www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 11: 45-54 (2011) DOI: 10.4194/trjfas.2011.0107

Feeding Habits of the Scalloped Spiny Lobstrer, *Panulirus homarus* (Linnaeus, 1758) (Decapoda: Palinuridae) from the South East Coast of Iran

Nassrin Mashaii[1,]*, Farhad Rajabipour[1], Arash Shakouri[2]

[1] Iranian Fisheries Research Organization, Brackish Water Fisheries Research Station, Bafq, Po.Box 89715/1123, Yazd, Iran.
[2] Chabahar University of Maritime, Dept. of Marine Biology, Daneshgah Blvd., Chabahar, Iran.

* Corresponding Author: Tel.: +98.352 422992; Fax: +98.352 422993;
E-mail: nassrinmashaii@yahoo.com

Received 01 June 2009
Accepted 01 October 2010

Abstract

Certain ecological aspects of the feeding habits of 260 scalloped lobsters *Panulirus homarus* collected during monthly dives off the southeast coast of Iran were considered. Parameters under consideration included: water temperature, salinity, turbidity, pH, dissolved oxygen and macrobenthose of the lobsters habitat. The mean number of empty stomachs varied from 25% to 62%. Statistical analysis revealed no monthly or seasonal significant difference in the frequency of non-empty stomachs (P>0.05). 1 to 6 prey items were distinguishable in each non-empty stomach. Monthly mean of point counts of prey obtained was from 8.76±4.18 to 154.95±73.62, without any significant difference by Tukeys' HSD test. Bivalves often had the maximum amounts of F*i* and P*i* amongst different prey items. Pearson χ^2 test did not show any significant difference between frequency of occurrence of each prey item with different length classes, sex, moulting condition and presence of eggs in females (P>0.05). Ivlev electivity index of crabs, gastropods and bivalves was close to 1 and sloped to -1 for polychaetes and echinoderms. This index revealed crabs, bivalves and gastropods were more important in the diet than sediment throughout the year. Frequencies of food occurrence suggest bivalves as the main food; crabs, gastropods, barnacles and algae as secondary food and polychaetes, fish, echinoderms and Ascidiacea as incidental food for *P. homarus* in the area. Spearmans' correlation coefficients of stomach fullness against different length classes, sexes, moulting and ovigerous females were not significantly different (P>0.05). There was only a significant Pearsons' correlation between the number of point for bivalves in the stomach against body weight (P<0.05).

Keywords: Lobster, *Panulirus homarus*, feeding ecology, Oman Sea, Iran.

İran'ın Güneydoğu Kıyısında Taraklı İstakoz, *Panulirus homarus* (Linneaus, 1758) (Decapoda: Palinuridae) Beslenme Alışkanlıkları

Özet

İran'ın güneydoğu kıyısında aylık dalış yapılarak toplanan 260 taraklı istakozun *Panulirus homarus* beslenme alışkanlıklarına bazı ekolojik unsurların etkisi incelenmiştir. Üzerinde durulan parametreler: su sıcaklığı, tuzluluk, bulanıklık, pH, çözünmüş oksijen ve makrobentostur. Ortalama boş mide sayısı %25 ile %62 arasında değişmektedir. İstatistik analizler, boş olmayan midelerin sıklığında aylık veya mevsimsel olarak anlamlı bir farklılık olmadığını ortaya koymuştur (P>0,05). Boş olmayan her midede 1 ila 6 farklı besin ayırt edilebilmektedir. Elde edilen besine ait aylık ortalama sayımlar 8,76±4,18 ile 154,95±73,62 arasında olup Tukey HSD testinin sonucunda istatistiksel olarak anlamlı bir fark görülmemiştir. Farklı besin grupları arasında çift kabuklular, genellikle azami F*i* ve P*i* miktarlarına sahip olmuştur. Farklı boy grubu, cinsiyet, kabuk değişim kondisyonu ve dişilerde yumurta varlığı olan her besin grubunun rastlanma sıklığı arasında Person χ^2 testi, istatistiksel olarak anlamlı herhangi bir fark göstermemiştir (P>0,05). Yengeçlerin, karındanbacaklılar ve çiftkabuklulara (bivalve) ait İvlev'in seçicilik göstergesi 1'e yakın bulunmuş ve çokkıllılar (polychaete) ve derisidikenliler (echinoderma) için -1'e doğru eğilim göstermiştir. Bu gösterge; yengeçlerin, çiftkabukluların ve karındanbacaklıların, yıl boyunca diyette diğer sedimenden daha önemli olduğunu göstermiştir. Besin bulunma sıklıkları; bölgede çiftkabukluların ana yem olduğunu, yengeçlerin, karındanbacaklıların, kaya midyelerinin ve alglerin ikincil yem olduğunu ve çokkıllıların, balıkların, derisidikenlilerin ve tulumluların (ascidiacea) *P. homarus* için yan besinler olduğunu öne sürmüştür. Farklı boy sınıflarına, cinsiyete, kabuk değiştirme ve yumurtalı dişilere karşılık mide doluluğuna ait Spearman'ın korelasyon katsayısı, istatistiksel olarak anlamlı bulunmamıştır (P>0,05). Vücut ağırlığına karşılık midedeki çiftkabuklulara ait puan sayısı arasında yalnızca Pearson'un korelasyonu anlamlı bulunmuştur (P<0,05).

Anahtar Kelimeler: Taraklı istakoz, *Panulirus homarus*, Beslenme ekolojisi, Umman Denizi, Iran.

Introduction

The scalloped spiny lobster, *Panulirus homarus*, is the only lobster species exploited in Iran due to limited stocks of other species in the area. All caught lobsters are exported and therefore have an important role in the fishing economy in the south east of Systan-o-Baloochestan province. Both the biological and economical aspects regarding the fishing of *P. homarus* lobsters in Iranian waters of the Oman Sea have been studied in recent years. These include; biosystematics and the appropriate tool (Sari, 1991), population dynamics (Fatemi, 1998), management of commercial catch (Mashaii and Rajabipour, 2002, 2003), numerous growth characteristics (Rajabipour and Mashaii, 2003), reproduction, feeding biology and ecology of the habitats (Mashaii, 2003).

Different aspects of the feeding ecology and nutrition have been studied for the different *Palinurus* spiny lobsters, e.g. *P. interruptus* (Castañeda-Fernández de Lara *et al*., 2005; Díaz-Arredondo and Guzmán-del-Próo, 1995); *P. argus* (Andrée, 1981; Briones-Fourzán *et al*., 2003), *P. cygnus* (Joll, 1982; 1984); *P. elephas* (Goñi *et al*., 2001); *P. longipes* (Dall, 1974, 1975); *P. echinatus* (Góes and Lins-Oliviera, 2009) and *P. homarus* (Radhakrishnan and Vivekanandan, 2004; Smale, 1978) in some countries except Iran. Despite the current rules and controls for lobster catching, continuous violation of the regulations has seen a decline in stock, necessitating an evaluation of the ecology and biology in order to reverse the damage to the lobster population. Hence in this study, feeding ecology of the spiny lobster, *P. homarus*, its habitat off the south east coast of Iran, its food preference, frequency of preys, comparison of importance of prey items between stomachs and the environment and the correlation between different feeding indexes against ecological and biological parameters have been investigated.

Materials and Methods

P. homarus samples were collected during monthly dives off the southeast coast of Ramin (60°40' E and 25°17' N) between January and December 1999. Lobsters were collected in the early morning period in order not to disrupt their nocturnal feeding activity (Berry, 1971). Carapace length (±0.1 mm), body weight (±0.01 g), sex of the lobster and presence of eggs in females were recorded in the laboratory. Gonad stages of females (Berry, 1971) were recorded and alimentary canals were removed following dissection of the carapace. Moulting was considered the presence of a soft shell under the old carapace. Alimentary canals were preserved in 4% formaldehyde in sea water for 24 h and then in 70% ethanol for later analysis. The percentage fullness of the stomach was visually calculated and categorised according to the following scale: 0) empty, 1) >0–25%, 2) >25–50%, 3) >50–75% and 4) >75–100% (Williams, 1981). Feeding contents were sorted and identified under a stereo-microscope and light microscope to the lowest taxonomic level possible (Gharanjik, 2000; Bosh *et al*., 1995; Jones, 1986; Sterrer, 1986) for each lobster. Importance of each prey in the stomach contents was measured using a point method (Williams, 1981). Length groups of the lobsters were defined by FISAT using the Bhattacharya method.

Various equations are used to determine the importance of prey items for species, which are:

(1) $Fi=(ni/N)*100$; F*i*: frequency of occurrence or frequency index of prey *i*; n*i*: number of stomachs containing prey *i*; N: number of non empty stomachs examined (Williams, 1981).

(2) $IPi=(Pij/Pj)*100$; IP*i*: point index; P*ij*: point number of the prey *i* in the stomach *j*; P*j*: total point numbers in the stomach *j* (Williams, 1981).

(3) $H=-(\sum(pi\ lnpi))$; H: Shannon diversity index of the prey; p*i*: proportion of prey *i* relative to the total number of preys (Beals *et al*., 1998).

(4) $Ei=(ri-pi)/(ri+pi)$; E*i*: Ivlev electivity index of the prey *i*; r*i*: the percentage of prey *i* in the stomach contents of the predator (number of *i* individuals/total number of prey individuals in the stomach *100); p*i* the percentage of the prey in the natural environment, which is calculated only from the prey eaten by the predator. This index is used to assess the selective feeding on preys associated with macrobenthic organisms (Ivlev, 1961).

A power model was applied to calculate regression indices (b_0 and b_1) between carapace length (L) and body weight (BW) as: $BW=b_0CL^{b1}$. The condition factor was obtained based on the allometric length groups for each lobster, as: $c.f.=BW*100/L^3$ (Pauly, 1983).

Tukeys' HSD test (P<0.05) was used to compare means of carapace length, body weight, condition factor, Shannon diversity index, and prey numbers in the stomachs of the examined lobsters. Frequency of empty stomachs, also prey in nonempty stomachs were considered using χ^2 test (P<0.005). Kruskal-Wallis and Pearson χ^2 test with crosstables were used to compare monthly, seasonally and yearly frequencies (P<0.005), as nonparametric statistics. Also, crosstables of each factor including length classes, sex, moulting, presence of eggs in females and season against frequency of each prey in nonempty stomachs were considered using Pearson χ^2 test (P<0.05).

Sediments and water samples from the lobster habitats were collected monthly by diving. Macrobenthose samples were collected using a quadrate sampler (0.25 m^2), preserved in 70% ethanol and stained using Rose Bengal (Williams and Williams, 1974). Macrobenthic organisms were counted under a stereo-microscope and identified to the lowest taxonomic level possible (Bosh *et al*., 1995; Jones, 1986; Sterrer, 1986). Variances of mean densities (N/m^2) were analyzed, then compared using Tukeys' HSD test ($P<0.05$). Water samples were collected early in the morning. Water temperature (±0.1°C) and pH (±0.01) was recorded immediately after transferring into 2 L plastic flasks to the surface using pH-meter (WTW). Concentration of dissolved oxygen, water turbidity and salinity (mg/L) were measured in the laboratory by the Winkler method, $AgNO_3$ titration (Clesceri *et al*., 1989) and spectrophotometer (Hatch), respectively.

Ecological data analyses were performed using Excel (2003) and SPSS (Ver. 11.5) software packages. Pearsons' two-tailed correlation coefficient of mean number of each prey item, Shannon diversity index of preys against carapace length, body weight, condition factor and different water factors were measured ($P<0.05$). Nonparametric statistics was used for two-tailed correlation coefficient of stomachs containing each prey item, also frequency of empty stomachs against different length classes, sex, moulting and presence of eggs in females, by Spearmans' correlation test ($P<0.05$).

Results

260 rock lobsters, *P. homarus* including 143 females and 117 males were collected and grouped by month with the exception of July and August, when monsoon weather resulted in disturbance to sea beds off the coast. 104 females were mature, 42 samples were ovigerous and 36 were moulting.

Carapace length frequencies of the examined lobsters were classified into three length classes <54 mm, 54< to <79 mm, 79< (Table 1). Mean carapace length and body weight of the lobsters were 71.39±15.85 mm and 370.68±13.06 g, respectively, with significant monthly difference especially in May when analysed by Tukeys' HSD test ($P<0.0001$). Mean condition factor was 4.176±0.099 without significant monthly difference ($P>0.05$).

Stomach fullness: of all the stomachs examined 146 stomachs contained food pieces and 114 were empty. Mean number of empty stomachs varied from 25% in March to 62% in June and December; mainly with 25% fullness (Figure 1).

Kruskal-Wallis test did not show any difference in the frequency of nonempty stomachs between months (χ^2=10.895, P=0.283) and seasons (χ^2=6.368,

Table 1. Monthly frequencies of sex, length group, molting condition and presence of food in the stomachs of *P. homarus* from south east of Iran, 1999

		Jan	Feb	Mar	Apr	May	June	Sep.	Oct.	Nov.	Dec.	Total
Sex	male	8	15	6	10	5	8	20	15	17	14	117
	nonovigerous female	11	13	2	10	3	4	10	25	15	6	101
	ovigerous female	3	8	2	3	2	1	7	11	5	1	42
Length	54<	1	7	1	4	0	0	5	7	12	2	39
	<54, >79	13	17	6	13	0	4	16	29	21	16	135
	79>	8	12	3	6	10	9	16	15	4	3	86
Molting	with soft shell	18	29	7	14	9	12	35	45	34	20	224
	without soft shell	4	7	4	9	1	1	2	6	3	1	36
Stomach	empty	9	17	4	12	5	8	10	22	14	13	114
	nonempty	13	19	6	11	5	5	27	29	23	8	146
Total		22	36	10	23	10	13	37	51	37	21	260

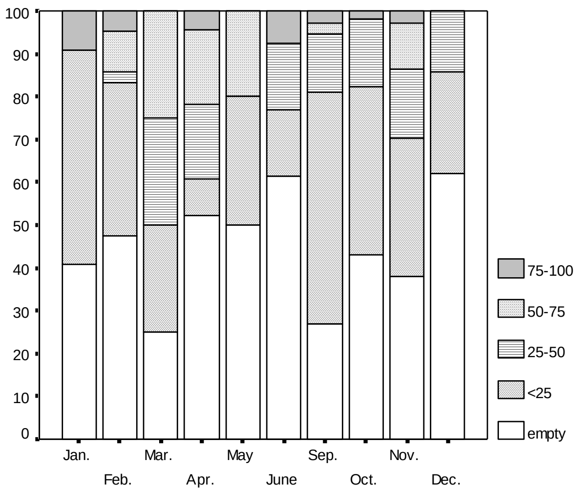

Figure 1. Monthly stomach fullness of *P. homarus* samples from south east of Iran, 1999.

P=0.95). No differences were noted for seasonality (P>0.005), but monthly significant difference (χ^2=7.811, P=0.005) was observed in September, by χ^2 test. Frequency of nonempty stomachs in September was significantly different, as was April (χ^2=3.86, P=0.049), June (χ^2=4.973, P=0.026) and December (χ^2=6.81, P=0.009), when using Pearson χ^2 test. Spearmans' correlation coefficient of stomach fullness against different length classes (-0.123, P=0.05), sex (-0.043, P=0.494), moulting (-0.05, P=0.425) and ovigerous females (0.055, P=0.515) showed no significant difference (P>0.05). Moreover, frequency of nonempty stomachs when compared with the previous parameters did not show any significant difference (P>0.005), by χ^2 test.

Stomach Contents

Stomachs of the examined lobsters contained pieces of shells and entrails of bivalves and gastropods, barnacles, crabs and other decapoda; operculum, chamber and body of polychaeta; scales and bone and muscle of fish. The observed bivalves belonged mainly to the Veneridae and Arcidae family and gastropods from the Fisturellidae family. The main barnacle type in the stomach contents was *Balanus*. Hermit crabs were more frequently decapods. Pieces of brown and green algae were observed in late spring and red algae in late autumn. 1 to 6 items were distinguishable in each non-empty stomach (Figure 2).

The mean number of points for the prey obtained ranged from 8.76±4.18 in January to 154.95±73.62 in June, without any significant difference between months (P>0.05), by Tukeys' HSD test. Yearly mean number of points for each prey was: bivalves 38.77±8.91; gastropods 2.97±0.79; other molluscs 0.15±0.02; crabs 23.41±7.14; barnacles 22.2±3.23; other crustacean 0.019±0.02; algae 31.02±4.12; echinoderms 1.72±0.16; polychaetes 10.16±1.02; fish 0.28±0.04; Ascidiacea 0.44±0.03 and digested preys 13.43±2.57. There was no significant difference between monthly frequencies for gastropods, barnacles, fish, echinoderms and Ascidiacea points (P>0.05), using the Tukeys' HSD test. Mean number of points for bivalves (P=0.0181) and polychaetes (P=0.0103) in May, crabs (P=0.0001) in April and algae (P<0.05) in June was significantly more than in other months. Shannon index varied between 0.038 in May to 0.423 in March, without any significant difference (P=0.527).

Frequency of Occurrence

F*i* of different prey items varied, bivalves it was 17.2-100; gastropods 12.5-81.1; decapods 10.5-75; barnacles 0-87.5; algae 0-39.1; polychaetes 0-33; echinoderms 0-14.8 and Ascidiacea 0-3.7 (Table 2).

Point Index

Bivalves often had the maximum amount of P*i* amongst different prey items. However, gastropods in October (15.15), barnacles in February (43.22), bivalves in May (79.41) and March (77.58), crabs in April (53.76), December (48.23) and October (45.02), and algae in June (77.84), had the most monthly P*i* amounts (Table 3).

Comparison of frequency of prey: Seasonal frequency of stomachs containing each prey item was significantly different in autumn and winter (P<0.0005), by χ^2 (Figure 3).

Total number of points of prey examined in stomachs of non-ovigerous females was higher than in ovigerous lobsters, and P*i* of the majority of prey items especially barnacles and algae, as well. However, P*i* of the majority of prey items among barnacles, gastropods and algae of moulting lobsters were less than for the others.

Pearson χ^2 test did not show any significant difference between frequency of each of prey item occurrence of with the different length classes, sex, moulting condition and presence of eggs in females (P>0.05). However, there was a seasonally significant

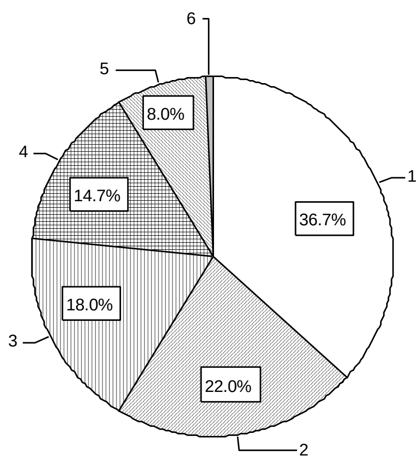

Figure 2. Percent of prey item numbers (1-6) in examined stomachs of *P. homarus* samples from south east of Iran, 1999.

Table 2. Monthly Frequencies of occurrence (F*i)* of different prey items of *P. homarus* from south east of Iran, 1999

	Jan.	Feb.	Mar.	Apr.	May	June	Sep.	Oct.	Nov.	Dec.
Bivalvia	30.8	54.5	100.0	81.8	100.0	60.0	55.6	17.2	47.8	75.0
Gastropoda	30.8	68.2	66.7	81.8	40.0	20.0	14.8	37.9	17.4	12.5
Barnacles	15.4	4.5	33.3	72.7	0.0	20.0	55.6	6.9	39.1	87.5
Crabs	15.4	40.9	0.0	72.7	40.0	60.0	37.0	51.7	43.5	75.0
Fish	7.7	0.0	0.0	0.0	20.0	0.0	11.1	0.0	0.0	0.0
Polychaeta	7.7	4.5	33.0	0.0	20.0	20.0	3.7	6.9	0.0	0.0
Other Molluska	7.7	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0
Other crustacea	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ascidiacea	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.4	0.0	0.0
Echinodermata	0.0	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.0	0.0
Algae	30.8	18.2	0.0	27.3	0.0	60.0	22.2	37.9	39.1	25.0
Unidentified food	46.2	18.2	0.0	9.1	0.0	0.0	22.2	44.8	56.5	50.0

Table 3. Monthly amounts of Point index (P*i*) of different prey items of *P. homarus* samples from south east of Iran, 1999

	Jan.	Feb.	Mar.	Apr.	May	June	Sep.	Oct.	Nov.	Dec.
Bivalvia	7.60	26.47	79.41	39.13	77.58	7.73	24.91	4.52	37.02	23.03
Gastropoda	11.95	7.80	2.20	2.56	0.47	0.20	0.96	15.15	0.87	0.27
Barnacles	15.21	43.22	13.23	2.12	0.00	2.08	15.87	5.88	11.07	16.53
Crabs	11.95	18.03	0.00	53.76	0.47	2.19	23.59	45.02	21.79	48.23
Fish	3.26	0.00	0.00	0.00	0.47	0.00	0.26	0.00	0.00	0.00
Polychaeta	1.08	2.68	2.94	0.00	20.98	9.92	0.87	0.67	0.00	0.00
Other Molluska	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
Other crustacea	0.00	0.00	2.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ascidiacea	0.00	0.00	0.00	0.00	0.00	0.00	0.09	1.58	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.00	0.00	0.00
Algae	19.56	0.89	0.00	0.80	0.00	77.84	16.05	10.85	3.86	1.35
Unidentified food	28.26	0.76	0.00	1.60	0.00	0.00	13.68	16.06	25.36	10.56

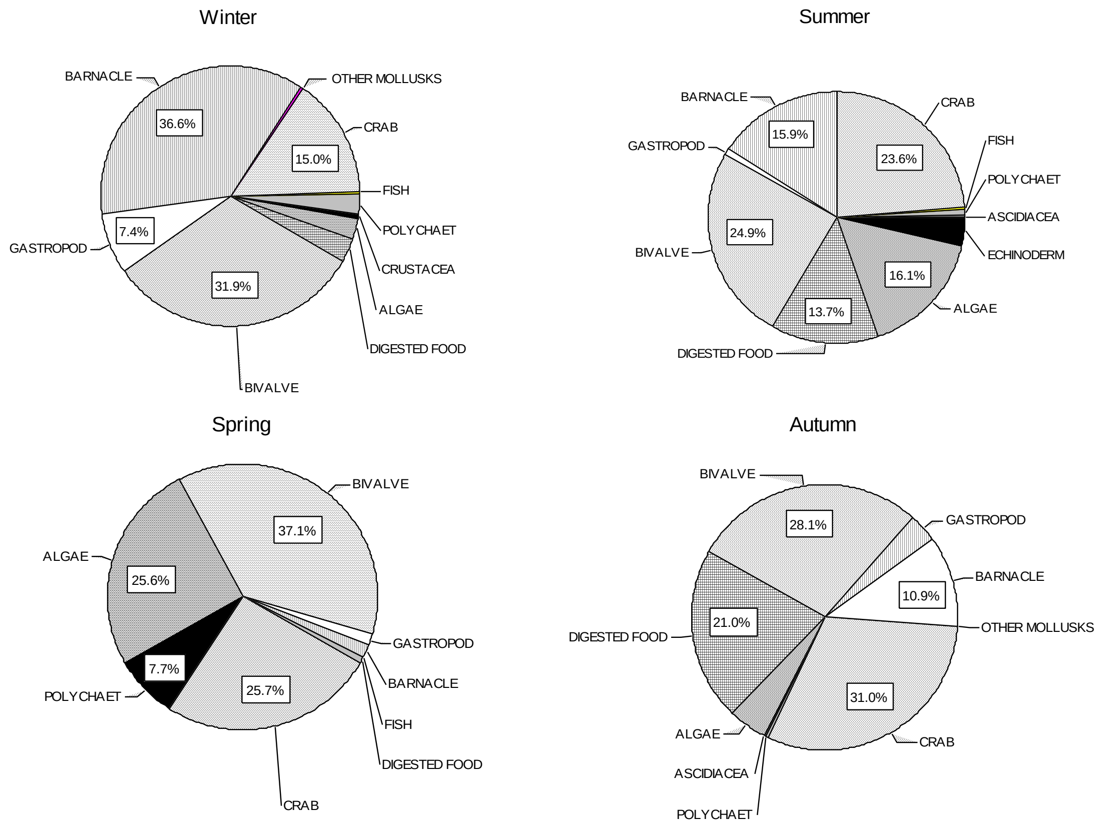

Figure 3. Seasonal frequencies of prey items in examined *P. homarus* samples from south east of Iran, 1999.

difference between F*i* for bivalves (P=0.047), gastropods (P=0.02), barnacles (P=0.0005) and echinoderms (P=0.001) by Pearson χ^2 test (P<0.05).

Macrobenthic organisms: Macrobenthic organisms collected from sediments in the lobster's habitat were from different taxons, mainly including Cephalochordata, Nematoda, Sipunculids, Ostracoda, Gastropoda, Bivalves, Polyplacophora, Scaphopoda, Amphipoda, Isopoda, Cumacea, Cladocera, Decapoda (mainly crabs), Echinodermata, Polychaeta, Oligochaeta, Mysidacea, Nemertea, Thanaidacea and Copepoda, Polychaetes, nematodes, bivalves, amphipods, ostracods, gastropods and crabs. These were observed during the majority of the study. The more frequent macrobenthic organisms were cephalopods, polychaetes and nematodes. Monthly frequencies of the main macrobenthic organisms in the examined stomachs were greater in autumn and spring than in winter and summer (Figure 4).

Ivlev electivity index of crabs was closer to 1 in all months. However it often sloped to 1 for gastropods and bivalves and -1 for polychaetes and echinoderms (Table 4).

Physico-chemical factors: Mean water temperature of the lobster habitats varied between 22.53±0.12°C in February to 31.17±0.42°C in May. Yearly mean temperature obtained was 25.56±2.78°C. Minimum and maximum amount for mean water salinity was 36.7±0.001 ppt in April and 42±0.001 ppt in June, respectively. The mean water salinity was 37.77±1.71 ppt, during the study period. The mean amount of dissolved oxygen varied from 4.2±0.17 mg/L in May to 7.37±0.15 mg/L in January, with a yearly mean of 6.07±1.12mg/L. Minimum and maximum amounts of means for pH was 7.84±0.02 and 8.42±0.001 in October and April, respectively. Mean water turbidity had minimum and maximum values from 0.33±0.58 to 9.67±0.58 in December and September, respectively. Yearly mean for water pH and turbidity of the lobster habitats was 8.22±0.17 and 3.03±2.98. Variance analysis showed significant difference between monthly means in water temperature, salinity, dissolved oxygen, pH and turbidity (P<0.00005). Also, these factors were significantly different among most of the study months (P<0.05).

Correlation coefficients: Spearmans' correlation coefficient of nonempty stomachs against different length classes (r=-0.123, P=0.05), sex (r=-0.043, P=0.494), moulting (r=-0.05, P=0.425) and presence of eggs in females (r=-0.06, P=0.51) was often close to 0 and two-way analysis did not show any significant difference (P>0.05).

Pearsons' two-tailed correlation coefficient for total number points for prey, points for each prey item and Shannon index against carapace length, body weight and condition factor were close to 0 and there was little significant correlation between the point number of bivalves in the stomach against body weight (r=0.164, P=0.048).

Pearsons' correlation coefficient for water temperature was only significant against number of

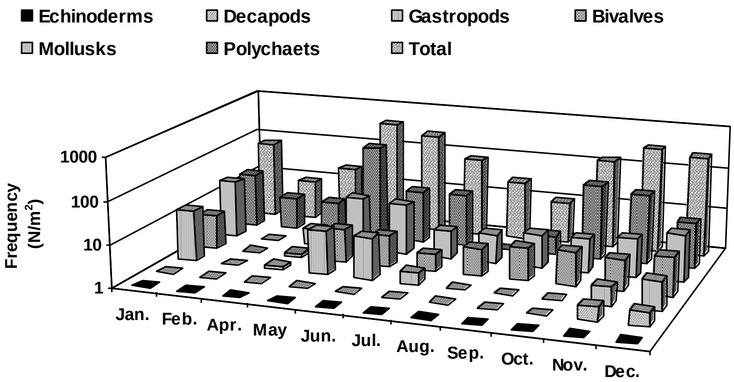

Figure 4. Monthly frequencies of macrobenthic groups from *P. homarus* habitat at south east of Iran, 1999.

Table 4. Monthly amounts of Ivlev index of the preys of *P. homarus* samples associated with macrobenthic organisms of the habitat at south east of Iran, 1999

	Jan.	Feb.	Apr.	May	June	Sep.	Oct.	Nov.	Dec.	Total
Bivalvia	-0.058	1	0.772	0.974	0.6	-0.425	0	0.897	0.769	0.42
Gastropoda	-0.351	0.322	0.25	1	0.904	1	1	0.018	0.739	-0.635
Echinodermata	-1	-	-	-	-1	1	-	-1	-	-0.5
Crabs	0.889	1	0.928	0.428	0.904	1	1	0.938	0.963	0.89
Polychaeta	0.926	0.437	-1	-0.353	0.176	-0.939	-0.97	-1	-1	-0.58
Total Molluska	0.25	0.789	0.647	0.902	0.142	-0.409	0.6	0.858	0.642	0.46

points for polychaetes in the stomach (r=0.674, P=0.033). There was a significant two-tailed converse Pearsons' correlation between total number of points for prey (r=-0.753, P=0.012), bivalves (r=-0.765, P=0.01) and polychaetes (r=-0.763, P=0.01) with dissolved oxygen; Ascidiacea (r=-0.887, P=0.001) with pH; also straight correlation between number of point for algae (r=0.681, P=0.043) with water salinity, and echinoderms (r=0.871, P=0.001) with water turbidity (Table 5).

Discussion

The frequency of nonempty stomachs of the rock lobster, *P. homarus* during the early morning (often higher than 50%) may be the result of nightly feeding activity (Berry, 1971). Post-monsoon qualities of sea water might have resulted in more significant nonempty stomachs in September, due to up swelling of nutrients and reasonable water productivity (Broch *et al*., 1991).

Yearly frequencies of different food items showed bivalves were the main food source. However, frequencies of gastropods and barnacles are different seasonally. Therefore, feeding rate of different items may be seasonally related. Different food items observed in the examined stomachs could be categorised for seasonal food preference based on the frequency of occurrence (Euzen, 1987) as: Winter: gastropods, bivalves (main), crabs, algae, barnacles (secondary), polychaetes, fish (incidental); Spring: bivalves, crabs, gastropods (main), barnacles, algae (secondary), polychaetes, fish (incidental); Summer: bivalves, barnacles (main), crabs, algae, gastropods, echinoderms, fish (secondary), Ascidiacea, polychaetes (incidental); Autumn: bivalves, algae, crabs, barnacles, gastropods (secondary), polychaetes, Ascidiacea (incidental).

Bivalves were observed in the stomach contents in all months (F*i*>50) with significant difference in spring. Additionally, the mean number points for prey was significantly higher in spring and April. Altogether, we can conclude that bivalves are the main food source; crabs, gastropods, barnacles and algae act as secondary food; and polychaetes, fishes, echinoderms and Ascidiacea as incidental food in the examined lobsters. Variation of F*i* and P*i* amounts were often proportionate to each other.

Comparison of importance of prey items between the examined stomachs and the environment by the Ivlev index revealed that crabs, bivalves and gastropods were more important in the diet, throughout the year. However, the presence of polychaetes and echinoderms were usually more important in sediments rather than in the lobster's stomachs. These results confirm our suggestion regarding the main and secondary groups of prey items.

In general, palinurid lobsters are omnivorous and consume mainly crustaceans, molluscs especially gastropods, fish and marine plants (Engle, 1979; Colinas-Sánchez and Briones-Fourzán, 1990; Díaz-Arredondo and Guzmán del Próo, 1995; Briones-Fourzán *et al*., 2003); although *P. inflatus* and *P. gracilis* do not appear to eat plants (Lozano-Alvárez and Aramoni-Serrano, 1996). Although crustaceans and gastropod prey are protein sources essential to the structure and overall function of lobsters (Kanazawa, 2000), plant material may also be important in the diet of lobsters. Joll and Phillips (1984) stated that

Table 5. Two-tailed Pearson correlation of point number of different preys and Shannon index (H) against carapace length (CL), body weight (BW), condition factor (CF), water temperature (Tem), salinity (Sal), dissolved oxygen (D.O.), pH and turbidity (Tur) of *P. homarus* habitat at south east of Iran, 1999

	Bivalvia	Gastropoda	Barnacles	Crabs	Other Molluska	Fish	Polychaeta	Ascidiacea	Echinodermata	Algae	Total points	H
CL	0.087	0.916	0.312	0.59	0.088	0.2	0.755	0.349	0.616	0.9	0.825	0.222
	0.142	0.0088	-0.084	-0.04	0.1416	0.1	0.026	0.078	0.0194	0	0.019	-0.1
BW	0.048	0.773	0.317	0.92	0.048	0.1	0.528	0.466	0.856	0.9	0.608	0.246
	0.164	0.024	-0.083	0.01	0.1641	0.1	0.0526	0.061	0.0151	-0	0.043	-0.1
CF	0.668	0.033	0.782	0.72	0.792	0.4	0.208	0.282	0.763	0.9	0.803	0.074
	-0.036	-0.1768	-0.02	0.03	0.022	0.1	-0.1048	-0.0896	0.0252	-0	-0.021	-0.15
Tem	0.085	0.623	0.136	0.62	0.092	0.6	0.033	0.606	0.62	0.4	0.107	0.234
	0.571	0.178	-0.506	-0.18	0.561	0.2	0.674	0.187	0.18	0.3	0.540	-0.41
Sal	0.543	0.663	0.98	0.35	0.486	0.5	0.365	0.675	_	0	0.399	0.283
	-0.235	-0.169	0.01	-0.36	-0.268	-0	0.344	-0.163		0.7	0.322	-0.4
D.O.	0.01	0.912	0.233	0.78	0.009	0.6	0.010	0.957	0.911	0.3	0.012	0.136
	-0.765	0.04	0.415	-0.1	-0.77	-0	-0.763	-0.020	0.041	-0.4	-0.753	0.506
pH	0.376	0.885	0.863	0.3	0.389	0.9	0.505	0.001	_	0.5	0.137	0.801
	0.337	-0.057	0.067	0.39	0.328	-1	0.257	-0.887		0.3	0.535	-0.1
Tur	0.814	0.97	0.646	0.54	0.813	0.7	0.801	0.974	0.001	1	0.707	0.177
	0.086	0.014	0.166	0.22	0.086	-0	-0.092	0.012	0.871	0	0.136	0.464

cellulose fibre stimulates growth and the assimilation of nitrogen in lobsters on high protein diets. When on low protein diets, the plant material acts as an extender, making a low protein diet adequate for normal growth and survival (Castañeda-Fernández de Lara *et al.*, 2005). Results of the present study confirm the role of algae in the normal diet of *P. homarus* as a secondary food item.

P*i* of algae in the examined stomachs was significantly higher in June. Blooms of the brown and green algae species occur in June in this area (Gharanjik, 2000). Also, higher P*i* and F*i* of barnacles in winter and polychaetes in May coincides with their increase in the habitats off coastal e regions and macrobenthic organisms in the sediment samples. Variation of bivalves, gastropods and polychaetes frequencies in sediments of the lobster habitats are often proportional with their frequencies in the diet of lobsters. Also, variations of Shannon index of diversity of macrobenthics in the diet and sediment coincide with each other. Previous studies revealed maximum diversity of macrobenthos in Chabahar Bay post-monsoon (August to November) and minimum in spring, with stability of some dominant groups (Eksiri, 1996). Diversity and competition between benthic populations are directly related, however, competition between different macrobenthic groups increases post-monsoon (Levinton, 1982). Spiny lobsters are the greatest predators of benthic populations and highly repress the secondary production of some macrobenthic groups. Frequency of macrobenthic organisms may be conversely related to seasonal frequencies of lobsters and the distance to their shelter (Jernakoff, 1987). Commercial catch of lobsters in Iranian waters in the Oman Sea is permitted post monsoon, mainly from mid September to November (Mashaii, 2003). Therefore the stability of bivalves' frequency in autumn in the present study may be an outcome of the effect of lobster catch in the area.

On the other hand, results showed significant correlation between the number of points of bivalves in the stomach against body weight. Therefore, larger lobster might consume more bivalves than others. As expected, larger predators may be more successful in catching mobile prey.

The variation in the total number of points for food in the examined stomachs was similar to the points counted for with water temperature and bivalves. Seasonal increase in temperature may result in more feeding, more bivalves and less barnacle consumption. Also, food items and their quantity in the diet may be reciprocally influenced by different environmental factors and population dynamics of the invertebrate items in the area. An expected higher metabolic rate due to an increase in water temperature must be also considered. Changes in seasonal nutrition may be related to differences in the quantity and quality of trophic groups eaten in the previous season (Castañeda-Fernández de Lara *et al.*, 2005).

Results of the present study showed significant correlation between the total number of points counted for prey, bivalves and polychaetes with dissolved oxygen. Variation of F*i* of the preys in different months mainly corresponds with their P*i* in correlation with environmental factors. The desired effect of increased seasonal dissolved oxygen on different bivalve population has been repeatedly reported (Yamamuro *et al*., 2000; Dolmer *et al*., 1999). Ecological information of the environment is fundamental in understanding the feeding ecology of spiny lobsters. Engle (1979) reported differences in the diet of *P. interruptus* that depended on local habitat characteristics.

Lozano-Alvarez and Aramoni-Serrano (1996) found higher densities of lobsters, *P. inflatus* with diminished nutritional condition in winter. They mentioned that this impoverishment could be the result of intra-species competition for food by migration of lobsters to the coastal habitat. Vega *et al*. (1996) found a migration of reproductive females to shallow waters (1–25 m) into the juveniles' habitat (<4 m) to carry out egg extrusion and hatching during spring-summer. This suggests that further research on possible trophic competition relating to different class sizes from migration patterns of *P. interruptus* is needed for clarification (Briones-Fourzán *et al*., 2003).

An increase in the total number of points of the prey examined in stomachs of non-ovigerous females and P*i* of the majority of prey items may be have resulted from a decrease in feeding activity in ovigerous lobsters that is also reported in other decapods (Freire and Gonzalez-Gurriaran, 1995; Wooton, 1992). Feeding pattern of non-ovigerous female decapods is similar to males (Freire, 1966). Nevertheless, the relationship between spawning time and feeding condition is important for some aquatics (Polovina and Ralston, 1987). Moulting and ovigerous female lobsters have less mobility than others and do not often leave their shelters. Therefore, immobile available prey such as algae and barnacles might be more easily utilized during this period. However, the relationship between moulting, metabolic and reproduction cycle in *P. homarus* has previously been confirmed (Berry, 1971). Changes in diet preferences between size classes or stages in lobsters have been observed in some palinurid species, as in *P. cygnus* (Joll and Phillips, 1984), *P. argus* (Andrée, 1981; Herrnkind and Butler, 1986), *Jasus edwardsii* (Edmunds, 1995), and *P. elephas* (Goñi *et al*., 2001). This general change in prey choice with ontogeny probably reflects an expanded foraging range and thus ability to exploit different habitats and unique prey (Andrée, 1981; Edgar, 1990; Briones-Fourzán *et al*., 2003). In general, it seems that availability of relatively large invertebrates concerning all infauna, epifauna and megafauna among mollusks and decapods are more suitable food items for *P. homarus* lobsters. Consumption of poorly mobile available invertebrates is suggested as a feeding pattern for other decapods (Edgar, 1990; Ropes, 1988).

Although results of this study present some ecological information on the feeding habits of the rock lobster *P. homarus* in its natural habitat in the Chabahar area, more research is needed to draw a more comprehensive pattern of their feeding characteristics based on population dynamics of macro-invertebrates, hydrobiology of the area with similar studies on feeding and habitats of *P. homarus* in the neighbouring areas of south east, Iran.

Acknowledgements

Many thanks to the Iranian Fisheries Research Organization, Offshore Fisheries Research Center of Chabahar for supporting this research.

References

Andrée, W.S. 1981. Locomotory activity patterns and food items of benthic postlarval spiny lobsters *Panulirus argus*. MSc. thesis. Tallahassee: Florida State University.

Beals, M., Gross, L. and Harrell, S. 1998. Diversity indices: Shannon's H and E. In: L.J. Gross, B.C. Mullin, S.E. Riechert, O.J. Schwarz, M. Beals and S. Harrell (Eds.), Alternative routes to quantitative literacy for the life sciences. University of Tennessee. Knoxville, Tennessee.

Berry, P.F. 1971. The biology of the spiny lobster, *Panulirus homarus* Linnaeus, 1758, of the east coast of southern Africa. South African Oceaonography Research Institute, Investigation Report, 28: 1-75.

Bosh, T.B., Dance, S.P., Robert, G.M. and Oliver, P.G. 1995. Seashells of Eastern Arabi. Mutivate Pub. UAE, 296 pp.

Briones-Fourzán, P., Castañeda-Fernández de Lara, V., Lozano-Álvarez, E. and Estrada-Olivo, J. 2003. Feeding ecology of the three juvenile phases of the spiny lobster *Panulirus argus* in a tropical reef lagoon. Marine Biology, 142(5): 855–865.

Broch, J.C., McClain, C.R., Luther, E.M. and Hay, W.W. 1991. The phytoplankton bloom in the north western Arabian Sea during the southwest monsoon of 1979. Journal of Geophysical Research, 96(C11): 623-642.

Castañeda-Fernández de Lara, V., Serviere-Zaragoza, E. and Hernández-Vázquez, S. 2005. Feeding ecology of juvenile spiny lobster, *Panulirus interruptus*, on the Pacific coast of Baja California Sur, Mexico. New Zealand Journal of Marine and Freshwater Research, 39: 425–435.

Clesceri, L.S., Greenberg, A.E. and Trussell, R.R. 1989. Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, 203 pp

Colinas-Sánchez, F. and Briones-Fourzán, P. 1990. Alimentación de las langostas *Panulirus argus* y *P. guttatus* (Latreille, 1804) en el Caribe Mexicano. Anales del Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, 17: 89–109.

Dall, W. 1974. Indices of nutritional state in the western rock lobster, *Panulirus longipes* (Milne Edwards). I. Blood and tissue constituents and water content. Journal of Experimental Marine Biology and Ecology, 16: 167–180.

Dall, W. 1975. Indices of nutritional state in the western rock lobster, *Panulirus longipes*, II. Gastric fluid constituents. Journal of Experimental Marine Biology and Ecology, 18: 1–18.

Díaz-Arredondo, M.A. and Guzmán-del-Próo, S.A. 1995. Feeding habits of the spiny lobster (*Panulirus interruptus* Randall, 1840) in Bahía Tortugas, Baja California Sur. Ciencias Marinas, 21: 439–462.

Dolmer, P., Kristensen, P.S. and Hoffmann, E. 1999. Dredging of blue mussels (*Mytilus edulis* L.) in a Danish sound: stock sizes and fishery effects on mussel population dynamic. Fish Research, 40(1): 73-80.

Edgar, G.J. 1990. Predator-prey interactions in seagrass beds: I. The influence of macrofaunal abundance and size-structure on the diet and growth of the Western rock lobster *Panulirus cygnus* George. Journal of Experimental Marine Biology and Ecology, 139: 1–22.

Edmunds, M. 1995. The ecology of the juvenile southern rock lobster, *Jasus edwardsii* (Hutton, 1875) (Palinuridae). PhD thesis. Hobart: University of Tasmania.

Eksiri, S.F. 1996. Identification and distribution of Polychaets in Chabahar Bay. MSc. thesis. Tehran: Azad Islami University. (In Persian).

Engle, J. 1979. Ecology and growth of juvenile California spiny lobsters (*Panulirus interruptus*, Randall). PhD thesis. Los Angeles: University of Southern. California.

Euzen, O. 1987. Food habit and diet composition of some fish of Kuwait. Kuwait Bulletin Science, 9: 65-85.

Fatemi, M.R. 1998. Population dynamics and stock assessment of the dominant lobster species in Chabahar. PhD thesis. Tehran: Azad Islami University, Department of Science and Research.

Freire, J. and González-Gurriarán, E. 1995. Feeding ecology of the velvet swimming crab *Necora puber* (Decapoda: Portunidae) in mussel raft areas of the Ría de Arousa (Galicia, NW Spain). Marine Ecology Progress Series, 119: 139–154.

Freire, J. 1966. Feeding ecology of *Liocarcinus depurator* (Decapoda: Portunidae) in the Ria de Arousa (Galicia, north-west Spain): effects of habitat, season and life history. Marine Biology, 126(2): 297-311.

Gharanjik, B.M. 2000. The marine algae of the Sistan and Baluchistan Province, Iran. Iranian Journal of Fisheries, 2(2): 57-70.

Góes, C.A. and Lins-Oliviera, J.E. 2009. Natural diet of spiny lobster, *Panulirus echinatus* Smith, 1869 (Crustacea: decapoda:Palinuridae), from São Pedro and São Paulo Archipelago–Brazil. Brazilian Journal of Biolology, 69(1): 143-148

Goñi, R., Quetglas, A. and Reñones, O. 2001. Diet of the spiny lobster *Panulirus elephas* (Decapoda: Palinuridae) from the Columbretes Islands Marine Reserve (north-western Mediterranean). Journal of the Marine Biological Association of the United Kingdom, 81: 347–348.

Herrnkind, W.F. and Butler IV, M.J. 1986. Factors regulating postlarval settlement and juvenile microhabitat use by spiny lobsters, *Panulirus argus*. Marine Ecology Progress Series, 34: 23–30.

Ivlev, V.S. 1961. Experimental Ecology of the Feeding of Fishes. Yale University Press, New Haven, 302 pp.

Jernakoff, P. 1987. Foraging patterns of juvenile western rock lobster *Panulirus Cygnus*. Journal of Experimental Marine Biology and Ecology, 113: 125-144.

Joll, L.M. 1982. Foregut evacuation of four foods by the Western rock lobster, *Panulirus cygnus* in Aquaria. Australian Journal of Marine and Freshwater Research, 33: 939–943.

Joll, L.M. 1984. Natural diet and growth of juvenile Western rock lobster *Panulirus cygnus*. PhD thesis. Perth: University of Western Australia.

Joll, L.M. and Phillips, B.F. 1984. Natural diet and growth of juvenile Western rock lobster *Panulirus cygnus*. Journal of Experimental Marine Biology and Ecology, 75: 145–169.

Jones, D.A. 1986. A Field Guide to the Seashores of Kuwait and the Arabian Gulf. University of Kuwait. Blandford Press, U.K., 160 pp.

Kanazawa, A. 2000. Nutrition and Food. In: B. F. Phillips, and J. Kittaka (Eds.), Spiny Lobsters: Fishery and Culture, 2nd edition, Fishing News Books, Blackwell Science, Oxford, 679 pp.

Levinton, J.S. 1982. Marine Ecology. Prentice-Hall,. Inc., Englewood Cliffs, N.J., 526 pp.

Lozano-Álvarez, E. and Aramoni-Serrano, G. 1996. Alimentación y estado nutricional de las langostas *Panulirus inflatus* y *Panulirus gracilis* (Decapoda: Palinuridae) en Guerrero, México. Revista de Biología Tropical, 44: 453–461.

Mashaii, N. 2003. The management survey of the rock lobster, *Panulirus homarus* Linnaeus, 1758, in the coastal waters of Systan and Balouchestan province. Final report of the project, Iranian Fisheries Research Organization, 157 pp. (In Persian).

Mashaii, N. and Rajabipour, F. 2002. A survey about commercial catch of the rock lobster, *Panulirus homarus* Linnaeus, 1758, in the Iranian seashores of Oman Sea, at 2000. Pajouhash-va-Sazandegi, In animal and fisheries sciences, 55: 44-49. (In Persian).

Mashaii, N. and Rajabipour, F. 2003. Commercial catch management of spiny lobster, *Panulirus homarus* Linnaeus, 1758, in the coastal waters of Sistan and Balouchestan province. Iranian Scientific Fisheries Journal, 12(3): 175-192. (In Persian).

Pauly, D. 1983. Some Simple Methods for the Assessment of Tropical Fish Stocks. FAO, Fisheries Circulation, 729, Rome, 53 pp.

Polovina, J.J. and Ralston, S. 1987. Tropical snappers and groupers: biology and fisheries management. The Quarterly Review of Biology, 63(1): 105-106.

Radhakrishnan, E.V. and Vivekanandan, E. 2004. Prey Preference and Feeding Strategies of the Spiny Lobster *Panulirus homarus* (Linnaeus) Predating on the Green Mussel *Perna viridis* (Linnaeus). Program and Abstracts of the 7th International Conference and Workshop on Lobster Biology and Management, 40 pp.

Rajabipour, F. and Mashaii, N. 2003. Length weight relationship of the spiny lobster, *Panulirus homarus* Linnaeus, 1758, from southeast of Iran. 7th International Conference and Workshop on Lobster Biology and Management, Hobart, Tasmania, 8-13th Feb. 2003. Abstract Book.

Ropes, J.W. 1988. The food habits of five crab species at Pettaquamscutt River, Rhode Island. Fisheries Bulletin, 87: 197-204.

Sari, A.R. 1991. Biosystematics of the Lobsters. MSc. thesis. Faculty of Science, University of Tehran, 163 pp. (In Persian).

Smale, J.M. 1978. Migration, growth and feeding in the Natal rock lobster *Panulirus homarus* (Linnaeus). South African Association for Marine Biological Research, Investigational Report No: 47.

Sterrer, W. 1986. Marine Fauna and Flora of Bermuda: A Systematic Guide to the Identification of Marine Organisms. John Wiley and Sons, New York: 232-256.

Vega, V.A., Espinoza-Castro, G. and Gómez-Rojo, C. 1996. Pesquería de langosta *Panulirus* sp. In: M. Casas-Valdez and G. Ponce-Díaz (Eds.), Estudio del Potencial Pesquero y Acuícola de Baja California Sur, La Paz, México, Centro de Investigaciones Biológicas del Noroeste, 350 pp.

Williams, D.D. and Williams N.E. 1974. A counterstaining technique for use in sorting benthic samples. Limnological Oceanography, 19: 152-154.

Williams, M.J. 1981. Methods for analysis of natural diet in portunid crabs (Crustacea: Decapoda: Portunidae). Journal of Experimental Marine Biology and Ecology, 52: 103-113.

Wooton, R.J. 1992. Fish ecology. Blackie and Son Ltd., Glasgow, 212 pp.

Yamamuro, M., Hiratsuka, J. and Ishitobi, Y. 2000. Seasonal changes in a filter-feeding bivalve *Musculista senhousia* population of a eutrophic estuarine lagoon. Journal of Marine Systems, 26(2): 117-126.