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Fishery and ecology of the spiny lobster *Panulirus homarus* (Linnaeus, 1758) at Khadiyapatanam in the southwest coast of India

R. Thangaraja and E.V. Radhakrishnan*
Central Marine Fisheries Research Institute, Post Box No 1603, Kochi-682018, India.

*Correspondence e-mail: evrkrishnan@yahoo.com

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Original Article

Abstract
Commercial exploitation of palinurid lobsters has been on the increase due to high demand and lucrative price for live lobsters in the international market. The spiny lobster *Panulirus homarus* caught generally by traps and bottom-set gillnets support significant commercial catches along the southern Indian coast. Fishery along the southwest coast is seasonal, extending from September to March and peak landings are during October to December. The catch gradually declines from January and the landing is negligible in April and May. The paper presents results of a field study carried out on the ecology of the lobster fishing ground at Khadiyapatanam, on the southwest coast of India. Hydrographical parameters were used to correlate the lobster catch from the coastal fishing grounds during the fishing (October-November) and the non-fishing season (April-May) for which lobster catch and the entangled associated fauna and flora from 8 bottom-set-gillnets operated at different depth zones were monitored. Mean catch in the bottom-set- gillnet varied from 1.6 to 0.68 kg/net/day during October-January and 0.1 kg/net/day during April-May. Negative correlation between bottom sea water temperature and the catch of *P. homarus* was observed. The environmental and ecological conditions, widespread beds of the brown mussel *Perna indica* are likely to be impacting the abundance of *P. homarus* at Khadiyapatanam fishing ground. The major groups of organisms in the fishing ground were echinoderms, fishes, sponges, crustaceans and molluscs. The paper discusses the probable influence of environmental and ecological factors that impact the distribution and fishery of *P. homarus* in the fishing grounds of Khadiyapatanam.

Keywords: *Panulirus homarus, bottom-set-gillnet, hydrobiological parameters, lobster ecology.*

Introduction

Since lobsters are benthic organisms, an understanding of benthic ecology, which encompasses the study of the associated organisms living on the sea floor, its interactions and its impacts on the surrounding environment are important. Ecological parameters are the limiting factors of distribution as each species has its own unique habitat where the ecological parameters are congenial to them for feeding, shelter and reproduction (Berry, 1971a). The effects of environmental variables on the distribution and abundance of the spiny lobster *Panulirus homarus* along the southwest coast of India is little understood. Studies on ecology of the spiny lobster fishing ground distributed along the Indian coast are few. Fishing of lobsters from Indian seas by traditional fishermen has been known since 1950s and 25 species of lobsters have been so far reported from Indian coast. (Radhakrishnan *et al*., 2007). Radhakrishnan *et al*. (2005) reported that the lobster resources in India are in a declining trend owing to unregulated fishing. Among the six species of shallow water lobsters recorded along the Indian coast, four species viz. *Panulirus homarus, P. ornatus, P. versicolor* and *P. polyphagus* are commercially exploited and exported. On the southern part of the coast *P. homarus* is the major species landed followed by *P. ornatus*. The coastal area of Kanyakumari district during 1960s and 1970s had a lucrative fishing for the lobsters. Landing decreased in the 1990s and beyond mostly due to intensive exploitation and probably due to the environmental and ecological changes in the spiny lobster habitat. Information on the ecology of the fishing ground on the southwest coast is limited to the studies on fishery, biology and movement of spiny lobster *Panulirus homarus* (Balasubramaniyan *et al*., 1960, 1961; Miyamato and Shariff, 1961; George, 1965).

The present paper discusses the probable influence of environmental and ecological factors that impact the distribution and abundance of *P. homarus* in the fishing grounds of Khadiyapatanam, Kanyakumari district, on the southwest coast of India.

Material and methods

Study area

Khadiyapatanam is a coastal fishing village (Fig. 1) located (8°08.12N lat, 77°18.13E long to 8°07.38N lat, 77°18.38E long) on the southwest coast of Kanyakumari district in Tamil Nadu State, India. It is located about 1.5 km north of Muttom, which was a major lobster landing centre in 1960s. Khadiyapatanam has a rocky sea shore consisting of reefs and the sea also has rich diversity of marine organisms due to the presence of natural rocky reefs stretching parallel to the coast. One of the major vocations of fishermen in Khadiyapatanam is fishing of lobsters using traditional gears like traps and gill nets. Skin divers also effectively hunt for lobsters and fishery of lobsters is done only in the near shore region extending to an area of 5-10 sq.km using country boats.

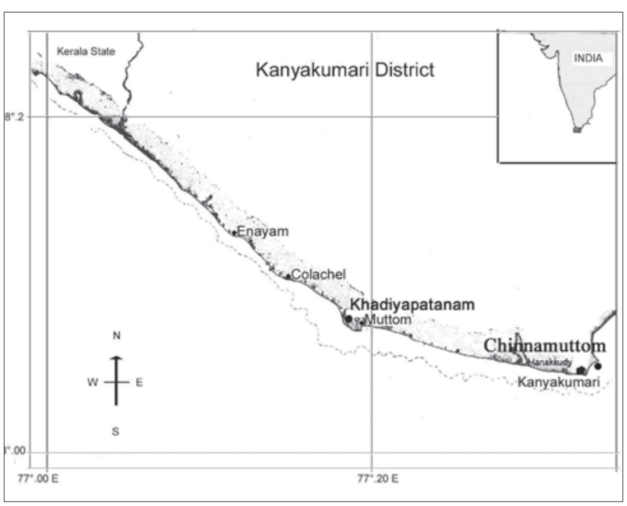

Fig. 1 Map showing Khadiyapatanam and nearby lobster landing centres on the southwest coast of India

Data collection and analysis

The lobster fishery in Khadiayapatanam commences in September and ends in March with peak landing from October to December. Bottom-set-gillnet (BSGN) is the major gear operated for lobster fishing. An average of 80 nets were operated by fishermen during October and November and 60 nets in December and January for a period of 25 days in each month (2006-2007). The lobster landing data were collected fortnightly from eight randomly selected nets operated in the fishing grounds. The position of these nets was marked by GPS and the hydrobiological data were collected from each site. These eight nets were operated in the same fishing grounds throughout the fishing season. The lobsters and associated living organisms entangled in each of the eight nets were recorded during the fishery (October to January) and non fishery periods (April to May). The quantity of lobsters and the associated fauna and flora from each net was recorded. The associated fauna were categorized into five major groups such as fishes, crustaceans, molluscs, sponges and echinoderms. All plant components were included under the associated flora. Monthly estimates were obtained by raising the day's average catch to the number of fishing days in the month.

Monthly surface and bottom water samples were collected from the fishing grounds during October - November and April - May and the environmental parameters such as temperature, salinity, pH, turbidity, TSS, chlorophyll and nutrients were estimated by standard methods given in Strickland and Parsons (1972) and Parson *et al*. (1989).

Bottom sediment samples were collected using a van Veen grab and the texture analysis was done following mechanical analysis of International Pipette Method (Tan, 1996). Sea bottom profile of the lobster fishing grounds were surveyed following English *et al.* (1997). Three locations at the Khadiyapatanam was surveyed following Line Intercept Transect (LIT) (50 m transects) in triplicates from intertidal shore to 2 km off shore. Quadrat survey to study the faunal composition of the rocky area in sub tidal zone was made in triplicate at five locations along the coast using SCUBA. A quadrat (1m^2) made of PVC pipes, which are divided into a uniform grid of 100 segments was used so that each cell in the grid has dimensions of 10x10 cm. Each cell represents 1% coverage in the sample unit. Georeference and depth of surveyed area were recorded. The data were recorded in a waterproof paper and used for further analysis. Rocks and benthic cover on the submerged rocks were estimated as percentage. The depth of each fishing ground was recorded using a rope marked in metres with a lead weight at the end. The biological study was restricted to *P. homarus*. The carapace length (CL) was measured to the nearest 0.1 mm with a vernier caliper following the method adopted by Berry (1971). The total weight was recorded to the nearest 0.1 g. Student's t test was conducted between average parameter of each season to determine whether significant variation exist between the seasons. Pearsons's correlation was carried out to test the relationship between temperature and lobster catch. All stastistical analysis were carried out using Microsoft Excel work sheets.

Results

Lobster fishery

The lobster fishing operations at Khadiyapatanam (Fig.1) were mostly carried out using bottom-set-gillnet (BSGN). When the water clarity is good, fishermen catch lobster by hand through skin diving. The depth of BSGN operation ranged from 3 to 15 m mostly in the vicinity of rocks. Apart from lobsters, the BSGN lands other fauna and flora entangled during hauling of the net. Since there was no significant difference in the size of lobsters landed by the nets operated at different depths, the catch data from eight nets operated for the study were pooled to estimate the landings. The average catch of lobsters and other associated fauna and flora landed by 8 nets during peak fishing (October- December) and lean months (April-May) are shown in Table 1. The average lobster catch/net/day varied from 1.6 kg in December to 0.68 kg in January. The lobster catch/net/day was raised to monthly estimates and the monthly landings and CPUE are shown in Table 2. The landings varied from 3180 kg in October to 1665 kg in December showing a decrease nearing the closure of the season. In October, lobsters constituted 40.3% of the total biomass landed and the other fauna and flora entangled in the net formed 45.9% and 13.8%, respectively. In November and December the percentage of lobsters in the total catch was only 25.2 and 20.8%, respectively. Fishes, crustaceans, molluscs, sponges and echinoderms were the major groups landed along with lobsters and the organisms entangled in the nets could be considered as a fair representation of the associated fauna in the fishing grounds. During April and May the lobster catch was negligible. However, the associated fauna and flora (fishes, echinoderms, molluscs, crabs and shrimps, sponges, gorgonians and seaweeds) together constituted 98% of the total landing. *Panulirus homarus* is the most dominant species (96%) followed by *P. ornatus* (2.7%) and *P. versicolor* (1.3%).

Table 1. Mean catch (± SD) of spiny lobsters and associated organisms landed by a single BSGN per day during the fishery and non fishery season at Khadiyapatanam

Months	Total biomass (g)	Lobsters (g)	%	Associated fauna (g)	%	Associated flora (g)	%
			Fishery Season 2006-2007				
October	3961.9 ±1548.0	1596.2 ± 804.4	43.96	1819.4 ±912.9	46.2	546.2 ±470.4	13.10
November	6014.4 ±3213.7	1395.6 ±618.7	25.18	3466.2 ±2454.3	54.5	1152.5 ±890.4	20.30
December	5341.2±2718.6	1111.2 ±577.8	20.80	2821.3 ±1655.4	52.8	1408.7 ±985.3	26.40
January	3749.4 ±1778.7	686.0±392.8	18.31	1707.5±898.9	45.54	1355.0±936.7	49.42
			Non Fishery season 2007				
April	5090.6 ±1259.9	50.0 ±92.5	1.89	3290.00 ±1189.8	67.8	1706.9 ±812.1	30.30
May	4130.0 ±1840.1	66.2 ±109.4	0.98	2375.00 ±1009.9	64.6	1688.8±1627.0	33.50

Size distribution and sex ratio

Though all the lobsters landed by the 8 randomly operated nets were sampled, biological study was restricted to *P. homarus*. The monthly size frequency of *P. homarus* landed at Khadiyapatanam during October-January is shown in Fig. 2. During October, 50-60 mm size was predominant (32%) followed by 60-70 mm CL (27%) size. In November, 31 % of lobsters landed belong to 70-80 mm CL size and in December, 50-60 mm CL size formed the bulk of the catch. The lobsters measuring > 80 mm CL formed only 8.6% of the total

Table 2. Monthly estimated landing of *P. homarus* at Khadiyapatanam

Month /Year	Total Landing (Kg)	CPUE /Net/Day (Kg)	Total No of BSGN operated
October	3180	1.6	80
November	2780	1.4	80
December	1665	1.1	60
January	686	0.68	60
April	N	0.050	8*
May	N	0.066	8*

* Net operated experimentally for two days, N= negligible.

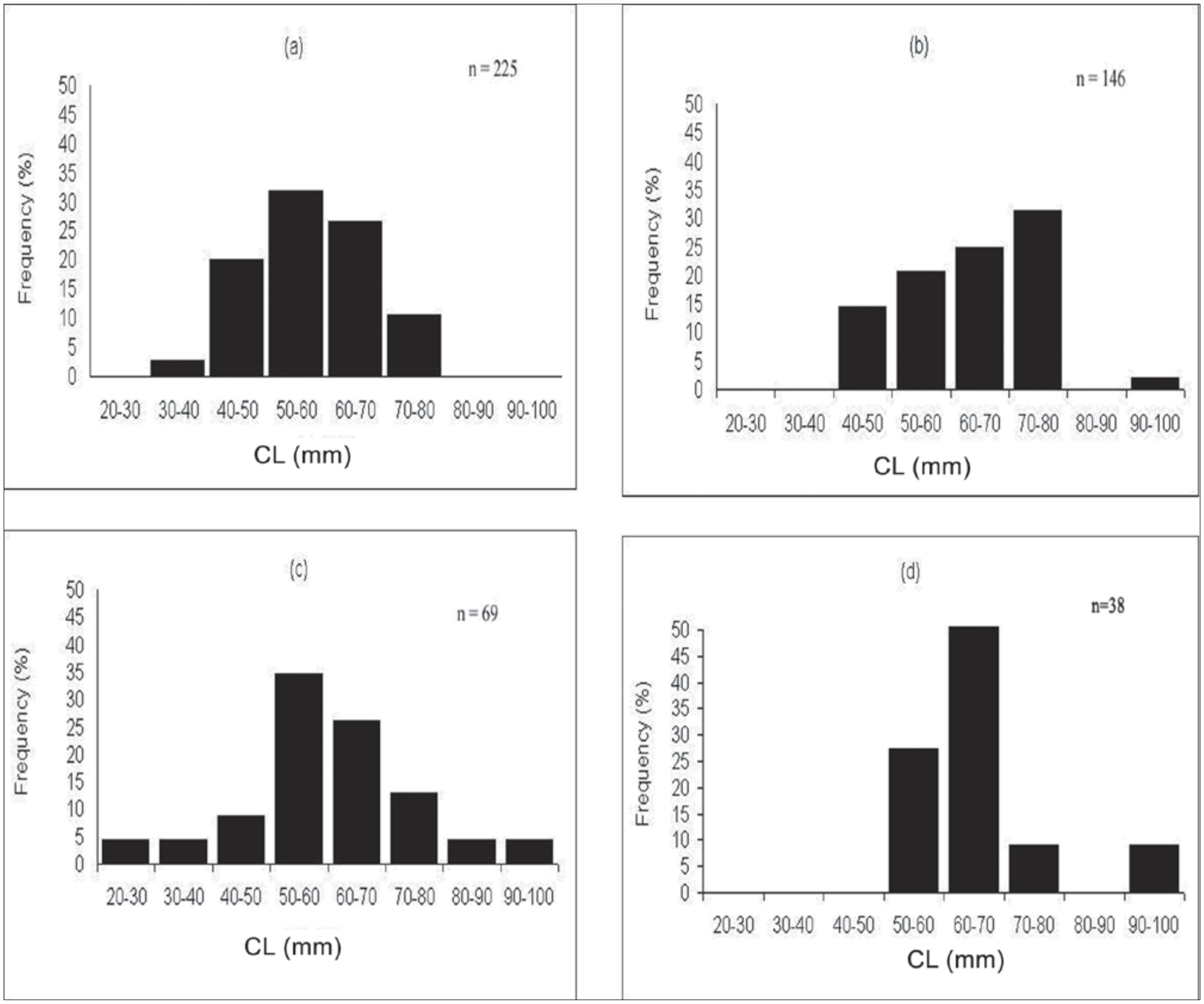

Fig.2. Length frequency distribution (CL mm) of *Panulirus homarus* in the fishery at Khadiyapatanam during (a) October (b) November (c) December and (d) January

lobsters landed in December and during January 60-70 mm CL size dominated followed by 50-60 mm CL (Fig.2.a, b, c, d). The mean carapace length of male and female lobsters landed in October was 52.7 ± 8.4 mm and 58.8 ± 11.3 mm, respectively (range, 32.0-76.0 mm CL for males and 40.0-78.0 mm CL for females). The mean total weight of males in October was 136.6 ± 79.8 g and females 204.3 ± 108.4 g. In December, the mean carapace length and weight of females in the fishery was 65.1 ± 17.0 mm CL and 303.0 ± 230.2 g compared to 57.2 ± 12.5 mm CL and 189.5 ± 84.3 g for males (range, 27.0-75.0 mm CL for males and 32.0-102.0 mm CL for females) and the females in the fishery were always larger than the males (Table 3). In January, the mean carapace length and weight of females in the fishery was 70.6± 19.0 mmCL and 387.1 ± 295.1 g compared to 63.8 ± 3.8 mm CL and 257.5 ± 61.0 g for males (range 54.0-102.0 mm CL for females; 63.0-69.0 mm CL for males) and the females in the fishery were larger than the males (Table 3).

The population of females was marginally higher in October and November whereas, preponderance of males was seen in December (56.5%). The egg bearing females in the fishery during these months ranged from 41.7% in December to 50% in November.

Hydrographical conditions in the fishing grounds

The environmental parameters such as salinity, temperature, dissolved oxygen, pH of bottom and surface waters from the fishing grounds where the 8 nets operated during October-November and April and May are presented in the Fig.3a-h.

Table 3. Biological details of *P. homarus* landed during fishery season at Khadiyapatanam

Months	October	November	December	January
Mean carapace length (mm)				
Males	52.7 ± 8.4	59.6 ± 14.4	57.2 ± 12.5	63.8± 3.8
Females	58.8±11.3	63.3 ± 11.2	65.1 ± 17.0	70.6± 19.0
Mean total length (mm)				
Males	161.5 ± 36.2	177.9 ± 44.7	187.4 ± 24.3	208.8± 22.6
Females	184.7± 39.5	194.3 ± 41.0	205.9 ± 57.2	2220.7± 67.9
Mean total weight (g)				
Males	136.6 ± 79.8	208.0 ± 130.7	189.5±84.3	257.5 ± 61.3
Females	204.3±108.4	251.7 ± 133.4	303.0±230.2	387.1 ± 295.1
Sex ratio (M:F)	1.1:1	1.2:1	1:1.3	1:1
Percentage of egg bearing females	43.0	50.0	41.7	10.2

Table.4. Mean values of hydrographical parameters of sea water from surface and bottom at lobster fishing ground of Khadiyapatanam during 2006-2007

Parameters		Average Depth	BOD	TSS	Chlorophyll	NO_3	$N0_2$	PO_4	SiO_3	NH_3
Months		m	ml/l	mg/m^3	mg/m^3	μmol/l	μmol/l	μmol/l	μmol/l	μmol/l
OCT 2006	SS	10.62±5.8	1.69±0.4	37.38±8.6	0.54±0.20	1.69±0.25	0.25±0.09	0.83±0.41	0.33±0.16	0.01±0.009
	SB	10.62±5.8	1.33±0.6	46.45±8.4	0.38±0.30	0.03±0.02	0.07±0.03	1.27±0.44	0.12±0.07	0.01±0.01
NOV 2006	SS	10.62±5.9	1.51±0.4	39.52±9.12	0.73±0.32	0.03±027	0.02±0.02	1.14± 0.18	0.04±0.02	0.01±0.004
	SB	10.62±5.8	0.98±0.2	41.87±7.48	1.24±0.31	0.07±0.05	0.03±0.03	1.67±0.55	0.04±0.02	0.02±0.03
Avg Oct-Nov	SS	10.62±5.8	1.60±0.2	38.44± 9.0	0.63±0.42	0.06±0.02	0.14±0.06	0.98±0.29	0.18±0.09	0.01±0.005
Avg Oct-Nov	SB	10.62±5.8	1.14±0.1	40.69±7.3	0.81±0.36	0.05±0.03	0.05±0.02	1.14±0.44	0.08±0.03	0.01±0.02
APR 2007	SS	10.62±5.9	0.6±0.2	55.48±5.2	0.4±0.10	0.12±0.13	0.07±0.06	0.75±0.50	0.17±0.04	0.07±0.07
	SB	10.62±5.7	0.76±0.1	52.42±5.9	0.53±0.30	0.06±0.02	0.09±0.05	0.43±0.33	0.22±0.07	0.02±0.01
MAY 2007	SS	10.62±5.8	0.63±0.1	66.83±0.3	0.11±0.10	0.06±0.01	0.03± 0.01	0.64±0.4	0.13± 0.02	0.11± 0.04
	SB	10.62±5.9	1.22±0.5	50.55±9.2	0.1±0.06	0.03±0.17	0.05±0.02	0.78±0.37	0.1±0.38	0.1±0.006
Avg Apr-May	SS	10.62±5.8	0.61±2	61.15±8.4	0.25±0.10	0.86±0.22	0.05±0.03	0.69±0.40	0.15±0.02	0.09±0.06
Avg Apr-May	SB	10.62±5.8	1.0±0.3	51.48±8.1	0.16±0.02	0.04±0.02	0.07±0.02	0.60±0.22	0.16±0.06	0.06±0.03

SS = Sea surface, SB = Sea bottom

The Total suspended Solids (TSS), nutrients and chlorophyll during the two periods are shown in Table 4. The average depth of operation of the BSGN was 10.6 m.

Average sea surface salinity ranged from 33.8±0.52 ppt during October-November to 34.7±0.15 ppt during April-May months. Student's t test revealed significant variation between two seasons (t critical=2.14, df=14 and P=0.0007). Sea bottom salinity ranged from 33.9 ± 0.61 ppt during October-November to 34.7±0.15 ppt during April-May months (t critical=2.11, df=14, P=0.001). Variation in salinity between the fishing and non-fishing months was 0.83 ppt at surface and 0.71 ppt in the sea bottom. Salinity variation between stations (Fig. 3. a,b) is not significant.

The SST was an average of 28.7 ± 0.12 ºC during October-November and 30.4 ± 0.16 ºC during the summer months of April and May (t critical = 2.14, df=14 and P = 8.29 E-13). Meanwhile, the sea bottom temperature was 28.3 ± 0.15 ºC during October – November and 29.43 ± 0.13 ºC during April-May (t critical =2.14, df =14 and P = 2.97 E-09). Significant variation in temperature between the two seasons was found both in surface and bottom waters. Variation in temperature between the fishing and non-fishing months was 1.71 ºC in surface and 1.12 ºC in the sea bottom. Difference in temperature of surface and bottom waters was 0.4 ºC during October-November and 0.9 ºC in April and May. Station-wise temperature is shown in Fig. 3. c, d .

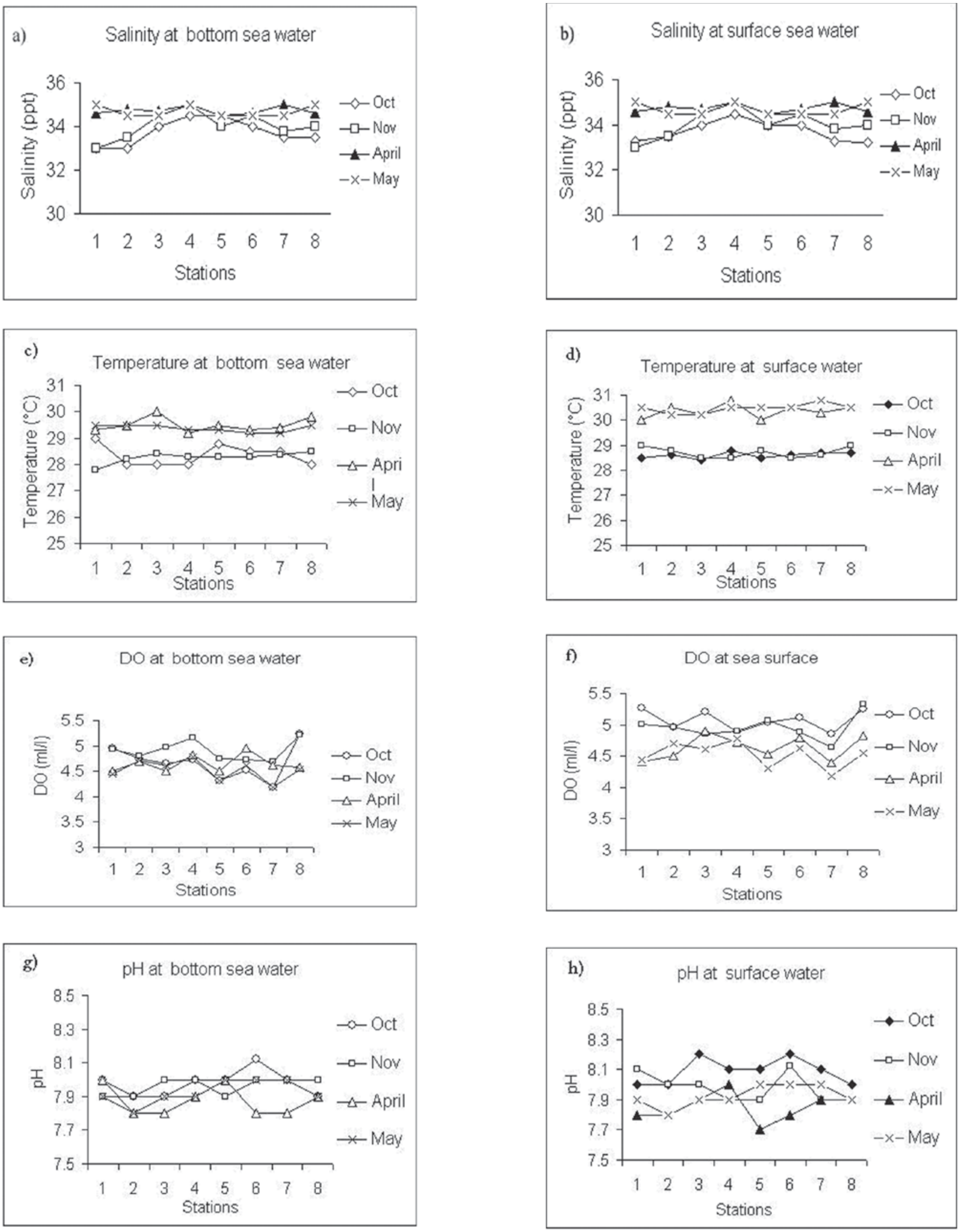

Fig. 3. Variations in salinity (a- bottom,b- surface), temperature (c-bottom, d- surface), dissolved oxygen (e-bottom, f- surface) and pH (g -bottom and h- surface sea water) during October, November, April and May months at Khadiyapatanam.

The DO content varied between 4.7 ± 0.25 ml/l during October – November and 4.5 ± 0.16ml/l during April – May. Variation in DO between October-November and April-May was 0.2 ml/l at sea bottom water (t critical=2.14, df=14 and P =0.0001). Sea surface DO was 5.01±0.17 ml/l during October – November and 4.58 ±0.16 ml/l during April –May with no significant difference (t critical=2.14, df=14 and P =0.080). The difference in DO content in surface waters between October – November and April-May was 0.43 ml/l. Station wise DO is shown in Fig. 3 e, f. The BOD level during both seasons were 1.14 and 1.03 ml/l at sea bottom and 1.6 and 0.6 ml/l in surface water (Table 4). The pH value ranged between 7.8 and 8.0 (Fig. 3 g, h).

TSS in the sea bottom waters of Khadiyapatanam was lower at 40.69 ± 7.3mg/l during October-November compared to 51.48 ± 8.1mg/l during April-May (t-critical =2.14, df =14 and P = 1.34 E -05). The surface water TSS ranged from 38.44 ± 9.0 mg/l during lobster fishery season to 61.15 ± 8.4 mg/l during non- fishing season months (t-critical =2.14, df =14 and P = 4.72 E -06). Significant variations in the TSS were observed between two seasons and sea bottom and surface water. Variation of total suspended solids between the fishing and non- fishing months was 10.79 mg/l at bottom and 22.71 mg/l in the sea surface was observed. The TSS in the surface water was also higher during April- May (61.15 ± 8.4 mg/l) compared to October-November (38.44 ± 9.0 mg/l). Month-wise observation of TSS is given in Table 4.

No significant difference (P>0.05) in nutrient ($N0_2$, NO_3, Sio3, NH_4, and PO_4) levels between October-November and April-May months and between surface and bottom waters were observed (Table 4). However, average chlorophyll content in surface waters during October and November (0.63 ± 0.42 mg/m^3) was significantly higher (t-critical=2.14, df=14, P=0.003) than April-May (0.25 ± 0.10 mg/ m^3). Chlorophyll pigment concentration at sea bottom was 0.81 ± 0.22 mg/ m^3 during fishery season and significantly lower at 0.16 ± 0.02 mg/ m^3 during the lean fishery season (t-critical=1.74, df=14, P=0.001) (Table 4). Although nutrients of sea water have no direct influence on lobster fishery, production of microalgae is depended on nutrient levels, which is the primary food for the mussels.

Associated benthic fauna and flora in the lobster ground

Since lobsters are bottom-living organisms, their distribution depends upon the nature of the substratum, the availability of food and other associated fauna and flora in the ecological habitat. The soil texture of the fishing grounds shows that the soil is predominately sandy (92%). The sediment texture of sea floor also plays an important role in lobster foraging movement within the habitat (Jernakoff,1987). Soft sediments with 89-92% fine sand, 8% clay and 3-1% silt favour lobster abundance in the study area. From the study it can be concluded that Khadiyapatanam coast with a rocky (87%) substratum is a suitable habitat for lobsters. The benthic cover of barnacles (15.7%), oysters 32.3%, sponges 2.0%, mussels 10.3%, corals and gorgonian 2.0%, macroalgae 35.2% and seaurchin 0.3% per square meter shows the richness of the submerged rocks at Khadiyapatanam (Fig.6). Lobster density differs according to the complexity of the habitats and the rich flora and fauna during October – December at Khadiyapatanam probably favour *P. homarus* for settlement and development.

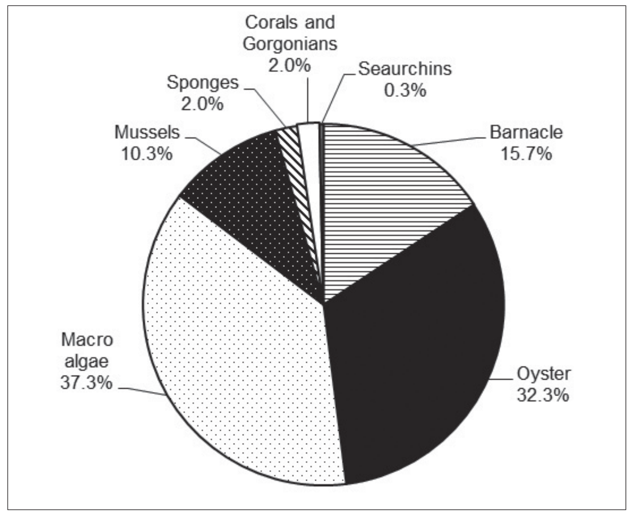

Fig.6. Percentage composition of organisms attached on the rocky area of the lobster fishing ground off Khadiyapatanam

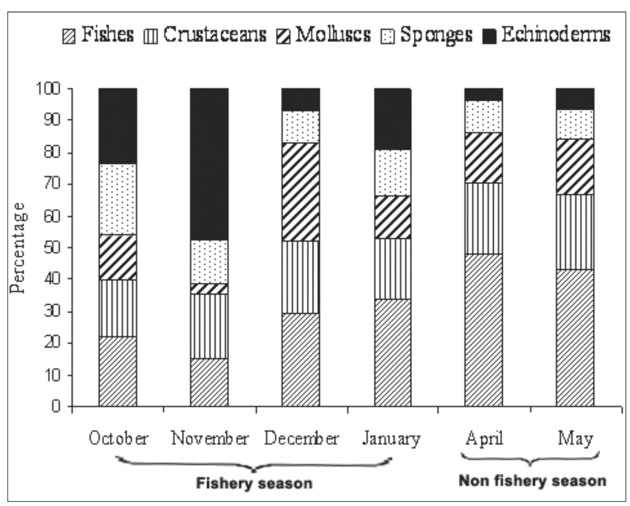

Fig.4. Average monthly composition of associated fauna landed by BSGN during fishery (October- January) and non fishery season (April-May) at Khadiyapatanam

Table 5. List of associated fauna and flora entangled in the BSGN operated along the study stations off Khadiyapatanam

Group	Genus/ Species/ Common name	Relationship
Fishes	*Lethrinus* sp . *Lutjanus.* sp., *Ambassis* sp., *Pampus* sp., *Scarus* sp., *Trichiurus lepturus, Arothron* sp., *Epinephelus* sp., *Anguilla bicolor, Gymnothorax fimbriatus* and *Odonus niger*	Prey -Predator
Crustaceans	*Scylla* sp., *Portunus pelagicus, Charybdis* sp., *Fenneropenaeus indicus* and Spider crabs	Prey
Molluscs	*Sepia* sp., *Loligo* sp. *Turbinella pyrum*	Prey - Predator
Echinoderms	*Stomoponeustes variolaris*, Star fishes, Brittle stars	Prey
Sponges	*Clarthria indica, C. pocera, C. arborescens, Psammoclema* sp., *Axinella ceylonensis, Dragmacidon* sp, *Acanthella cavernosa, Haliclona* sp., *Amphimedon* sp and *Spongia* sp.	Shelter
Seaweeds	*Ahnfeltia plicata, Caulepra racemosa, Chaetomorpha linoides,Chaetomorpha media, Gracilaria corticata, Gracilaria fergusoni, Gracilaria verrucosa, Hypnea musciformis, Padina commersonii, Sargassam wightii, Spatoglossum asperum, Ulva reticulata,Ulva fasciata* and *Enteromorpha* sp.	Shelter/ Food

The associated fauna and flora entangled in the net belongs to 10 genera of fishes, 5 species of crustaceans, 3 species of molluscs, 10 species of sponges, 3 groups of echinoderms and 14 species of seaweeds. The rich bed of mussels may play important role in the predator – prey relationship of lobsters. The sponges and macroflora available in this ground probably provides shelter for lobsters. The composition of the associated fauna is found to be different between the fishing and non-fishing periods (Fig.4). During October and November, sponges and echinoderms were most dominant (mean: 18% and 35.7%, respectively), whereas during April and May the representation of these organisms was very low (mean: 9.9% and 4.8%, respectively).

Fishes constituted 46% of the total fauna entangled during April and May. The group- wise composition of the associated fauna entangled in the BSGN is shown in Table 5. The echinoderms were mostly represented by the seaurchin *Stomoponeustes variolaris*, brittlestars and starfish. The seaurchin and starfish populations were higher during October and November (33%) and substantial reduction was noticed during April- May months (4.7%). The mud crab *Scylla serrata*, the blue-swimming crab *Portunus pelagicus* and *Charybdis* sp. were occasionally represented in the BSGN catch. The sponge fauna was constituted by ten species and *P. homarus* is mostly seen in association with sponges and seaurchins. A wide variety of marine seaweeds were found in the fishing grounds of which the common forms were *Gracilaria corticata, Ulva* sp., *Chaetomorpha* sp., *Padina* sp. and *Sargassum* sp.

The sub-tidal rocks in this region are covered by brown mussel mats which are harvested by fishermen from November-February. There is a close association between the presence of mussels and lobsters and the lobsters may be preying upon the mussels, especially when the size suits the mouth.

The mean bottom water temperature in the fishing grounds was 28.3°C during October-November and 29.5°C in April-May. A strong negative correlation between bottom sea water temperature and the catch of *P. homarus* was observed (Fig. 5). The turbidity due to suspended solids was low during October-November, probably due to the influence of northerly currents during November to January along the west coast of India.

Discussion

The region between Thiruvananthapuram on the north and Kanyakumari in the south is known for its lobster fisheries since 1950s. Lobster fishing is carried out in 38 fishing villages in Kanyakumari district of which 36 are on the west coast (Vijayanand *et al.*, 2007). During 1960s, the major lobster landing centres were Muttom and Colachel (Fig.1). Commercial fishing began in late 1950s and there has been an artisanal fishery for lobsters in Kanyakumari district for nearly six decades. During 1950s and 1960s, anchor hooks, traps and scoop nets were used (Balasubramaniyan *et al.*, 1960, 1961; Miyamoto and Shariff, 1961; George, 1965). While the Muttom fishermen used more of anchor hooks, traps were mostly used by Colachel fishermen. However, these gears have been now replaced by the bottom-set-gillnet in some of the fishing villages, except a few, where the traditional

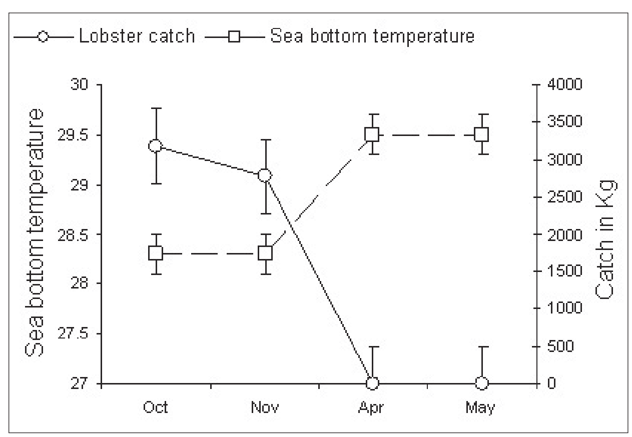

Fig.5. Lobster catch and bottom seawater temperature at Khadiyapatanam during October-November and April-May

trap is still used. Anchor hooks and scoop nets are not in operation now. The BSGN is deployed at dusk around the submerged rocks and hauled back in the early morning. The nets are operated at depths varying from 3 to 15 m and 60 to 80 nets are used during the peak fishing season. Landing of the catch is in morning and the nets are deployed again at dusk. Fishermen engage in gillnet fishing for small pelagics during the day and lobster fishing provide an additional income to them. During non-fishing months (April-May), the fishermen are engaged in trap fishing of reef-dwelling fishes. *P. homarus* is a shallow water species and lobsters of all sizes are caught at all depths and no size dependent distribution in relation to depth was observed. The investigation on biology and fishery of *P. homarus* carried out in late 1950s and 1960s at Muttom (south of Khadiyapatanam) and Colachel (north of Khadiyapatanam) showed that the fishery existed from November-April with peak landing in December (George, 1965). The total landing was reported in numbers and on conversion to weight (assuming average weight of *P. homarus* caught as 300 g), the combined landing of *P. homarus* at Muttom and Colachel during 1958-59 was estimated to be 39 t. The landing which was declined to 15 and 14 t during 1959-60 and 1960-61 was regained to 32 t in 1961-62. The fishing village Muttom just south of Khadiyapatanam (Fig. 1) had a landing of 25 t in 1961-1962. Currently only few Muttom fishermen operate gill nets and the major landing is at Khadiyapatanam. The present landing of 7.6 t in 2006 being just 31% of the catch during 1961-62.

George (1965) observed six year groups of *P. homarus* in the fishery and is of the view that an age group which comes into the fishery at 131-140 mm TL could be traced during the succeeding five years reaching about 300 mm TL at the end of the fifth year. There was no mention about the movement of the population away from the fishing grounds during the summer months and their reappearance again after southwest monsoon. The abundance of mussels and other food organisms in the fishing grounds during October-December may be responsible for the rich fauna of lobsters along this part of the coast. The re-appearance of lobsters after southwest monsoon every year and their absence during the summer months poses the question whether there is an endemic lobster fauna in the region or do they move to the southwest coast on the commencement of the season and move away during summer months when the environmental conditions are unfavorable. The most preferred size of mussel also may not have been available during this time. Laboratory experiments on predator-prey relationship have shown 20-30 mm size mussel as the most preferred size for lobster measuring 60-65 mm carapace length (Radhakrishnan and Vivekanandan, 2004). *P. homarus* exhibit a size dependent preference for mussels. The hydrobiological conditions and the faunistic composition during the fishery and non fishery season corroborate the conclusion. However, no long distance movement of lobsters was observed during the tagging experiments conducted in the same region (Mohamed and George, 1968). Spawning of the brown mussel *P. indica* starts in July and the spat fall is completed by August which coincides with the commencement of lobster fishery along the coast. The possibility of new recruits entering into the fishery from east coast of India cannot be ruled out. The presence of juveniles and subadults at the beginning of the season suggest that the Muttom-Khadiyapatanam area has suitable conditions that facilitate settlement and contribute to renewal of population every year.

The peak landing during October-December may be due to two reasons: i) the favourable coastal environmental conditions and ecology prevailing due to the influence of the northerly current and ii) the abundance of preferred food of the lobster, the brown mussel *P. indica* and seaurchins in the area. Though landing data from October-January alone is shown in the present study (peak fishing) fishery commences in September and continues up to March with meagre landing during September and January-March. George (1965) reported November-April as the fishing season in Muttom and Colachel during 1958-1962. There has been subtle difference in hydrobiological parameter between the fishery and non-fishery season. The relatively cooler water during November-December probably favour the benthic flora and fauna to flourish, which favour the movement of the lobster population to this area for feeding and breeding. The environmental and ecological conditions, especially abundant food in the form of mussel probably favour the breeding of *P. homarus* during this period. Temperature seems to have a direct impact on the lobster catch with higher catch during October-December and lower during the summer months (March-April). Nutrient and chlorophyll level may not have a direct effect on lobster abundance though they could be considered as secondary factors supporting lobster abundance by way of providing phytoplankton as the food for the mussels. The abundance of lobster in the study area is also supported by soft sediment texture of the sea floor. Jernakoff (1987), Karnofsky *et al*. (1989) and Cox *et al*. (1997) found the sediment fraction of sea floor playing an important role in movement and behavior of lobsters during foraging.

P. homarus feeds on a wide range of animal food. However, the preferred food is the brown mussel *P. indica* which is available in plenty during October-December. The lobster ground at Khadiyapatanam is also known for lucrative mussel fishery. The brown mussel fishery commences during end of September with peak production in October-November months (Joel and Ebenezer, 1989). Studies in South Africa have shown that predation could alter the abundance and size structure of mussel, urchin and gastropods (Mayfield *et al.*, 2000). Shears and Babcock (2002) also reported that abundance of seaurchins is controlled by lobster and fishes along the New Zealand coasts. The large quantity of crushed mussel shells (20-30 mm) found scattered in the intertidal region during the study shows that the lobsters prefer smaller mussels than the larger ones for feeding as they could be easily dislodged from the rocks. Similar size dependent predation strategy was found by Radhakrishnan and Vivekanandan (2004) in *P. homarus* fed with *Perna viridis* under experimental conditions. From this study it can be concluded that *P. homarus* prefer rocky habitats with the associated flora and fauna of seagrass, algae, seaurchins, sponges and molluscs for settlement. There seems to be a close faunistic association of lobster with seaurchins which is considered to be a good food for larger lobsters. The observed pattern is consistent with information referred to by several authors who have studied settlement and habitat of the lobster fauna in other regions (Rios *et al.*, 2007). During April–May, the lean fishing months, there has been a drastic decline in population of seaurchins along the Khadiyapatanam coast (Fig.4.). Rajakumar and Ebanasar (2008) also reported reduction in seaurchins during summer months off Muttom and Colachel grounds adjacent to Khadiyapatanam.

Several studies have examined the effect of temperature on lobster catches from commercial fisheries. The major environmental factor influencing the abundance and availability of *P. homarus* throughout their range probably may be due to the cyclic fluctuation in temperature during the fishing and the non-fishing season. A relationship between temperature and seasonal catchability of Western rock lobster was documented by Morgan (1974). The total landing and the bottom water temperature shows a highly significant inverse correlation (Fig.5). However, positive correlation in catch rates of *Homarus americanus* with increasing bottom water temperature was reported from the lobster fisheries off eastern Canada (Drinkwater *et al.*, 2006). Environmental parameters of current strength and water temperature have been shown to be the important influencing factors that determine the level of settlement of *P. cygnus* peurulii along the west Australian coast (Caputi *et al.* 2001). Although direct correlation between bottom water temperature and catch rate could be established, the factors influencing the fishery need to be further investigated. It is important to understand the mechanisms that affect the catch variability in relation to the environment. The catchability could be affected by a host of factors related to lobster biology, environment and the type of fishing.

October-December are the peak breeding period for *P. homarus* along the southwest coast of India when the majority of females in the fishery are egg bearing (Table. 3). George (1965) also observed peak breeding of the species in November and December in the same area. *P. homarus* is a shallow water species and no movement or migration of egg bearing lobsters to deeper areas was evident. However, high percentage of egg bearing females in the catch during this period probably indicate breeding aggregation by *P. homarus*. Tagging experiments suggest that *P. homarus* does not undertake long distance migrations, though local movements occur mainly for foraging for food (Mohamed and George, 1968). Though Kanyakumari coast had a lucrative fishery of lobsters during sixties and seventies, landings gradually decreased with the increased demand for lobsters in the export market. The resource was subjected to extreme fishing pressure with the introduction of gillnets and trammel net fishing (Radhakrishnan *et al.*, 2005). Significant decline in *P. homarus* fishery is a classic example of recruitment overfishing, which is not precluded by growth overfishing (Radhakrishnan *et al.*, 2007). Fishing using gillnet and trammel nets has led to maximum damage to the resource by exploitation of undersize lobsters. George (1965) cautioned that fishing of small size lobsters (90-140 mm TL) by the traps might affect the fishery at a later stage. Though trap fishing is an ecofriendly method compared to trammel net fishing, the composition of the catch with more of younger lobsters would have prompted him to suggest enforcement of a minimum size limit for the lobster fishery in Kanyakumari. George (1965) proposed a minimum size limit of 130 or 140 mm TL for capture of *P. homarus* from this region. However, no regulations were imposed on fishing by the state government. Though minimum size for export was set at 200 g (Radhakrishnan *et al.*, 2005) for live *P. homarus* (160 mm TL), smaller *P. homarus* lobsters are being exported illegally. Enforcement of regulatory measures have to be implemented by maritime state governments for future sustenance of the fishery. Research investigation on recruitment in relation to environmental factors, especially the influence of coastal current on peurulus settlement has to be undertaken to estimate the recruitment levels which may probably help in management of the stock in the future.

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