



Analysis of habitat characteristics of the scalloped spiny lobster *Panulirus homarus* (Linnaeus, 1758) in their home range along the southern coast of Sri Lanka

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ABSTRACT

The present study was aimed to investigate the quality of home range habitat characteristics of the scalloped spiny lobster *Panulirus homarus* (Linnaeus, 1758) in southern coastal region of Sri Lanka. Four sites were selected from south-east (Patanagalle, Godawaya) and south-west (Weligama, Hikkaduwa) regions of the southern coast of Sri Lanka (SCSL). The bottom water quality data and benthic substrate types of their home range habitats were monitored and noted in a 25 x 25 m area covering 16 subsampling points with locality information. With the use of geographical information system (GIS) tools, the spatial distribution maps of environmental parameters were created and submerged bottom substrate types of the four sites were graphed. Salinity, temperature and dissolved oxygen correlated well with depth. Hikkaduwa site was found rich in corals with less number of scalloped spiny lobsters. Sites of south-east region of the SCSL (Patanagalle, Godawaya) were found less polluted having rocks and sandy bottom with high occurrence of scalloped spiny lobsters. Results of the study showed that Patanagalle site (south-east of SCSL) could be suggested as the most suitable site for culturing scalloped spiny lobsters.

Keywords: GIS, Habitat mapping, Marine ecology, *Panulirus homarus*, Spiny lobster, Sri Lanka, Water quality

Introduction

More than 45 species of spiny lobsters (Family: Palinuridae) inhabit temperate and tropical seas from the intertidal zone to depths approaching 1000 m (Holthuis, 1995). According to Jayawickrama (1991) six species have been recorded from Sri Lanka viz., *Panulirus homarus*, *P. ornatus*, *P. versicolor*, *P. longipes*, *P. polyphagus* and *P. penicillatus*, but currently only five species except *P. polyphagus* are found (Upul, 2009). Generally, only one or a few species of spiny lobsters co-occur in a particular region for e.g., *P. elephas* in the Mediterranean and *P. argus* and *P. guttatus* in the northern Caribbean. But in the southern coastal habitats of Sri Lanka, multiple species of spiny lobsters co-occur. *P. homarus* usually inhabits sand-stone reefs and rocks for shelter with pale turbid conditions of the surf zone to depths of 20 m in the continental shelf (Holthuis, 1991; Kulmiye and Mavuti, 2005).

Water quality parameters such as temperature salinity, dissolved oxygen, ammonia content and pH have shown significant effects on the immune system of crustaceans (Vargas *et al.*, 1998; Le Moullac *et al.*, 1998; Cheng and Chen, 2000, 2002; Lamela *et al.*, 2005) which also play an important role on commercial lobster mariculture (Vidya

and Shoji, 2012). Among these parameters, salinity is one of the major factors that may significantly affect the physiology, growth and survival of aquatic organisms (Bindhu *et al.*, 2007) including lobsters (Vidya and Shoji, 2012). Dissolved oxygen and temperature of water are also critical factors affecting metabolic rate of spiny lobsters. Water temperature determine the growth rate of crustaceans (Hartnoll, 1982) and has been shown to affect the growth of a number of spiny lobster species including *Jasus lalandii* (Dubber *et al.*, 2004), *Jasus edwardsii* (Crear *et al.*, 2000; Thomas, *et al.*, 2000), *Panulirus argus* (Lellis and Russell, 1990), *P. cygnus* (Phillips *et al.*, 1977), *P. homarus* (Kemp and Britz, 2008) and *P. interruptus* (Serfling and Ford, 1975). The optimum ranges of water quality parameters vary with different stages in the life cycle of spiny lobsters and preferable home range habitat conditions in certain locations can lead to increase in number of individuals in a relevant stock.

Habitat complexity provides refuges and barriers that fragment the area, resulting in more heterogeneous assemblages (Sebens, 1991). The complex ocean water current pattern of the southern coast of Sri Lanka (SCSL) shapes the habitat diversity seasonally. Also diurnal changes of the coastal area cause selection of a preferable home range habitat for scalloped spiny lobsters.

Spatial habitat analysis can be applied for measuring and modeling spatial patterns in biotic variables, to understand the mechanisms that manage critical aspects of the ecology of species, such as their distribution (Legendre and Legendre, 1998; Liebhold and Gurevitch, 2002) and for lobster stock assessment (Evans *et al.*, 1996). The Geographic Information System (GIS) can be successfully applied as a fundamental analysis tool in estimation of the spatial relationships between the occurrence of macrobenthos species and related environmental factors (Jong-Kuk *et al.*, 2011).

There are several research findings of preferential habitats for different developmental stages of spiny lobsters in the Caribbean area (Childress and Herrnkind, 1996; Davidson *et al.*, 2002). But studies on suitable home range habitat characteristics and habitat qualities of *P. homarus* in the Indian Ocean rare. The habitat diversity of the SCSL is very high and spiny lobsters in this region are not equally distributed even though there are dens with rocks and muddy sand which are their preferred habitats. The present investigation was undertaken to study the habitat characteristics of their home range along the southern coast of Sri Lanka aimed at formulation of suitable management strategies.

Materials and methods

Four sampling sites along the SCSL, comprising Hikkaduwa, Weligama, Godawaya (Ambalanthota) and Patanagalle (Yala-Kirinda) were selected based on the heterogeneity of the SCSL as well as based on the information gathered from lobster fishermen on areas of scalloped spiny lobster (*P. homarus*) abundance (Fig. 1).

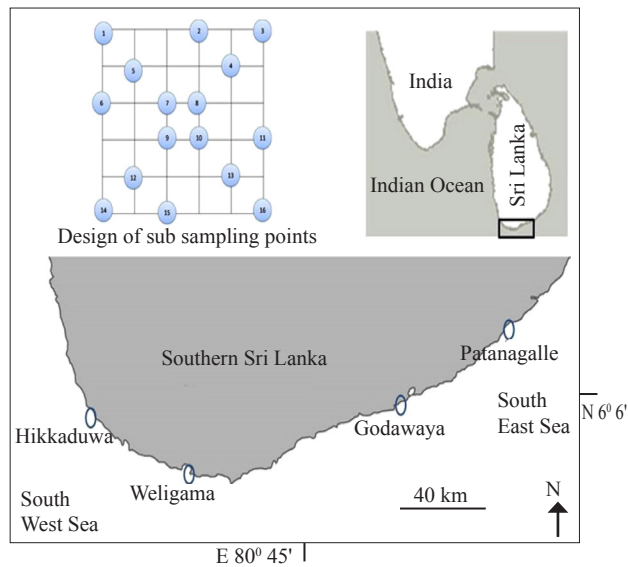


Fig. 1. Sampling sites of *P. homarus* in southern coast of Sri Lanka

Samples were collected from the selected sites during the period of calm weather during November to December 2012.

A fiberglass boat (12 feet long) with a 10 HP engine was used for sampling. Water quality parameters and the benthic environment were monitored within an area of 25 m² demarkated at each sampling site, with 16 subsampling points in each site as depicted in Fig. 1. Differential GPS (Pathfinder Pro XR Trimble Co., CA, USA) with 3 m horizontal accuracy was used for accurate positioning of the subsampling points. Bottom water samples were collected, observed number of lobsters were counted and bottom substrate types were noted at each sub-sampling point with the help of two SCUBA divers (Table 1). Depth of each subsampling point was measured using the depth gauge of the SCUBA diving kit. The recorded data in the field were noted on a waterproof slate for further use.

Temperature of the bottom water was measured just after collecting water samples using Ruthner water sampler (KC Denmark; 11.001) and salinity was measured using a salinity refractometer. Dissolved oxygen (DO) bottles (250 ml) were filled with bottom water from each subsampling point and preserved using Winkler solutions A and B at the site and the DO level was estimated as per Strickland and Parsons (1968).

The significant mean differences of temperature, salinity, DO and depths between each site were tested by Kruskal-Wall non-parametric test ($p < 0.05$). Water quality parameters of the four sites were pooled and the Spearman correlation method was used to test correlation between the different parameters separately. All the statistical analyses were done using SPSS version 20.

Water quality parameters and depths of sixteen subsampling points in each site were used for spatially mapping of habitat quality. The locality information of each site was noted in degrees using GPS meter (Pathfinder Pro XR Trimble Co., CA, USA; $\pm 1\text{m}$) and those data were converted into meters by GeoCalc 4.2 software. Environmental parameters were re-arranged in an excel sheet with X and Y coordinates to prepare spatial distributional maps. Physicochemical parameters were spatially mapped by interpolating attributes of subsampling points of each site by Natural Neighbor Interpolation Technique in ArcGIS 10.1 version.

Results

The locality information of the each sampling site is included in Table 1. The habitat quality of *P. homarus* has been defined by various environmental factors including temperature, salinity, DO, depth

Table 1. Details of geographic distribution, abundance of lobsters and average environmental parameters of selected sampling sites

Sampling site	Region	Date of sampling	Latitude	Longitude	No. of lobsters observed	Average values of environmental parameters			
						Temperature (°C)	Salinity (‰)	DO (mg l ⁻¹)	Depth (m)
Hikkaduwa	South-west	16/11/2012	06° 07' 45.4" - 06° 07' 46.2" North	80° 05' 49.9" - 80° 05' 50.7" East	26	28.344 ± 0.397	37.063 ± 1.124	8.113 ± 1.744	11.019 ± 1.411
Waligama	South-west	26/09/2012	05° 56' 36.5" - 05° 57' 38.1" North	080° 28' 020" - 080° 27' 031" East	28	28.063 ± 0.629	36.313 ± 0.544	7.488 ± 0.797	7.863 ± 1.823
Godawayaya	South-east	15/10/2012	06° 06' 24.3" - 06° 06' 25.1" North	081° 03' 20.3" - 081° 03' 21.1" East	34	27.781 ± 0.446	36.188 ± 0.680	5.900 ± 0.826	5.756 ± 1.188
Patanagalle	South-east	8/11/2012	06° 20' 32.9" - 06° 20' 34.6" North	081° 30' 3.8" - 081° 30' 4.9" East	72	28.594 ± 0.455	35.156 ± 0.747	7.800 ± 1.613	8.113 ± 1.925

and type of bottom substrate in this study. Spatial distribution of environmental parameters of the four selected sites in the SCSL are represented in Fig. 2 and 3.

The average water quality parameters and observed number of lobsters in each site are presented in Table 1. Highest number of individuals (72) of scalloped spiny

lobsters was recorded in Patanagalle (south-east). Average water quality parameters in the site showed highest temperature (28.594±0.455°C), lowest salinity (35.156±0.747‰) and medium values of DO (7.800±1.613 mg l⁻¹) as well as depth (8.113 ± 1.925 m).

There was no significant difference in the mean water quality parameters among four different sites

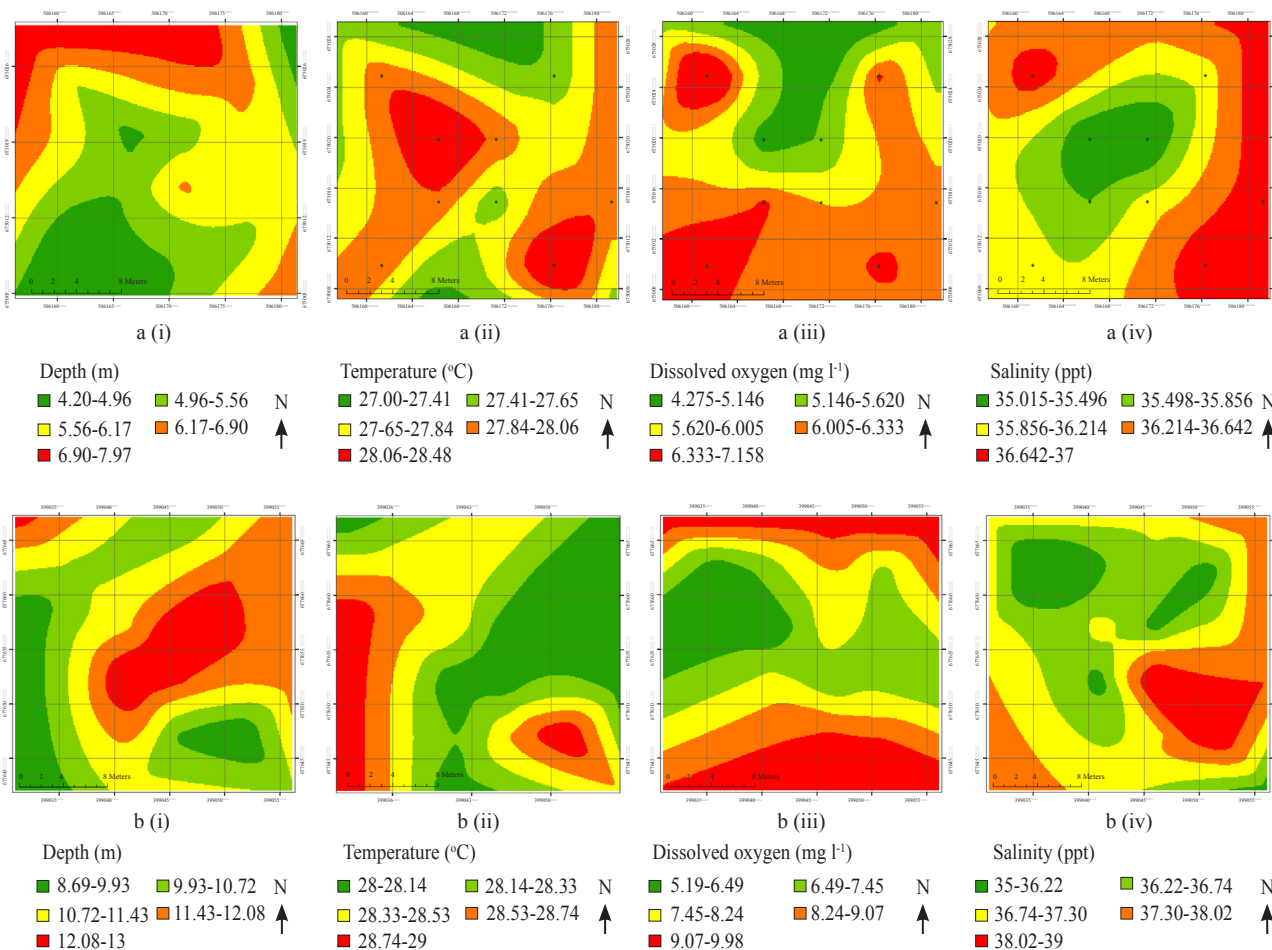


Fig. 2. Spatial distribution of environmental parameters of the sampling sites. (a) Godawayaya, (b) Hikkaduwa (i) Depth, (ii) Temperature, (iii) Dissolved oxygen, (iv) Salinity

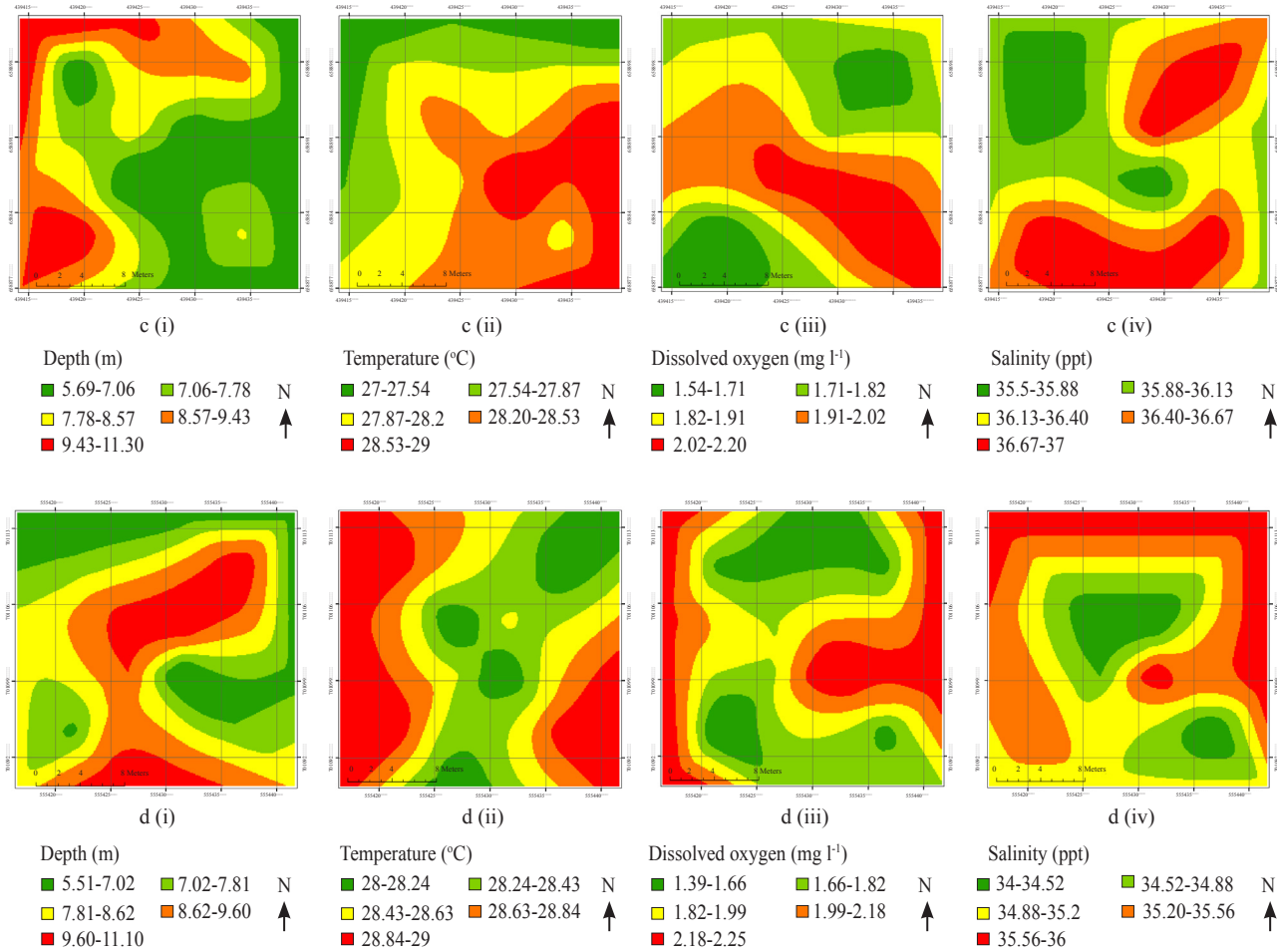


Fig. 3. Spatial distribution of environmental parameters of the sampling sites. (c) Weligama, (d) Patanagalle (i) Depth, (ii) Temperature, (iii) Dissolved oxygen, (iv) Salinity

($p > 0.05$). According to Spearman correlation analysis, non-significant negative correlation was observed between temperature vs depth as well as temperature vs salinity. Non-significant positive correlation between temperature vs DO; salinity vs depth, salinity vs DO and depth vs DO was found. Significant positive correlation ($p < 0.05$) was observed between temperature and DO.

Fig. 4. explains the distribution of bottom substrate conditions of different sites where *P. homarus* are abundant. The bottom of Hikkaduwa and Weligama (south-west) sites mostly comprised coral, sand and rocky substrates. Hikkaduwa site was rich with more coral (44%) and less muddy sand substrate (25%) while Weligama site was rich in muddy sand (44%) with less corals (19%). Patanagalle and Godawaya (south-east) sites were rich with rock and sand substrates, where there was no coral. More than 60% of the Patanagalle site had rocks and rest of the habitat was muddy with coarse sand. Godawaya site had small amount of silt (13%) with much of muddy and coarse sands (50%).

Discussion

Environmental parameters are very important which determine suitable habitat conditions for spiny lobsters. Results of the present study show the patterns of bottom substrate conditions and quality of environmental parameters of different home range habitats of *P. homarus* frequently abundant in the SCSL. Environmental factors affect age, growth, survival and reproduction including molt stage, social conditions and nutrition of the lobsters (Kemp and Britz, 2008; Vidya and Shoji, 2012). Also they can act singly or in combination to cause sub-lethal stress on lobsters. Temperature, salinity and DO are major factors which affect the biology of lobsters (Bindhu *et al.*, 2007; Kemp and Britz, 2008). Studies have found that adults are more resistant to fluctuations and extremes in temperature, salinity and DO than earlier life stages. The bottom substrate conditions could influence changes in these environmental parameters. Pollution by tourism activities in the SCSL also affects home range habitat characteristics and abundance of lobsters in the area.

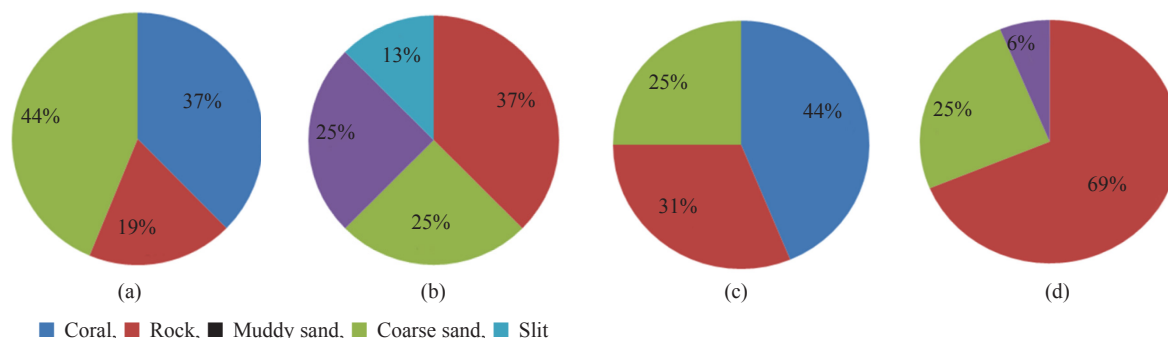


Fig. 4. Percentage of bottom substrate conditions of the four selected habitats

Temperature fluctuations may reduce growth and increase mortality of lobsters. Results of the present study shows that at low depths, water temperature and DO are having a higher positive correlation. Several studies of temperature effects on lobster embryo development (Perkins, 1972; Aiken and Waddy, 1986) and larval development (Hughes and Matthiessen, 1962; Charmantire *et al.*, 1991) have been done. Offshore areas, which are generally cooler, appear to produce larger first stage larvae than inshore waters (Rogers *et al.*, 1968). Cooper and Uzmann (1980) estimated that pre-adult lobsters tolerate temperatures from 18 to 30.5°C at optimal DO and salinity levels. Temperature range recorded for scalloped spiny lobster habitats in the present study was 27-29°C and this could be an average optimum temperature for *P. homarus* with the optimum salinity and DO levels in the SCSL.

Several studies have been carried out on salinity effects on lobsters' embryonic development (Aiken and Waddy, 1986; Charmantier and Aiken, 1987), on larvae (Sastry and Vargo, 1977) and also on juveniles and adults (Aiken and Waddy, 1986; Vidya and Shoji, 2012) and for different sexes (Jury, 1992). According to these studies, salinity levels significantly affect them biologically and too much freshwater can cause their cells to swell, leading to mortality. Lobsters have been found dead in their dens following abnormally low salinities caused by high winds and heavy spring runoff. Low salinity is more stressful at higher seawater temperatures (Thomas and White, 1969), metabolically stressful and energetically costly for lobsters and salinity below 10 may result in mortality (Jury, 1992). Results of the present study indicated that the scalloped spiny lobster, *P. homarus* usually prefer 35-37 ppt salinity range showing high abundance in the selected sites of the SCSL. Freshwater intake near Patanagalle, Godawaya and Weligama sites could be attributed to the reduction in the salinity as compared to Hikkaduwa site.

There are several reports on the DO requirement of lobsters at various stages of development (Miller *et al.*, 1992; Poucher *et al.*, 1992). In such a dynamic environment, DO of upper water layer always fluctuate and with the increasing depth, DO is reduced and fixed. DO of the selected sites in this study ranged from 5.9 mg l⁻¹ (Godawaya) to 8.1mg l⁻¹ (Hikkaduwa), which could be the tolerable DO range for high abundance of scalloped spiny lobsters in the SCSL. Hikkaduwa site showed more DO levels than other sites which could be due to greater coral substrate which increases dissolved oxygen in water by wave action. According to the results of the current study, it has been indicated that lobsters prefer low DO levels.

Benthic habitat characteristics are vital for the fourth-stage or post-larval lobsters which is a transitional stage between a free-swimming to benthic existence. If a substrate is not suitable, larvae return to the pelagic form and search a preferable habitat again. Post-larval spiny lobsters prefer macroalgal covered rock substrates, followed by rock-on-sand, mud and sand substrates (Barshaw and Bryant-Rich, 1988) and small lobsters choose gravel substrates over silt-clay substrates (Pottle and Elner, 1982). Flat sandy or muddy habitats with no shelters are less preferred by young lobsters (Cobb, 1971), but adults usually use sand areas for foraging in nights. According to Wahle and Steneck (1991), the early-benthic-phase (EBP) of lobsters in the range of 5 - 40 mm CL (claw length) were most commonly found in cobble habitats and rarely found in featureless mud, sand or bedrock substrates where larger lobsters were common. Shelters under eelgrass, rocks and boulders are of prime importance to lobsters (Karnofsky *et al.*, 1989) and are used as a retreat from predators and adverse environmental conditions (Lavalli and Barshaw, 1986).

Adult lobsters are relatively hardy and can survive a range of environmental conditions in a variety of habitats. Their preferred habitat is dependent on several

correlated factors such as temperature, salinity, DO and benthic substrates. Current study provides an insight into the spatial distribution patterns of selected habitat characteristics for *P. homarus*, using GPS technology in the SCSL. Interestingly, the results suggest that *P. homarus* has chosen diverse habitats in different regions of the SCSL. However, the observed abundance of *P. homarus* in the south-east region was higher than the south-west of the SCSL, where the substrates comprise rocks and sand. Although Hikkaduwa and Patanagalle (Yala) sites are named as nature reserves, Patanagalle is less affected by human influences and thus has lower pollution levels. These factors also could be reasons for the high abundance of *P. homarus* in Patanagalle than in the other sites. The data and observations from this study could be utilised as reference materials for future lobster culture programs especially in the site selection process. Patanagalle site could be suggested as the most suitable habitat area to implement future lobster culture programs of *P. homarus* under proper conservation and management strategies.

The next step in understanding long term effect of changes of environmental parameters and bottom substrate types should be an integrated physiological approach including the studies of body fluid, osmosis, respiration, excretion, feeding and behaviour of spiny lobsters. Such detailed investigations would possibly provide the necessary data to assess the effects of constant and fluctuating habitat conditions. It is also required to improve the knowledge of the fisheries ecology of lobsters in the area in order to make the corresponding adjustments to the management plan, if a viable population is expected.

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