ± 0.17	93.9 ± 0.37
Final weight (g)	97.9 ± 2.02^{b}	112.6 ± 4.84^{b}	130.3 ± 1.17^{b}	138.6 ± 15.55^{b}
Survival (%)	82.5 ± 0.57^{a}	100	100	66.6 ± 0.81^{a}
Daily Growth Coefficient	0.11 ± 0.03^{b}	0.38 ± 0.05^{b}	0.7 ± 0.07^{b}	0.9 ± 0.14^{b}
Apparent Feed Intake	0.87 ± 0.15^{b}	2.29 ± 0.67^{b}	3.36 ± 0.88^{b}	3.83 ± 1.31^{b}

Values bearing different superscripts are significantly different (a: $p<0.05$, b: $p<0.01$).

Denton and Jones (1982) reported that salinity was a sole factor affecting the growth of cultured shrimp *Penaeus merguiensis* under normal culture conditions. Identification of optimum environmental conditions like salinity and pH is very important for obtaining better growth in captivity, where feeding can be done accurately based on the stocking density and demand.

Water quality parameters play an important role in the production rate of commercial lobster culture. The present experiment mainly concentrated on salinity, which is an important parameter controlling growth and survival. It also focused on the responses which could be expected if the salinity range moves outside the preferred range. Generally, it is expected that seawater salinity of 35 ppt will be ideal for growth and survival of a marine animals like lobsters. Present study also confirmed that 35 ppt seawater is optimal for the growth of *P. homarus*. Growth at 35 ppt was significantly higher than the lower salinities; however, the significantly lower survival at 35 ppt is anomalous. The findings of the present study are in general agreement with those of Clive (2009) in *P. ornatus,* which reported higher growth at 35 ppt as expected but survival was significantly lower in this salinity. They have attributed three possible reasons for increased mortality at this salinity which are almost similar in the present investigation also and are detailed below.

First, water quality for 35 ppt treatment was affected by elevated ammonia level on six occasions and this might have caused the mortality. Accumulation of ammonia may be a critical limiting factor affecting the growth and survival. Forteath (1990) also recommends that total ammonia should be below 0.5 mg l^{-1} and levels of ammonia nitrogen should not exceed 0.1 mg l^{-1} . Toxicity of ammonia is a complex issue because of the inter-relationships of the balance of the ammonia (NH_3) and ammonium (NH_4^+) ions, with temperature, pH and salinity (Young-Lai *et al.,* 1991; Schmitt and Uglow, 1997). The ammonia levels that lobsters were exposed to in the present experiment may have been deleterious and contributed to compromised health and possibly death. Survival in 35 ppt treatment was 66.6% and in 20 ppt, it was 82.5% over 80 d trial, and the surviving lobsters grew well and suffered no other observed effects, suggesting that the impact of ammonia is not highly significant on growth.

The second reason contributing to mortality at 35 ppt treatment is cannibalism. Cannibalistic behaviour of various species of lobsters has been reported by several authors. This is more acute when environmental conditions are optimal, animals are very active, food intake higher and moulting is most frequent. Dead lobsters observed in 35 ppt treatment tanks were freshly moulted ones. Post- moult individuals are more susceptible to cannibalism because of their soft new skeleton. Insufficient dens to protect themselves can also increase cannibalism. If mortality had been caused by the physiological impact of reduced water quality (*i.e.,* increased ammonia), death would have occurred during inter-moult also.Cannibalism was observed only upon the newly moulted healthy animals. Third reason for mortality at 35 ppt is the increased potential of diseases caused by organisms (bacteria, fungi, viral) that are more virulent under their preferred environmental conditions.

Mortality was not observed for 30 and 25 ppt salinity treatments, but there was a considerable decline in the growth rate of lobsters in the above salinity treatments when compared to 35 ppt salinity. The experiment proves that salinity variations up to 25 ppt are tolerable by the species but there is a decline in the growth of the animal resulting in reduced weight gain. Growth rate has drastically declined for 20 ppt salinity treatment with low survival. Parry and Potts (1965) reported that at low salinity, cultured organisms spend more energy to maintain the osmotic balance. The osmotic stress may lead to lower survival and reduction in the growth of individuals. The energy spent in maintaining osmotic balance may be the main cause for the decreased growth and survival of lobsters in lower salinities. A decline in oxygen consumption at low salinity was also reported in acclimated *Fenneropenaeus californiensis* juveniles (Villarreal *et al.,* 2003). According to Kinne (1971), stenohaline organisms, suffer from osmotic damage whenever the salinity deviates significantly from the normal conditions. Several studies in different species of spiny lobsters have shown that decreasing salinity affects their metabolic rates, causes variations in their oxygen consumption, heart and scaphognathite rates (Parry and Potts, 1965; Kinne, 1971; Schmitt *et al*., 1997; Villarreal *et al.,* 2003). Reduced salinities may indeed buffer against disease. Mortality at 20 ppt salinity may be either due to any of these reasons. Cage culture of *P. homarus* at Vizhinjam, where salinity often varies seasonally between 25 and 35 ppt has been successful, although the level of production was moderate. Survival rates obtained were 75% and 70.56% in the cage and tanks respectively (Syda Rao *et al*., 2010), which are comparable with the survival rates of 70-95% of *P. ornatus* as reported by the lobster growers in Vietnam (Anon, 2009a; b).

The results of the present study indicate that the Indian spiny lobster *P. homarus* exhibits varying growth rates under varying salinities, and 35 ppt salinity is observed as the optimum for the growth under captivity. Variations in salinities induce stress on the organism which in turn affects its physiology thereby resulting in poor growth rate of lobsters. Thus, if salinity control is possible within a spiny lobster production facility, a decision would need to be made as to which was more economically advantageous: an animal to attain market size within the shortest period of time possible, or one that could be held for longer duration using the same advantages. The next step in understanding long term effect of changes in salinity should be an integrated physiological approach including the studies of body fluid, osmosis, respiration, excretion, feeding and behaviour. Such detailed investigation would possibly provide the necessary data to assess the effects of constant and fluctuating salinities.

Acknowledgments

The authors express their gratitude to Dr. G. Syda Rao, Director, CMFRI, Kochi. The present study is funded in part by a grant from the Council of Scientific and Industrial Research (CSIR).

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Date of Receipt : 13.05.2011
Date of Acceptance : 17.03.2012