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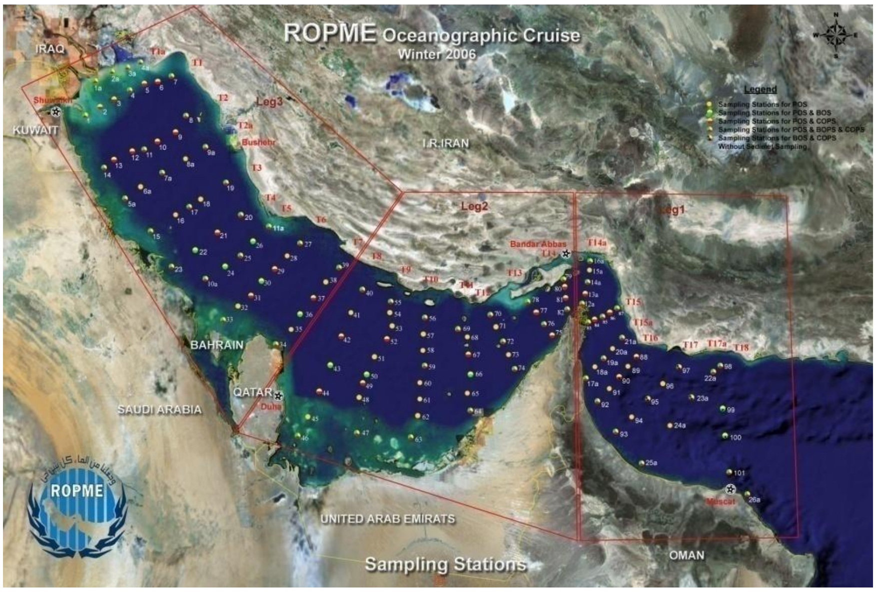
ROPME Oceanographic Cruise - Winter 2006



Technical Report Series

Technical Report : No. 7

Decapod Larvae in the ROPME Sea Area

February 2012

ROPME Oceanographic Cruise - Winter 2006

Technical Report Series:

1. Physical Oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll-*a*
5. Phytoplankton
6. Zooplankton
7. Decapod Larvae
8. Ichthyoplankton
9. Tintinnids
10. Meiobenthos
11. Macrobenthos

Disclaimer

This Report has been prepared by Kuwait Institute for Scientific Research, as the Principal Investigator on 'Decapod Larvae' under a contract with ROPME. The Report is being separately subjected to peer review and linking with other relevant data and information, in order to develop an integrated understanding of the ROPME Sea Area. Meanwhile, in order to bestow the benefit of viewing the results in their preliminary form and promote a general level of understanding of the marine environment of the Region, notwithstanding the possible delay by peer review, this document is being brought out as part of a special Technical Report Series in the very form in which it was submitted by the Principal Investigator. Owing to this reason, ROPME shall not accept responsibility on the accuracy of data or interpretations contained in this Report. ROPME does not also subscribe to the inappropriate terms used to denote parts or full of the ROPME Sea Area inadvertently used by the Principal Investigator or provided in the published references and citations.

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Preface

In recognition of the importance of the oceanographic Cruises in the ROPME Sea Area to understand the state of the marine environment, ROPME Council has assigned high priority to the ROPME scientific Cruises. In pursuance of the Council Decision CM12/7, ROPME was mandated to coordinate a comprehensive oceanographic Cruise in Winter 2006. The Cruise was planned in such a way that the results and reports of the studies can find their way into the synthesis of ROPME State of the Marine Environment Report.

As a result of sustained efforts, cooperation of Member States, guidance of the designated scientific committee for the Cruise, encouragements from the Executive Committee of ROPME and the generous provisions made by the Council, the historic Winter Cruise was carried out successfully on board of M/V Ghods of I. R.Iran during 1st February and 11th March 2006.

Totally, 115 stations covering the RSA have been surveyed and 97 experts from ROPME Member States participated in the Cruise. The survey covered most of the main oceanographic disciplines.

The collected samples during the Cruise were distributed on a competitive basis to the competent laboratories in the Region and elsewhere for detailed analyses while sub-sample sets were kept in ROPME Marine Sample Bank to enable repetitive analyses in future, when required.

To enhance benefits from the reproduced results of the Cruise among Regional scientific community towards a better understanding of the marine environment in the RSA and to enable furtherance of marine researches, ROPME Secretariat decided on the publication of the results in a series of Technical Reports as follows:

1. Physical Oceanography
2. Contaminants in Marine Sediments
3. Nutrients
4. Chlorophyll-*a*
5. Phytoplankton
6. Zooplankton
7. Decapod Larvae
8. Ichthyoplankton
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The present Technical Report is devoted to the taxonomy, spatial occurrence and abundance of decapod larvae in the RSA. The analyses of decapod larvae samples and reporting have been conducted by a team of scientists led by Dr. Faiza Y. Al-Yamani at Kuwait Institute for Scientific Research (KISR) under a contract with ROPME.

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EXECUTIVE SUMMARY

A total of 59 stations were sampled for decapod larvae. The results of samples and data processing indicated that there were differences in the distribution and abundance as well as in the biodiversity of planktonic decapods of the inner RSA (ROPME Sea Area) compared to the Sea of Oman, in the RSA.

Seven morphotypes, 23 families, 27 genera and 10 species of planktonic and larval decapods were identified within the RSA plankton collection. Among the planktonic and larval decapods collected during the winter season, the sergestid shrimps (families *Luciferidae* and *Sergestidae*) were the most abundant group. Other recorded groups were considerably less in percentage composition of the total decapods assemblage.

One third of the identified planktonic decapods in the RSA had aggregated distribution, while the rest showed regular distribution. The RSA can be adequately classified into 3 major subregions in terms of sergestids dominance: Northwestern inshore; Central inshore and Offshore.

Dominance in winter assemblage of the RSA shrimp *Lucifer hanseni* showed swarming conditions in the central part of the inner RSA. The Strait of Hormuz could be a nursery area for this species. Occurrence of penaied shrimps *Penaeus semisulcatus* and *Parapenaeopsis stylifera* protozoeae in the winter season in the RSA showed that reproduction of commercial penaeids is continuous year around.

Presence in the RSA waters of larvae of deep sea mud shrimp *Solenocera* sp., sergestid shrimp *Sergestes* sp., oceanic luciferid shrimp *Lucifer typus*, pelagic caridean shrimp *Thalassocaris obscura,* and oplophorid shrimp *Acanthephyra* sp. indicated the influence of the Indian Ocean waters on the RSA.

Distribution of pleocyemata larvae (Brachyura, Caridea, Anomura, Thalassinidae) in the RSA was patchy and showed spatial dissociation. Brachyuran larvae were most abundant in northwestern waters (Kuwaiti waters), Caridea larvae – in the Strait of Hormuz, Anomura larvae – in the waters off the Saudi coast, and Thalassinidae – in the waters off Qatar. In general, the diversity of planktonic Decapoda is increasing toward the Sea of Oman.

1. Introduction

Success in the larval life of decapods is one of the principal determinants for a successful recruitment, and it is an important element in the evaluation of the fisheries of the different species. The studies on larval decapods, which have been undertaken in the inner ROPME Sea Area (RSA), have generally focused on larvae of the commercially exploited penaeid shrimps (Price, 1979; Mohammed *et al*., 1981; Grabe and Lees, 1992; Price *et al*., 1993). Al-Aidaroos (1993) reviewed the springtime distribution of decapod larvae in the western inner RSA subsequent to the Gulf War. In September 1981, Dames and Moore (1983) began a year-long investigation of fish and shellfish resources in Kuwait Bay and adjacent waters. Objectives included the identification of seasonal and spatial patterns in the abundance of meroplankton.

Grabe and Lees (1995) studied distribution and composition of larval pleocyemate decapods in Kuwait Bay. They reported that caridean, stenopidideanean, anomuranan and thalassinidean larvae were more abundant during spring through fall months and least abundant during winter. Taxa those were somewhat more abundant along the southern periphery of Kuwait Bay, where habitats were more diverse, included *Diogenes* spp. (Anomala), *Upogebia* spp. (Thalassinidea), porcellanids (Anomala) and alpheids (Caridea). Larvae, which were more abundant along the northern shore of Kuwait Bay and in the Khor Al-Sabiya waters, where mud flats are extensive, included *Ogyrides orientalis* (Caridea), *Emerita asiatica* (Anomura) and two callianassids (Thalassinidea).

Study of the life history of penaeid shrimps has received great importance with the increased commercial value of many shrimp species. Previous studies in the western inner RSA indicated that spawning of *Penaeus semisulcatus* takes place during winter and spring (Al-Attar and Ikenoue, 1974; Basson *et al*., 1977; Price and Jones, 1975). Price and Jones (1975) reported that the main breeding season of penaeid species in the RSA occurs in October and extends at least until April. They also found from plankton surveys along the Saudi coast that penaeid larvae occur throughout the year, but are more abundant from November until April. Price (1979) studied the temporal variation in abundance of penaeid shrimp larvae off Ras Tanura, in the western RSA. In a later study, Price (1982) reported on the distribution of penaeid shrimp larvae along the RSA coast of Saudi Arabia. Michel *et al*. (1982 a; b) studied the zooplankton of Kuwait and the western RSA south of Kuwait waters.

Grabe and Lees (1992) reported that the most abundant penaeids larvae are *Parapenaeopsis stylifera* and *Metapenaeus* spp., although Kuwait Bay may not be a major spawning area for these species. However, Khor Al-Sabiya, a river-like channel northeast of Kuwait Bay, may serve as a nursery for at least two of the penaeids (*Metapenaeus* spp. and *Penaeus semisulcatus).* Both *P. stylifera* and *Metapeaneus* spp. were the most abundant larvae during late spring. *Penaeus semisulcatus* larvae exhibited fall and spring-summer maxima but were never locally abundant in Kuwait Bay.

Price *et al*. (1993) compared zooplankton and penaeid larval abundance at Ras Tanura and Safaniya on the Saudi inner RSA coast in April 1992 with data collected from the same localities during the same period in the 1970s. At Ras Tanura, mean penaeid larval abundance was significantly lower in 1992 (0.275 m^{-3}) than 1976 (6.77 m^{-3}), whereas mean zooplankton abundance showed no significant change. Data also suggested that penaeid larval abundance at Ras Tanura was lower in 1992 than 1975, 1977 and 1978. At Safaniya, penaeid larval abundance was significantly lower in 1992 (0.009 m^{-3}) than in 1978 (16.70 m^{-3}). Possible reasons for the observed patterns include natural environmental changes, 'normal' background impacts (e.g., coastal reclamation, dredging and oil pollution) and impacts arising from the 1991 Gulf War. It was suggested that interactions between these and perhaps other factors, rather than any single cause, might be involved.

Al-Aidaroos (1993) reported that the penaeid larvae (protozoea and mysis stages) in the western coast of the inner RSA constituted on average, 3.7% of the total decapod larvae in April to May 1992. They were recorded in high numbers at Manifah with 130/100 m^3 in abundance and second at Bahrain with an abundance of 54/100 m^3. The Manifah area is considered as possible nursery grounds for penaeid species (90% of *Penaeus semisulcatus*), while Bahrain station is believed to be a breeding and nursery area. Both areas seem to harbor the early stages of penaeid larvae. Abu Ali area was also considered as a nursery area for penaeid species, but the occurrence of larvae in this area was rare, may be due to the geomorphology of the area and the effect of heavy oil pollution that occurred during the Gulf War of 1991.

Al-Yamani and Khvorov (2007) confirmed the findings of Grabe and Lees (1992) that larvae of *P. stylifera* are the most abundant penaeid in Kuwait waters. Similar pattern was reported for Khuzestan coastal waters (northern sector of the inner RSA) by Dehghan and Eskandary (2007). Authors suggested that *P. stylifera* larvae might have less dependence on the estuarine waters compared to *Metapenaeus affini*s. *M. affinis* larvae were the second abundant penaeid species in the northern waters of Kuwait, while *P. semisulcatus* larvae showed the lowest abundance (Al-Yamani and Khvorov, 2007).

2. Materials and Methods

2.1 Field Collection

Decapod larvae were collected by oblique plankton tows (plankton net ring diameter of 60 cm; mesh size of 500 microns) from 59 stations within the ROPME Sea Area (RSA) during February – March 2006 (Figure 1, Table 1). A total of 59 plankton samples were collected.

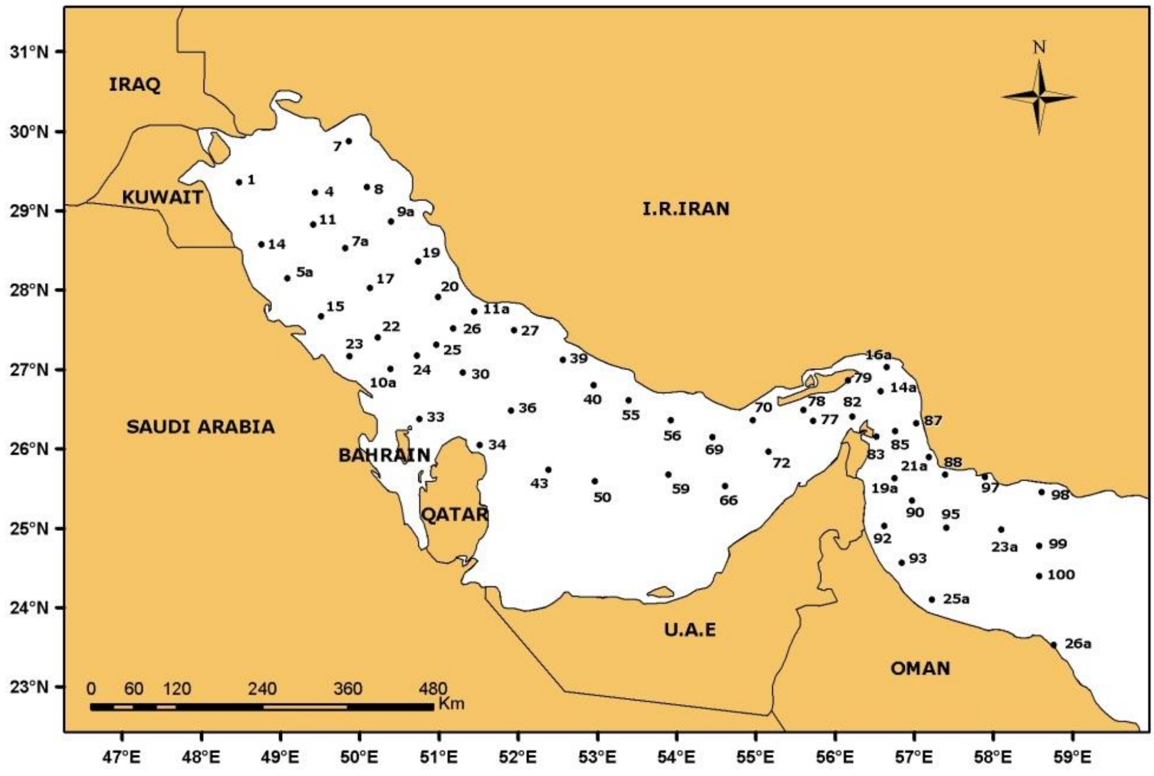


Figure 1. Map showing the locations of sampled stations in the ROPME Sea Area during February-March 2006.

Table 1. Sampled stations along transects in the ROPME Sea Area during February-March 2006

Tr. #	St. #	Date D/M/Y	Position		Tr. #	St. #	Date D/M/Y	Position	
			Lat (°N)	Long (°E)				Lat (°N)	Long (°E)
18	26a	3/2/06	23°31.000'	58°46.100'	9	55	22/2/06	26°36.057'	53°24.057'
18	100	3/2/06	24°23.404'	58°35.244'	8	40	23/2/06	26°47.800'	52°57.400'
18	99	3/2/06	24°46.136'	58°35.100'	8	43	23/2/06	25°43.513'	52°23.170'
18	98	3/2/06	25°26.801'	58°36.914'	7	34	28/2/06	26°02.500'	51°31.200'
17a	23a	4/2/06	24°58.210'	58°06.300'	7	36	28/2/06	26°28.190'	51°54.900'
17a	25a	4/2/06	24°05.505'	57°13.813'	7	39	1/3/06	27°07.000'	52°34.100'
17	93	5/2/06	24°33.147'	56°50.739'	6	27	1/3/06	27°29.200'	51°57.000'
17	95	5/8/06	24°59.595'	57°24.758'	6	30	1/3/06	26°57.100'	51°18.500'
17	97	5/2/06	25°38.200'	57°54.000'	6	33	2/3/06	26°21.800'	50°45.500'
16	88	5/2/06	25°40.043'	57°24.048'	5	10a	2/3/06	26°59.800'	50°23.700'
16	90	6/2/06	25°20.310'	56°58.530'	5	24	3/3/06	27°10.100'	50°43.500'
16	92	6/8/06	25°01.340'	56°37.800'	5	25	3/3/06	27°18.290'	50°58.400'
15a	19a	6/2/06	25°37.386'	56°45.487'	5	26	3/3/06	27°30.497'	51°11.060'
15a	21a	6/2/06	25°53.400'	57°11.300'	5	11a	3/3/06	27°43.179'	51°27.088'
15	87	7/2/06	26°18.900'	57°01.800'	4	20	3/3/06	27°54.410'	50°59.518'
15	85	8/2/06	26°13.000'	56°46.000'	4	22	4/3/06	27°23.887'	50°13.952'
15	83	8/2/06	26°08.763'	56°31.767'	4	23	4/3/06	27°09.561'	49°52.363'
14a	14a	9/2/06	26°43.200'	56°34.590'	3	15	5/3/06	27°39.842'	49°30.928'
14a	16a	9/2/06	27°01.400'	56°39.300'	3	17	5/3/06	28°01.115'	50°07.896'
14	79	13/2/06	26°51.046'	56°10.378'	3	19	5/3/06	28°21.033'	50°44.312'
14	82	13/2/06	26°23.771'	56°13.583'	02a	09a	6/3/06	28°51.200'	50°24.200'
13	77	14/2/06	26°20.671'	55°43.561'	02a	07a	6/3/06	28°31.145'	49°49.321'
13	78	14/2/06	26°28.769'	55°36.474'	02a	05a	6/3/06	28°08.501'	49°05.508'
12	70	14/2/06	26°32.104'	54°57.957'	2	14	7/3/06	28°33.885'	48°45.702'
12	72	15/2/06	25°57.254'	55°10.080'	2	11	7/3/06	28°49.120'	49°25.120'
11	66	15/2/06	25°31.090'	54°37.156'	2	8	8/3/06	29°17.580	50°05.490'
11	69	16/2/06	26°08.382'	54°27.506'	1	7	8/3/06	29°52.106'	49°52.049'
10	56	21/2/06	26°20.905'	53°55.864'	1	4	9/3/06	29°13.245'	49°26.487'
10	59	21/2/06	25°39.885'	53°53.944'	1	1	9/3/06	29°21.000'	48°29.000'
9	50	22/2/06	25°35.092'	52°58.225'					

The net mouth opening was fitted with a calibrated digital flowmeter (Hydro-Bios, model 438110) to measure volume filtered through the net. Readings of flowmeter were taken before and after each tow. The volume of the filtered water by the net was determined as follows:

Number of revolutions (flowmeter) x 0.3 x net opening area (m^2) x 1000 = Volume of Water Filtered.

Collected samples were carefully transferred to one-liter labeled bottles and preserved in 4% buffered formalin for further analysis.

2.2 Sample Processing

In the laboratory, samples were sorted out into different taxonomic groups, identified to the lowest taxon possible, and individuals of each taxon were counted under a stereomicroscope after subsampling (Motoda, 1959; Van Guelpen *et al*., 1982).

2.3 Identification

Decapoda are in the form of five pairs of thoracic appendages on the last five thoracic segments. The frontal three pairs function as mouthparts and are generally referred to as maxillipeds; the remainders are pereiopods. In many decapods, however, one pair of legs has enlarged pincers; the claws are called chelae, so those legs may be called chelipeds. Further appendages are found on the abdomen, with each segment capable of carrying a pair of biramous pleopods, the last of which form part of the tail fan (together with the telson) and are called uropods. Classification within the order Decapoda depends on the structure of the body, legs and gills, and the way in which the larvae develop. General details of body structure of decapod larva is displayed on Figure 2.

Identification of decapods was largely based on gross morphological features and verified by cross-checking with the original description of each species. The keys and identification references used were obtained from Gurney (1936; Menon and Williamson, 1971; Omori, 1975; 1992; Shinkarenko, 1979; Hayashi and Tsumura, 1981; Rothlisberg *et* *al*., 1983; Jackson *et al*., 1989; Ingle, 1992; Al-Yamani *et al*., 1995; Al-Khayat and Jones, 1996; Pohle *et al*., 1999; Dos Santos and Lindley, 2001; Conway *et al*., 2003; and Dos Santos and Gonzales-Cordillo, 2004).

After identification, RSA planktonic decapoda collection (reference collection) was prepared. List of the planktonic decapoda identified are found in Table 2.

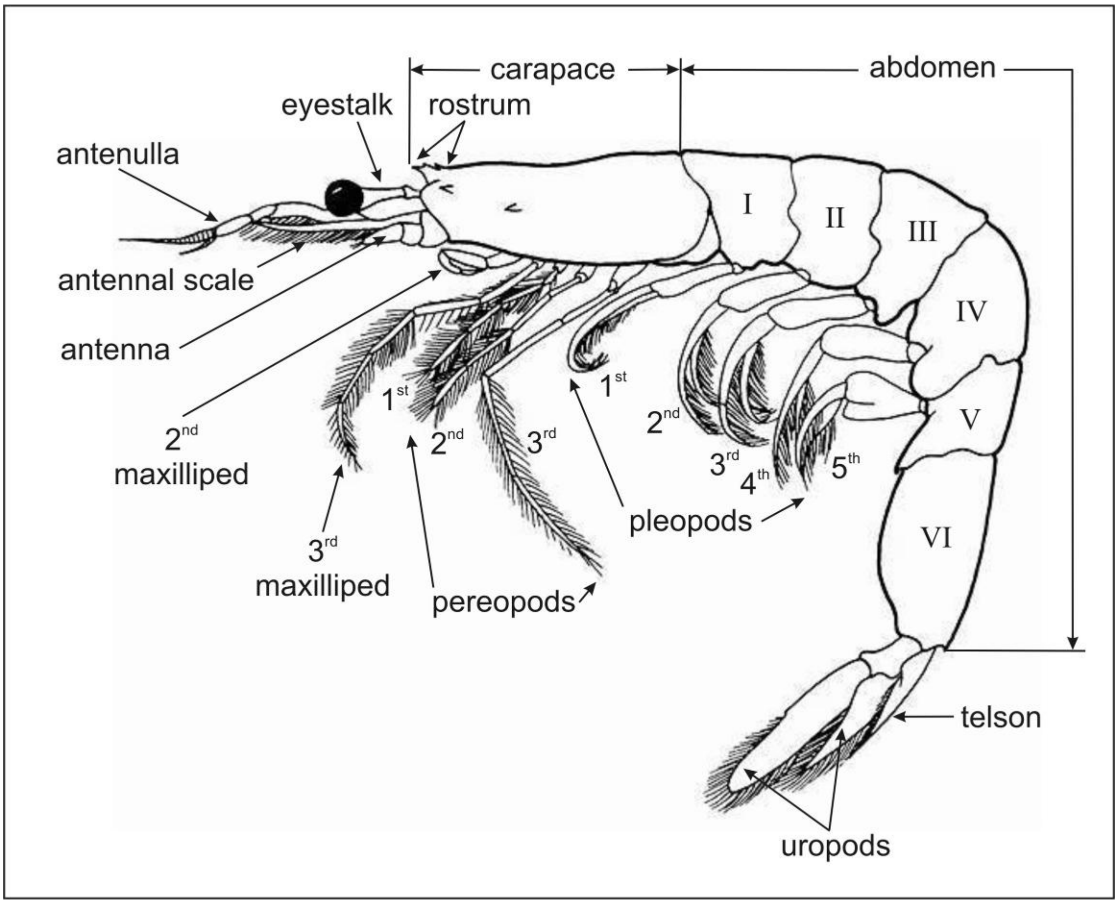


Figure 2. Schematic drawing of a Sergestoid shrimp.

Table 2. List of the Identified Taxa of Planktonic Decapoda from the RSA

Suborder	Infraorder	Family	Genus/Species
Dendrobranchiata	Sergestoidea	Luciferidae	*Lucifer hanseni*
			Lucifer typus
		Sergestidae	*Sergestes* sp.
	Penaeoidae	Penaeidae	*Metapenaeus ensis*
			Parapenaeopsis stylifera
			Penaeus semisulcatus
		Solenoceridae	*Solenocera crassicornis*
			Solenocera hextii
Pleocyemata	Anomura	Diogenidae	*Diogenes* sp.
			Paguristes sp.
			Dardanus sp.
		Galatheidae	*Galathea* sp.
		Paguridae	*Pagurus* sp.
		Porcellanidae	*Pachycheles* sp.
	Brachyura	Leucosidae	*Ebalia* sp.
			Leucosia sp.
		Ocypodidae	*Macrophthalmus* sp.
			Ilyoplax frater
		Parthenopidae	*Parthenope* sp.
	Caridea	Alpheidae	*Alpheus* sp.
		Hippolitidae	*Lysmata* sp.
			Latreutes sp.
		Oplophoridae	*Acanthephyra* sp.
		Palaemonidae	*Palaemon* sp.
			Periclimenes sp.
		Thalassocarididae	*Thalassocaris obscura*
	Thalassinidae	Callianassidae	*Callianassa* spp.
		Upogebiidae	*Upogebia* sp.
		Laomediidae	*Laomedia* sp.
	Stenopodidea	Stenopodidae	*Stenopus* sp.

2.4 Data Analysis

Abundance of decapods was expressed as individuals/m^3 (ICES Zooplankton Methodology Manual, 2000). Raw abundance data were normalized by applying a log (x+l) transformation.

Distribution fitting procedures were applied to verify the assumption of normality.

In order to analyze spatial distribution of raw abundance data, the traditional statistical methods were used, which include estimation of the mean population density (M), standard deviation (S.D.), and standard error of mean (S.E.).

The spatial distribution of species was defined by application of a model suggested by the coefficient of dispersion, I, and calculated as:

$$I = S.D.^2/M$$

There is a quick test for the type of spatial pattern (Sharov, 1995) as follows:

if $I << 1$ then regular distribution;
if $I \approx 1$ then random distribution;
if $I >> 1$ then aggregated distribution.

Also for estimation of spatial distribution, the Kriging procedure was used (Surfer 8.0 Golden Software, Inc.). Spatial mapping of planktonic decapods was performed.

To account for the variability measured, correlations between abundance and echo sounder depth of sampled locations were performed. Correlation coefficients were calculated.

3. Results and Discussion

3.1 Taxonomy of Decapod Larvae

Phylum Arthropoda Latreille, 1829

Subphylum Crustacea Brunnich, 1772

Class Malacostraca Latreille, 1802

Subclass Eumalacostraca Grobben, 1892

Superorder Eucarida Calman, 1904

Order Decapoda Latreille, 1802

Suborder Dendrobranchiata Bate, 1888

Superfamily Penaeoidea Rafinesque, 1815

Family Penaeidae Rafinesque, 1815

Genus *Metapenaeus* Wood-Mason, 1891

Species *Metapenaeus ensis* (De Haan, 1844)

Protozoea II (Figure 3 a-b)

Synonym: *Metapenaeus mastersii* Hall, 1962

Reference: Jackson *et al*., 1989.

Description: Carapace does not completely cover thorax (Figure 3 a). Abdomen bifurcate posteriorly with each furca bearing at least seven spines. No spines arise from posterior half of carapace. Eyes mobile (E in Figure 3 a). Uropods absent. Two pairs of supraorbital spines (Figure 3 b). Inner pair of supraorbital spines filamentous and less than half as long as outer pair.

Measurements: Total length 2.5 mm; length of carapace 0.88 mm.

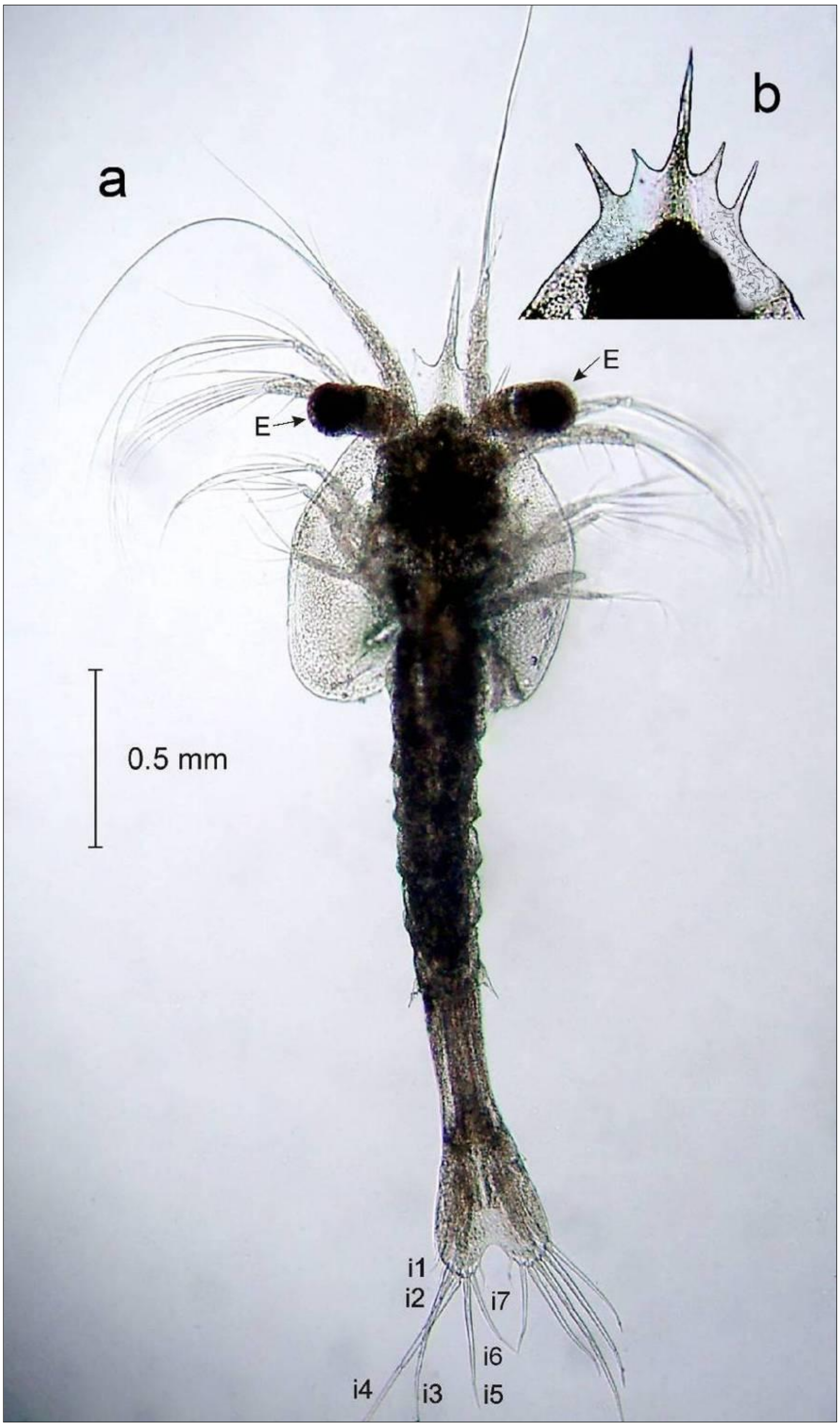
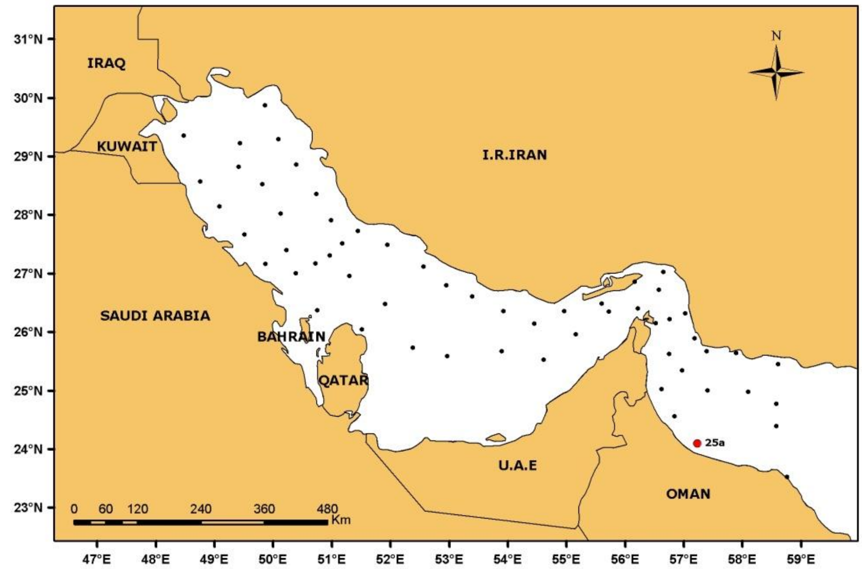


Figure 3. *Metapenaeus ensis*, protozoea II. a. general dorsal view; b. anterior part of carapace.

E. eye; i1-i7. 1st - 7th telson spines

Geographical Distribution: Indo-West Pacific Region.

Site of Occurrence in RSA: Sea of Oman: Station 25 a.



Site of occurrence of *Metapenaeus ensis*, protozoea II in RSA

Family Penaeidae Rafinesque, 1815

Genus *Parapenaeopsis* Alcock, 1901

Parapenaeopsis stylifera (Milne Edwards, 1837)

Protozoea III (Figure 4 a-d).

Synonyms: *Penaeus styliferus* Milne Edwards, 1837; *Penaeopsis stylifera* Milne Edwards, 1837.

References: Habib-ul-Hassan, 1984; Jackson *et al*.,1989.

Description: Carapace with only rostral spine round (Ca, Ro in Figure 4 a, b). The eyes are stalked, compound. Biramous uropods present (Ex Ur, En Ur in Figure 4 c, d). Dorsal abdominal spines present (DSp in Figure 4 d). Caudal furca wide (Figure 4 c). Eight pairs of caudal spines (i1 - i8 in Figure 4 c, d).

Measurements: Total length 1.6 mm; length of carapace 0.4 mm.

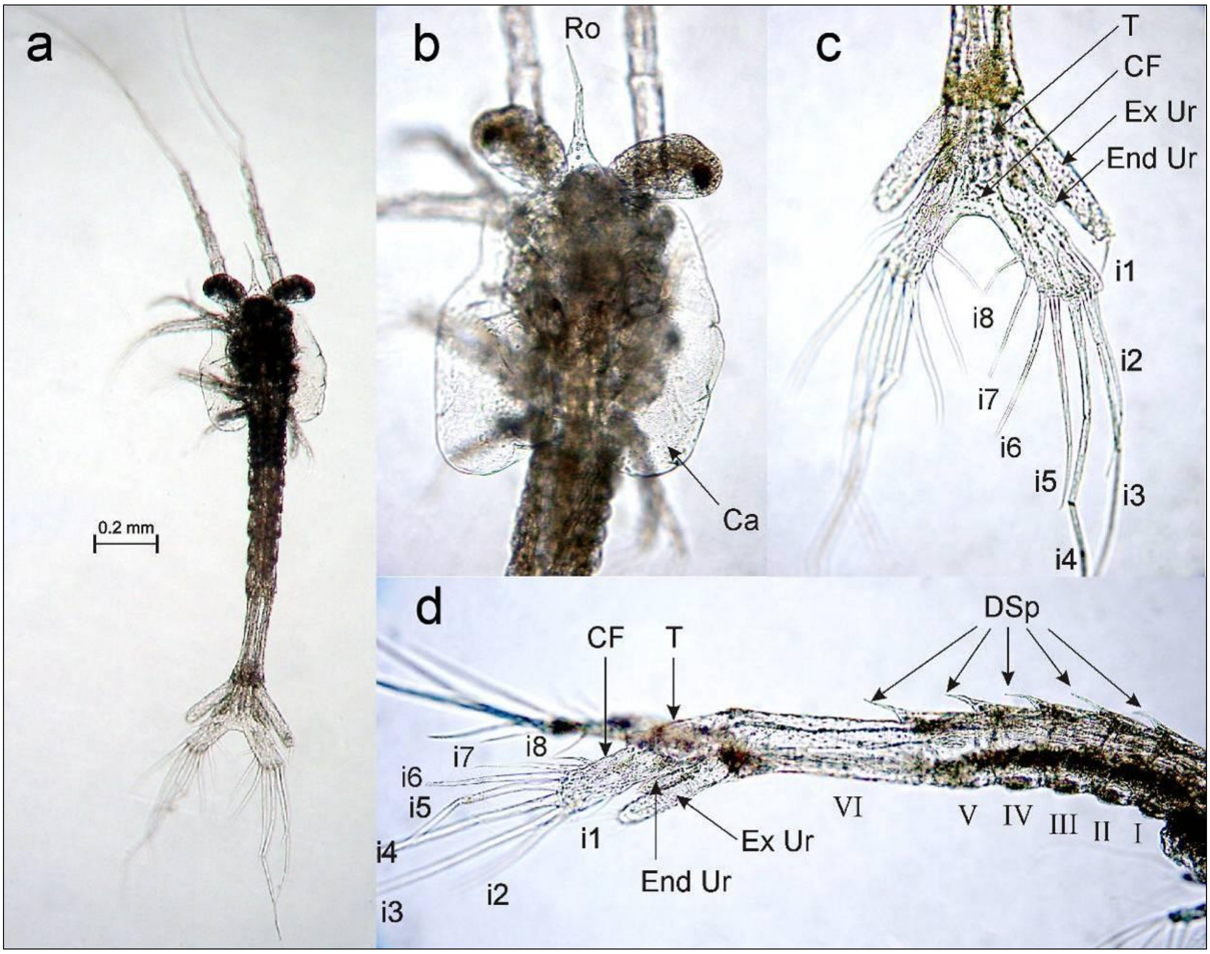


Figure 4. *Parapenaeopsis stylifera*, protozoea III. a. dorsal view; b. dorsal view of carapace; c. dorsal view of telson, d. lateral view of abdomen and telson.

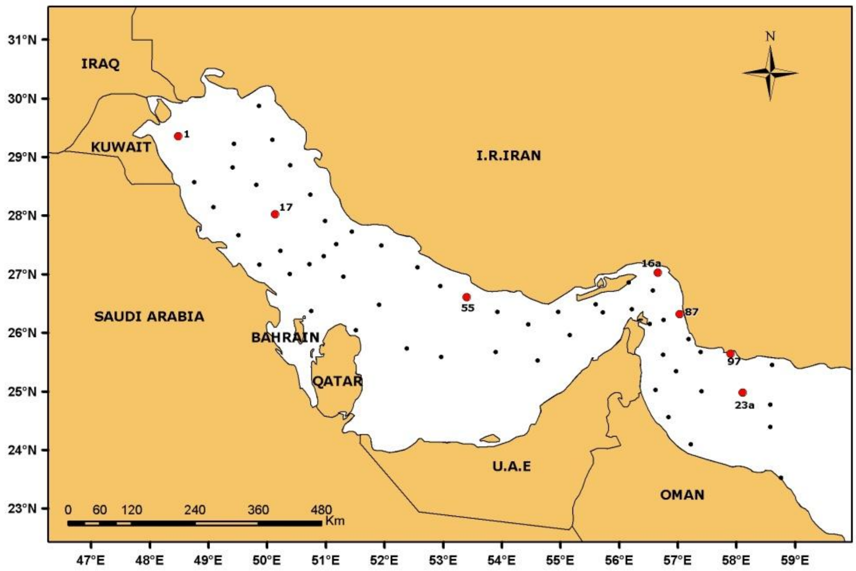
Ro. rostrum; Ca. carapace; T. telson; CF. caudal furca; Ex Ur. exopod of uropod; En Ur. endopod of uropod; i1 - i8. 1^{st} - 8^{th} telson spines; DSp. dorsal spines; I – VI. abdominal somites.

Geographical Distribution: Indo-West Pacific Region.

Sites of Occurrence in RSA:

Sea of Oman: Stations 16a, 23a, 87 and 97.

Inner RSA: Stations 1, 17 and 55.



Sites of occurrence of *Parapenaeopsis stylifera*, *p*rotozoea III in RSA

Family Penaeidae Rafinesque, 1815

Genus *Penaeus* Fabricius, 1798

Penaeus semisulcatus de Haan, 1850

Protozoea I (Figure 5 a-d)

References: Habib-ul-Hassan, 1982; Jackson *et al.*, 1989.

Description: Carapace is round (Figure 5 a, b) with a median notch at the anterior end (MN in Figure 5 b). The last six thoracic segments are free from the carapace (Figure 5 c). Abdomen is unsegmented. An ocellus is present (Figure 5 a, b). The antennule is about the same size as the antenna (Figure 5 a).

Measurements: Total length 1.1 mm; length of carapace 0.4 mm.

Figure 5. *Penaeus semisulcatus*, protozoea I. a. general dorsal view; b. dorsal view of carapace; c. dorsal view of thorax (Th, I-VI - thoracic segments) and abdomen; d. dorsal view of telson.

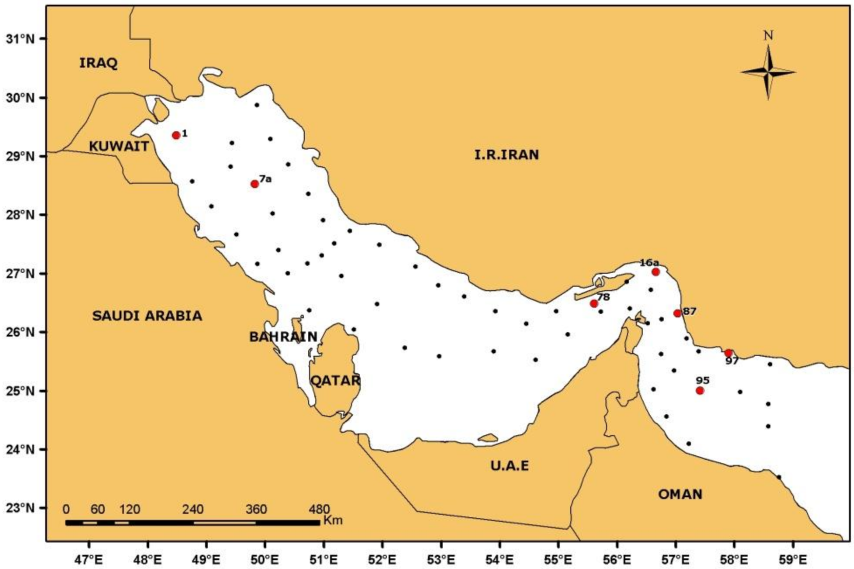
An1. antennules; An2. antenna; E. eye; O. ocellus; MN. median notch; T. telson; CF. caudal furca; i1-i7. 1st - 7th telson spines.

Geographical Distribution: Indo-West Pacific Region.

Sites of Occurrence in RSA:

Sea of Oman: Stations 16a, 87, 95 and 97.

Inner RSA: Stations 1, 7a and 78.



Sites of occurrence of *Penaeus semisulcatus*, protozoea I in RSA

Penaeus semisulcatus de Haan, 1850

Protozoea III (Figure 6 a-d)

References: Habib-ul-Hassan, 1982, Jackson *et al.*, 1989

Description: There is a pair of prominent supraorbital spines (SSp in Figure 6 b) and projecting rostrum (R in Figure 6 b). Presensce biramous uropods (Ur in Figure 6 a, d) and dorsomedian spines (DSp in Figure 6 d). There is one pair of lateral spines on the fifth and sixth abdominal segments (LSp in Figure 6 c, d). Caudal furca bears 8+8 spines (i1-i8 in Figure 6 d).

Measurements: Total length 2.3 mm; length of carapace 0.6 mm.

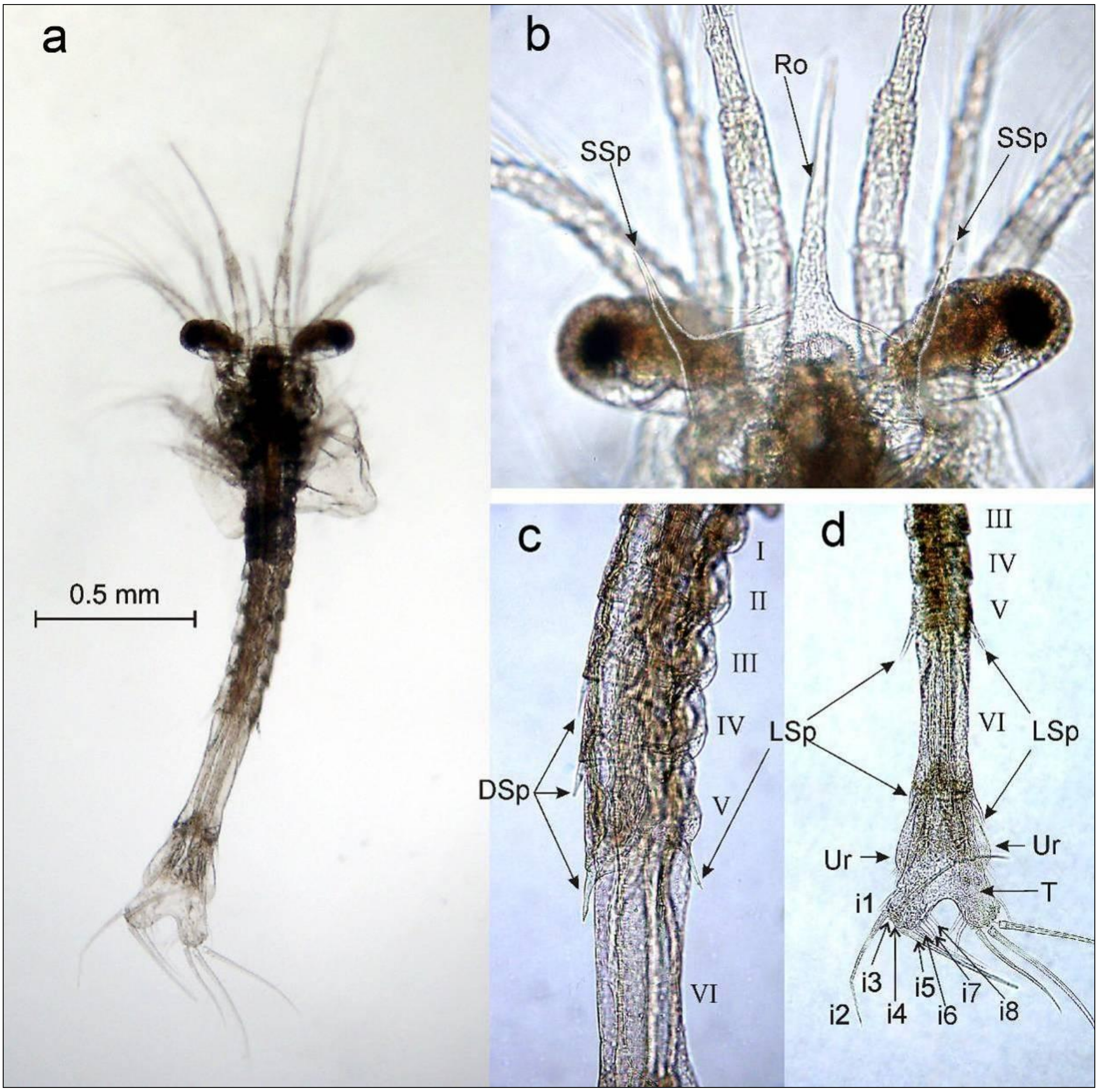


Figure 6. *Penaeus semisulcatus*, protozoea III. a. general dorsal view; b. dorsal view of frontal segments of carapace; c. dorsal view of abdomen; d. dorsal view of distal part of abdomen (III-VI abdominal segments) and telson.

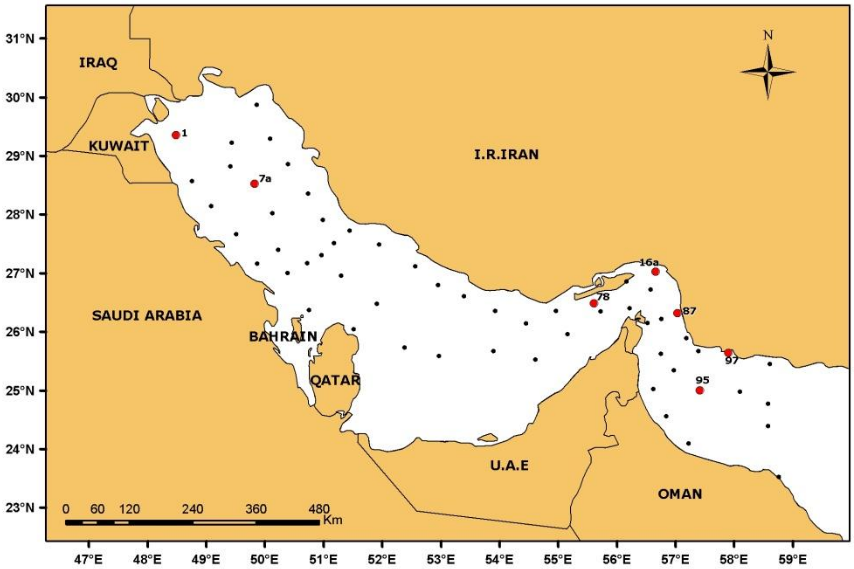
R. rostrum; SSp. supraorbital spines; LSp. lateral spines; DSp. dorsomedian spines; I-VI. abdominal segments; T. telson; Ur. biramous uropods; i1-i8. telson spines.

Geographical Distribution: Indo-West Pacific Region.

Sites of Occurrence in RSA:

Sea of Oman: Stations 16a, 87, 95 and 97.

Inner RSA: Stations 1, 7a and 78.



Sites of occurrence of *Penaeus semisulcatus*, protozoea III in RSA

Family Solenoceridae Wood-Mason, 1891

Genus *Solenocera* Lucas 1850

Solenocera crassicornis (Milne Edwards, 1837)

Protozoea III (Elaphocaris) (Figure 7)

Synonyms: *Penaeus crassicornis* Milne-Edwards, 1837; *Solenocera indicus* Nataraj, 1945; *Solenocera kuboi* Hall, 1956; *Solenocera sinensis* Yu, 1937; *Solenocera subnuda* Kubo, 1949.

References: Dos Santos and Lindley, 2001; Cheung, 1963; Farfante and Kensley, 1997.

Description: Carapace with spines and processes. Carapace margin serrate, spines robust (Figure 7). Margin of carapace fringed with 5 pairs of lappets, serrated between 1st and 2nd and between 3rd and 4th (Figure 7, Lap). Each abdominal tergum with one dorsal and pair of lateral spines (LSp). Telson (T) bifurcate posteriorly, each half with 7 setae (i1-i7).

Measurements: Total length 2.8 mm; length of carapace 1.1 mm.

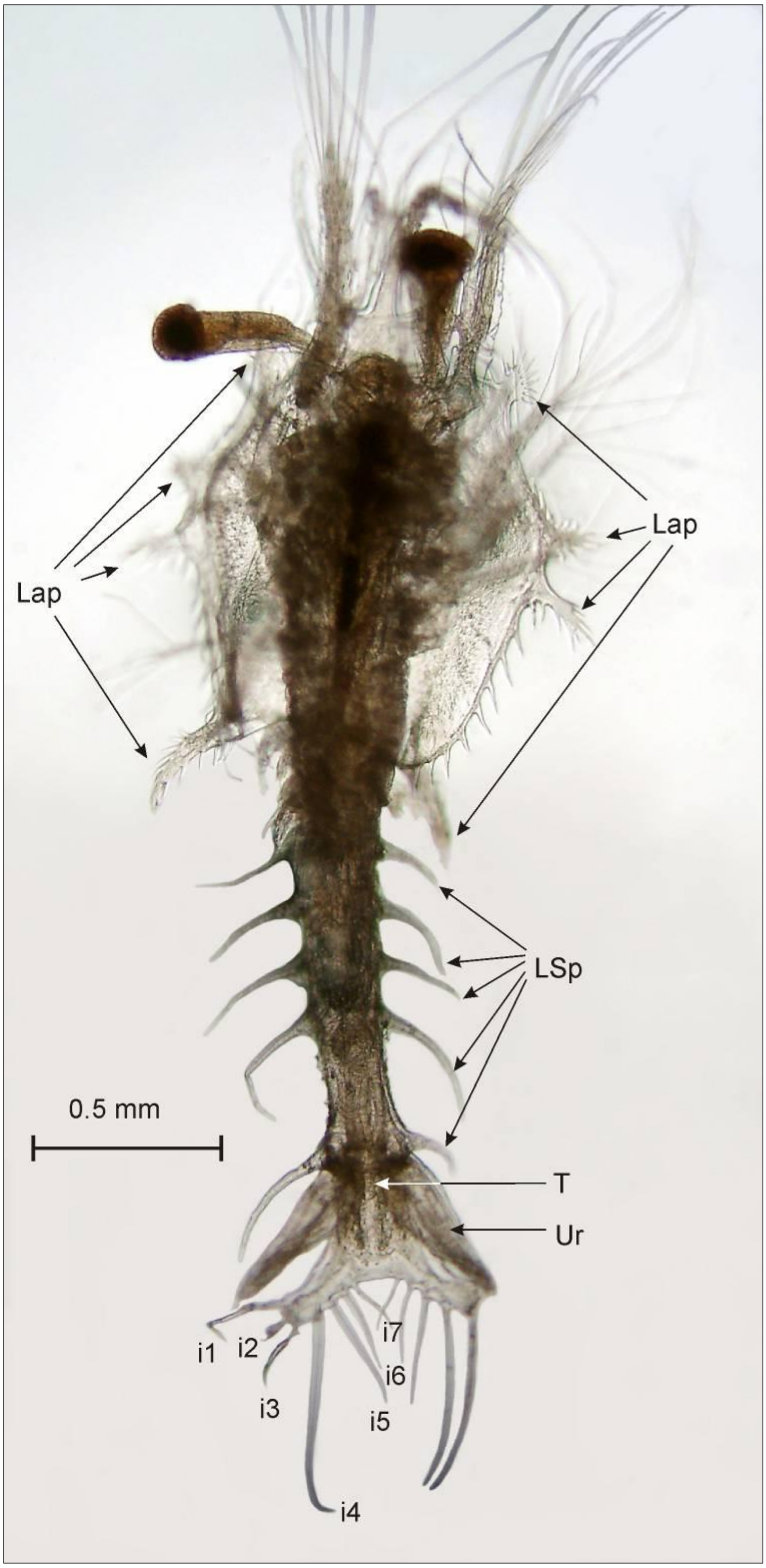


Figure 7. *Solenocera crassicornis*, protozoea III, dorsal view.

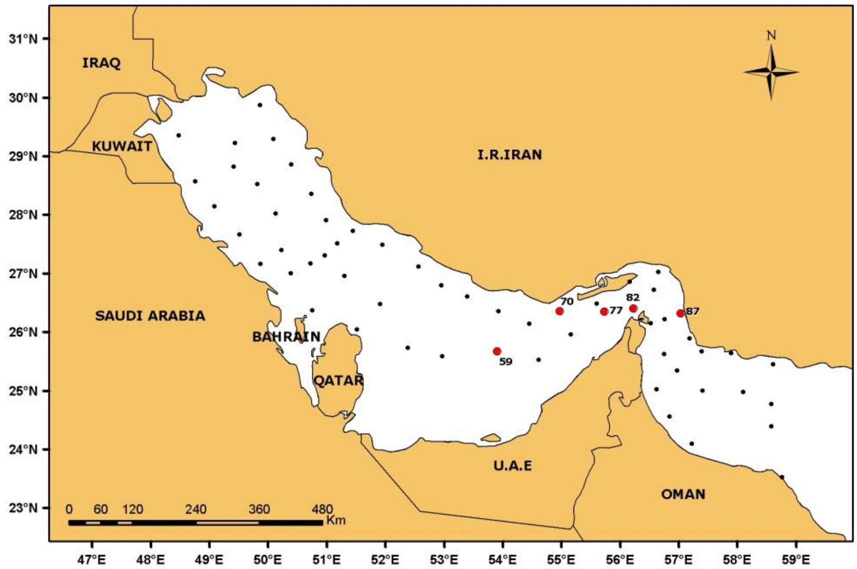
Lap. lappets; LSp. lateral abdominal spines; T. telson; Ur. uropods; i1 -i7. 1^{st}-7^{th} caudal setae.

Geographical Distribution: Inner RSA, along the northeast and east coasts of the Arabian Sea from Pakistan to south India and off Sri Lanka. Further east it extends as far as China, Japan and New Guinea.

Sites of Occurrence in RSA:

Sea of Oman: Station 87.

Inner RSA: Stations 59, 70, 77 and 82.



Sites of occurrence of *Solenocera crassicornis*, protozoea III in RSA

Solenocera crassicornis (Milne Edwards, 1837)

Mysis (Acanthosoma) (Figure 8 a-e)

References: Holthuis, 1980; Cheung, 1963.

Description: No spinules on surface of carapace (Figure 8 a, b), no lappets; small spines near serrated lateral margins; dorsal organ still present (DO in Figure 8 b); carapace fused with all thoracic tergites. Spines on abdominal terga as in protozoea, but lateral spines much smaller and 2nd dorsal spine largest (Figure 8 a). Telson deeply forked (Figure 8 d, e), 4 setae on each inner margin of each prong (i1 - i4 in Figure 8 d, e), pair of small spines on outer margins proximal to fork (i5 in Figure 8 e). Uropods well developed, numerous long setae on each margin of endopod and on inner margin of exopod (Ex Ur, End Ur in Figure 8 d). First 3 pereiopods with rudimentary chelae (Ch in Figure 8 c); all pereiopods with natatory exopods.

Measurements: Total length 5.9 mm; length of carapace 1.6 mm.

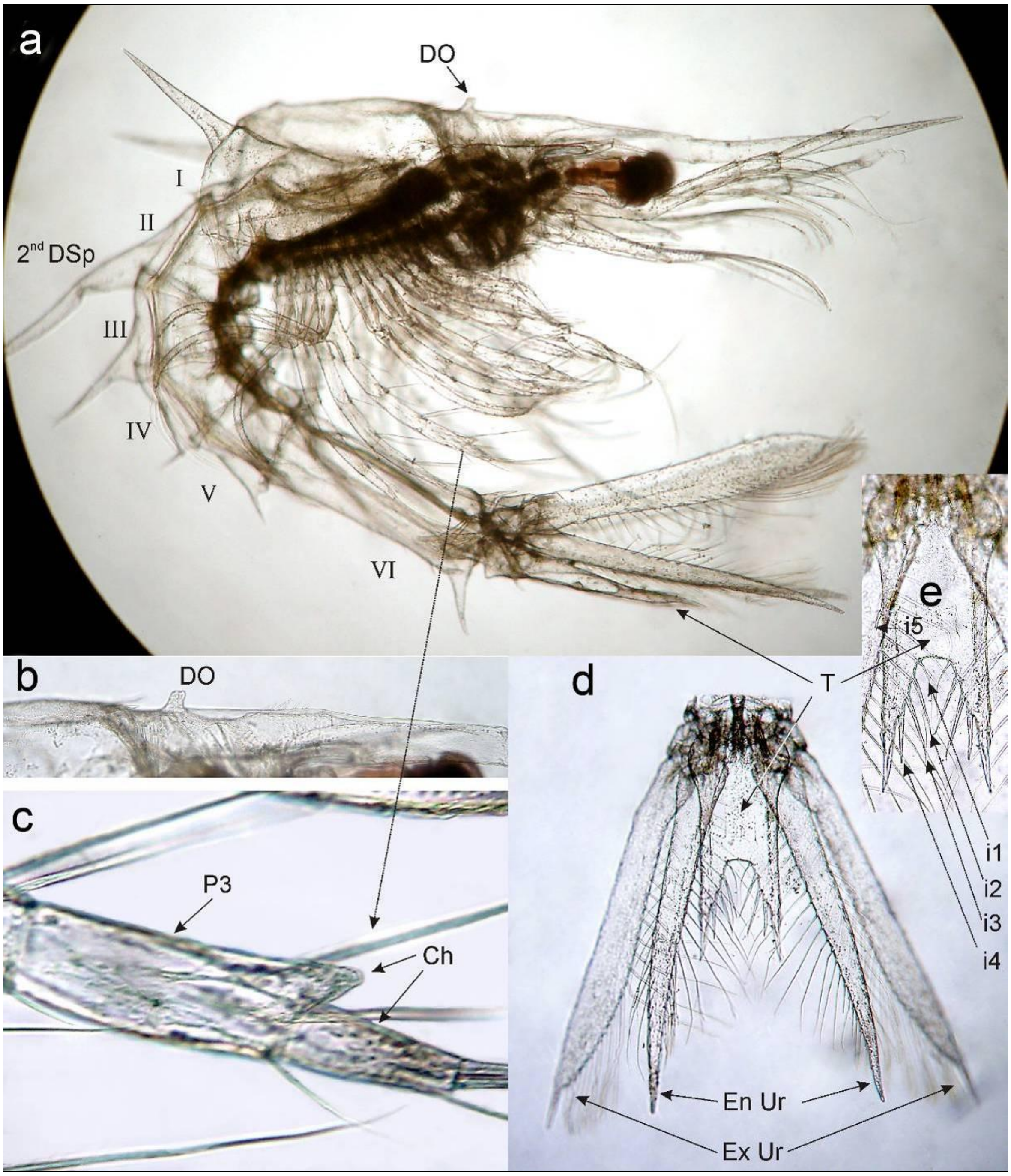


Figure 8. *Solenocera crassicornis*, mysis. a. lateral view; b. dorsal surface of carapace; c. distal part of 3rd pereopod; d. caudal fan; e. telson.

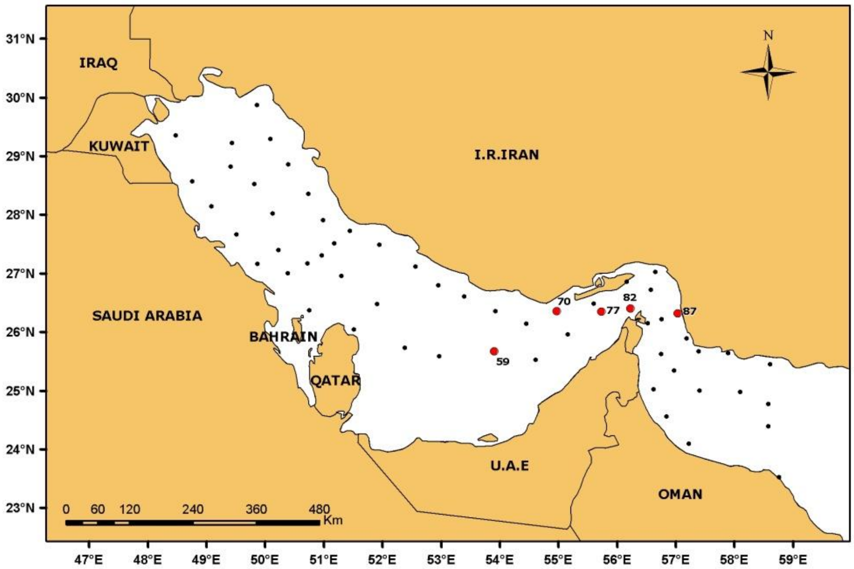
DO. dorsal organ; DSp. dorsal spines; I-VI. abdominal tergites; DO. dorsal organ; Ch. rudiment chelae; P3. 3rd pereopod; T. telson; Ex Ur. exopod of uropod; En Ur. endopod of uropod; i1-i4. inner setae; i5. outer setae.

Geographical Distribution: Inner RSA, along the northeast and east coasts of the Arabian Sea from Pakistan to south India and off Sri Lanka. Further east it extends as far as China, Japan and New Guinea.

Sites of Occurrence in RSA:

Sea of Oman: Station 87.

Inner RSA: Stations 59, 70, 77 and 82.



Sites of occurrence of *Solenocera crassicornis*, mysis in RSA

Family Solenoceridae Wood-Mason, 1891
Genus *Solenocera* Lucas 1850

Solenocera hextii Wood-Mason and Alcock, 1891.

Protozoea III (Elaphocaris) (Figure 9 a-b)

References: Dos Santos and Lindley, 2001; Cheung, 1963.

Description: Carapace with spines and processes (Figure 9 a). Carapace margin serrate, spines robust. Dorsal organ (on anterior median part of carapace) large (DO in Figure 9 a). Each abdominal tergum with one dorsal and pair of lateral spines (Figure 9 a). Telson bifurcate posteriorly, each half with 8 setae (i1 - i8 in Figure 9 b).

Measurements: Total length 2.6 mm; length of carapace 1.0 mm.

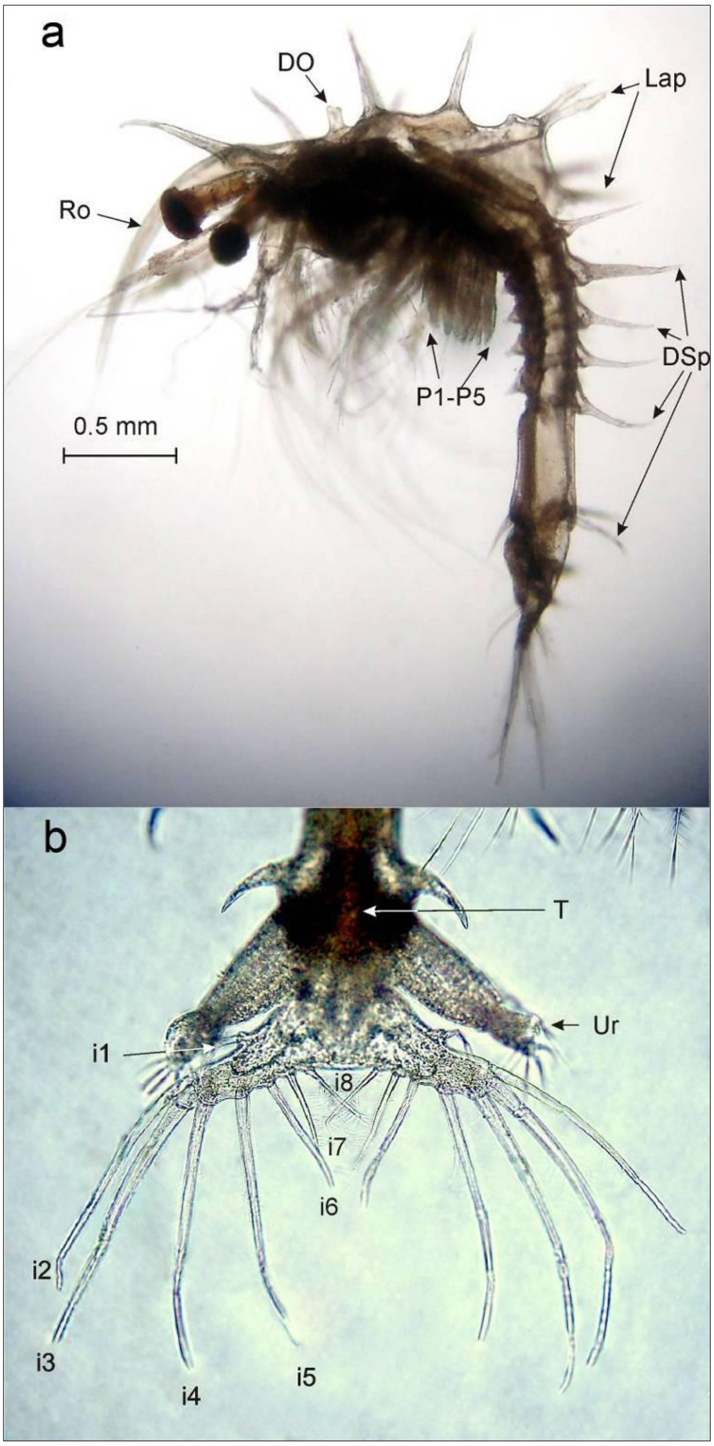
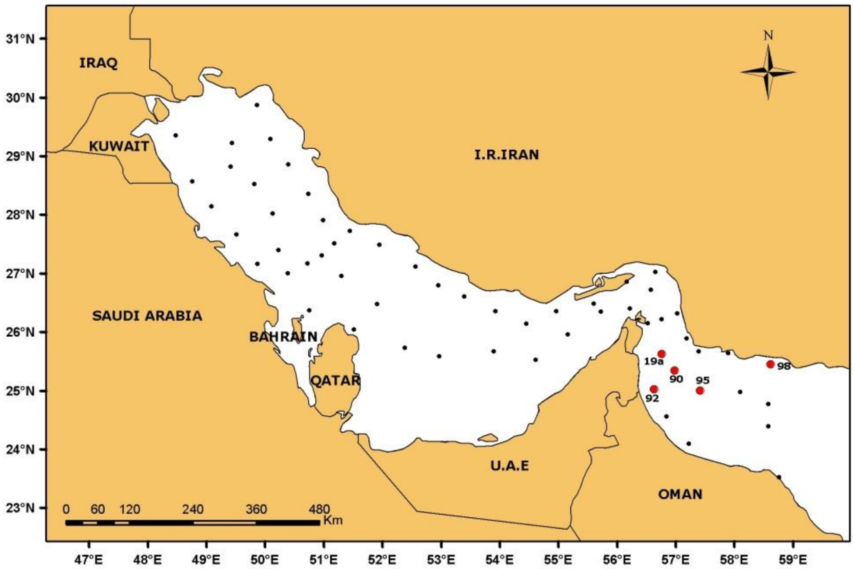


Figure 9. *Solenocera hextii*, protozoea III. a. lateral view; b. dorsal view of telson (T).

Ro. rostrum; DO. dorsal organ; Lap. lappets; DSp. dorsal abdominal spines; P1-P5. rudiments of thoracic legs (pereopods); Ur. uropod; i1-i8. 1^{st}-8^{th} caudal setae.

Geographical Distribution: *S. hextii* occurs in the Arabian Sea from the Gulf of Aden to the south coast of India. Found at depths between 115 and 500 m.

Sites of Occurrence in RSA: Sea of Oman: Stations 19a, 90, 92, 95 and 98.



Sites of occurrence of *Solenocera hextii*, protozoea III in RSA

Superfamily Sergestoidea Dana, 1852

Family Luciferidae de Haan, 1849

Genus *Lucifer* Thompson, 1829

Lucifer hanseni Nobili, 1905

Protozoea III (Figure 10 a-d)

References: Hashizume, 1999; Dos Santos and Lindley, 2001.

Description: Carapace posterior margin with 3 small spines (Sp in Figure 10 a, b). Both rudimentary eyestalks situated closely together (h in Figure 10 c). Third spine (i3) of telson about 3 times as long as 4th one (i4).

Measurements: Total length 0.98 mm; length of carapace 0.34 mm.

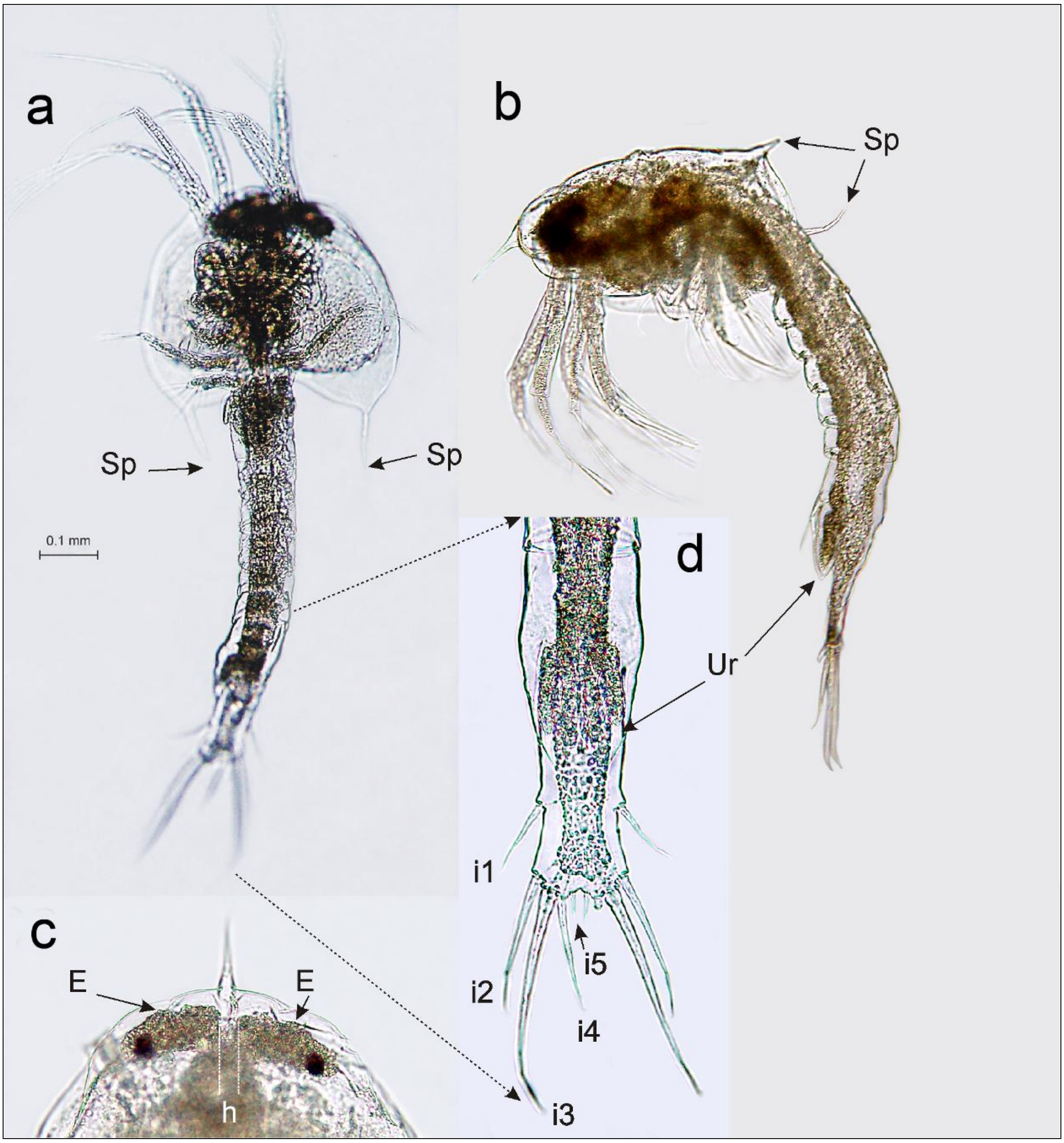


Figure 10. *Lucifer hanseni*, protozoea III. a. dorsal view; b. lateral view; c. frontal part of carapace (dorsal view); d. telson (dorsal view).

Sp. spines; Ur. uropod; E. eye; h. distance between rudimentary eyestalks; i1-i5. 1st - 5th spines of telson.

Geographical Distribution: Indo-West Pacific Region, from Madagascar to Australia, Red Sea.

Sites of Occurrence in RSA:

Sea of Oman: Stations 14a, 16a, 19a, 21a, 23a, 25a, 26a, 83, 85, 87, 88, 90, 92, 93, 97, 98, 99 and 100.

Inner RSA: Stations 1, 4, 8, 11, 14, 15, 17, 19, 20, 22, 23, 24, 26, 27, 30, 33, 34, 36, 39, 40, 43, 50, 55, 56, 59, 66, 69, 70, 72, 77, 78, 79, 82, 5a, 9a, 10a, and 11a.

Lucifer hanseni Nobili, 1905

Mysis I (Figure 11 a-d)

References: Hashizume, 1999; Dos Santos and Lindley, 2001.

Description: Carapace smooth, dorsomedian spines absent on abdominal somites 1-5, abdominal somites with ventral spines (Sp in Figure 11 a, b). Uropod with tooth (J) on lateral margin of exopod not reaching to posterior edge (K) of exopod (Figure 11 c). Second spine (i2) of telson about 2 times as long as the first one (i1) (Figure 11 d).

Measurements: Total length 2.15 mm; length of carapace 0.50 mm.

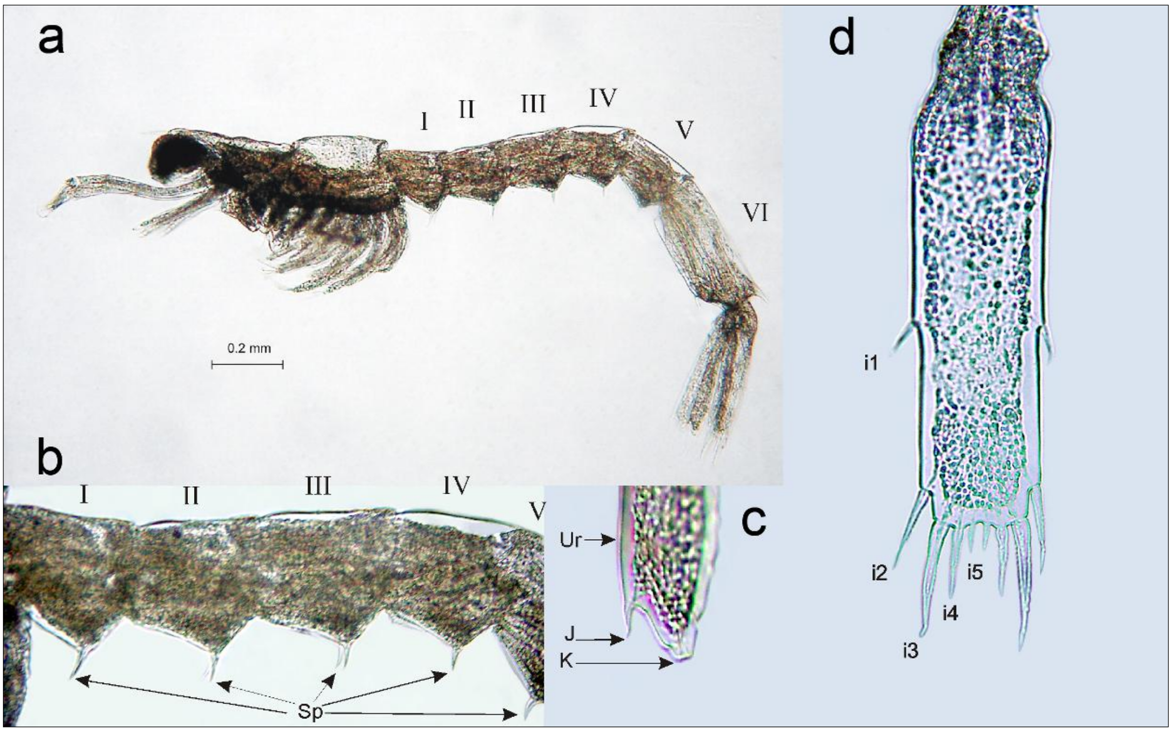
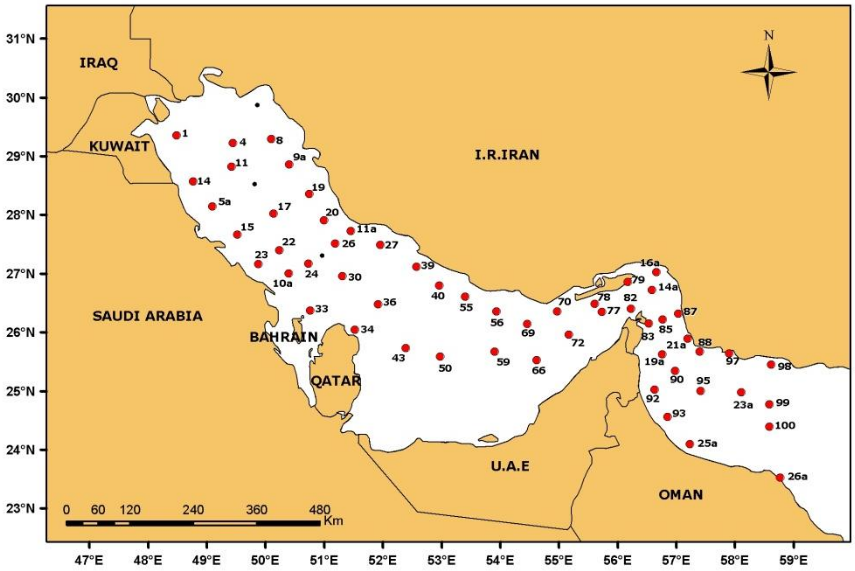


Figure 11. *Lucifer hanseni*, mysis I. a. general lateral view, b. abdomen, c. distal part of exopodal uropod, d. telson.

I-VI. abdominal somites; Sp. ventral spines; J. tooth on lateral margin of exopodal uropod; K. posterior edge of exopodal uropod; i1-i5. 1st-5th spines of telson.



Sites of occurrence of *Lucifer hanseni*, protozoea II and mysis I in RSA

Family Sergestidae Dana, 1852

Genus *Sergestes* H. Milne Edwards, 1830

***Sergestes* sp.**

Protozoea II (Elaphocaris) (Figure 12)

References: Dos Santos, Lindley, 2001; Illig, 1927; Karuppasamy *et al*., 2006.

Description: eyes stalked (E in Figure 12). Carapace with spines and processes. Carapace margin smooth, spines long and slender. Lateral and posterior processes with long lateral spines. Anterior, lateral and posterior carapace processes with numerous long lateral spines. Lateral lappets of carapace with 10 spines (Lap in Figure 12).

Measurements: Total length 1.20 mm; length of carapace 0.75 mm.

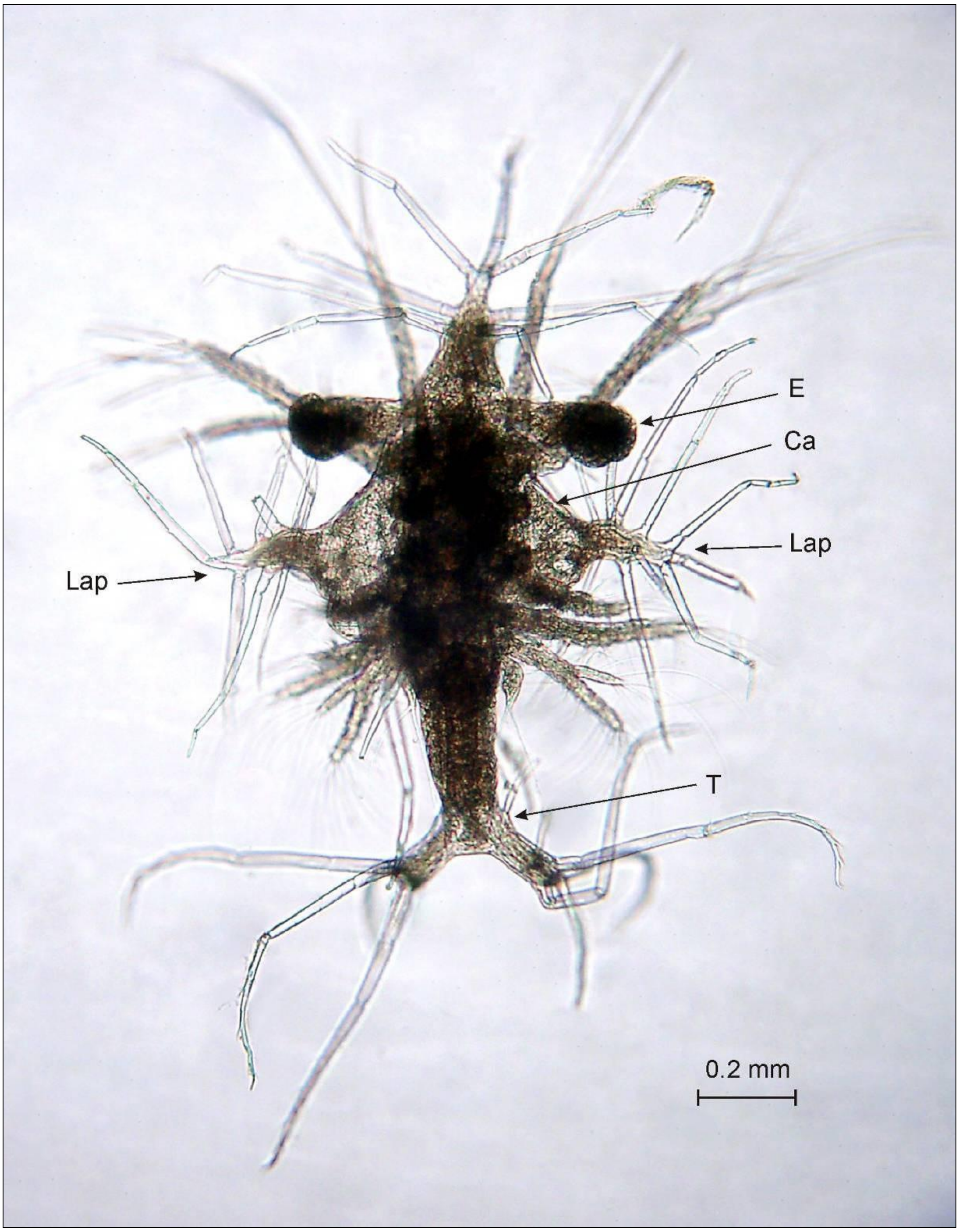


Figure 12. *Sergestes* sp. protozoea II.

E. eyes; Ca. carapace; Lap. lateral lappets; T. telson

Sites of Occurrence in RSA:

Sea of Oman: Stations 25a, 90, 93, 95, 99 and 100.

***Sergestes* sp.**

Mysis (Acanthosoma) (Figure 13 a-b)

References: Dos Santos, Lindley, 2001; Illig, 1927; Karuppasamy *et al*., 2006.

Carapace with many spines and processes (A, Lap, LSp in Figure 13 a). Carapace margin smooth, spines long and slender (A, Lap, LSp in Figure 13 a). Carapace without posterior dorsal spine (A, Ca in Figure 13 a), eye asymmetrical (A, E in Figure 13 a). Eyestalk equal width of eye (A, E in Figure 13 a).

Measurements: Total length 2.9 mm; length of carapace 0.8 mm.

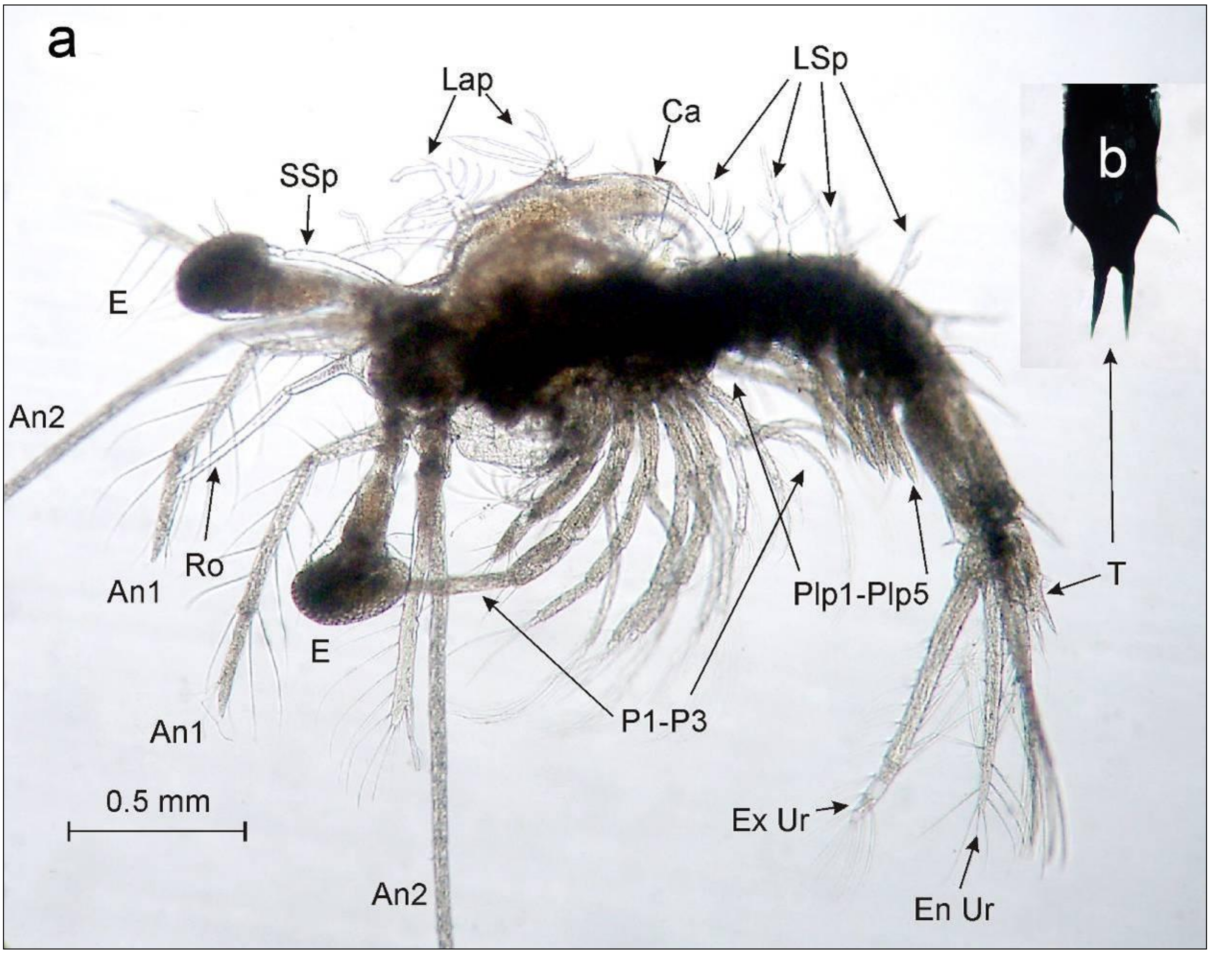
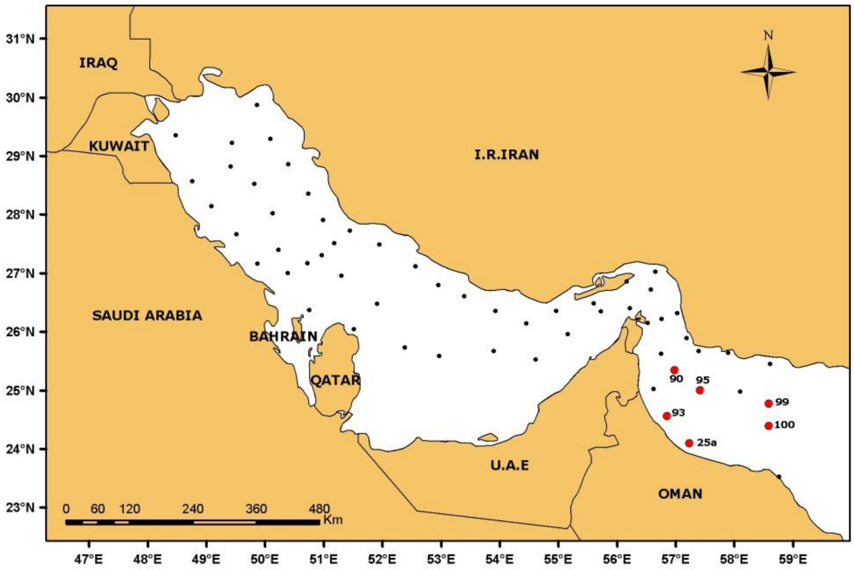


Figure 13. *Sergestes* sp., mysis (acanthosoma). a. lateral view; b. telson.

An1. antennule; An2. antenna; Ro. rostrum; SSp. supraorbital spine; E. eye; Lap. lappets; Ca. carapace; LSp. lateral spines; P1-P3. 1st - 3rd pereopods; Plp1 - Plp5. 1st - 5th pleopods; T. telson; Ex Ur. exopod of uropod; En Ur. endopod of uropod.



Sites of occurrence of *Sergestes* sp., protozoea II and mysis in RSA

Suborder Pleocyemata Burkenroad, 1963

Infraorder Stenopodidea Claus, 1872

Family Stenopodidae Claus, 1872

Genus *Stenopus* Latreille, 1819

***Stenopus* sp.**

Zoea I (Figure 14 a-d)

References: Gurney, 1936; Bourdillon-Casanova, 1960; Williamson, 1976.

Description: Body not covered with spicules; abdomen with one spine; postero-ventral carapace margins rounded (Figure 14 a, b); a median dorsal spine of somite 3 (DSp in Figure 14 c); no median ventral spine on somite 5 (V in Figure 14 c), no pleural spines on somites 1-6 (I-VI in Figure 14 c); no supraorbital spines; rostrum (Ro) longer than antennular peduncle (Figure 14 b); telson triangular with concave posterior margin (T in Figure 14 d), telson formula 3 + 3 (i1 – i3 in Figure 14 d).

Measurements: Total length 3.8 mm; length of carapace 0.6 mm.

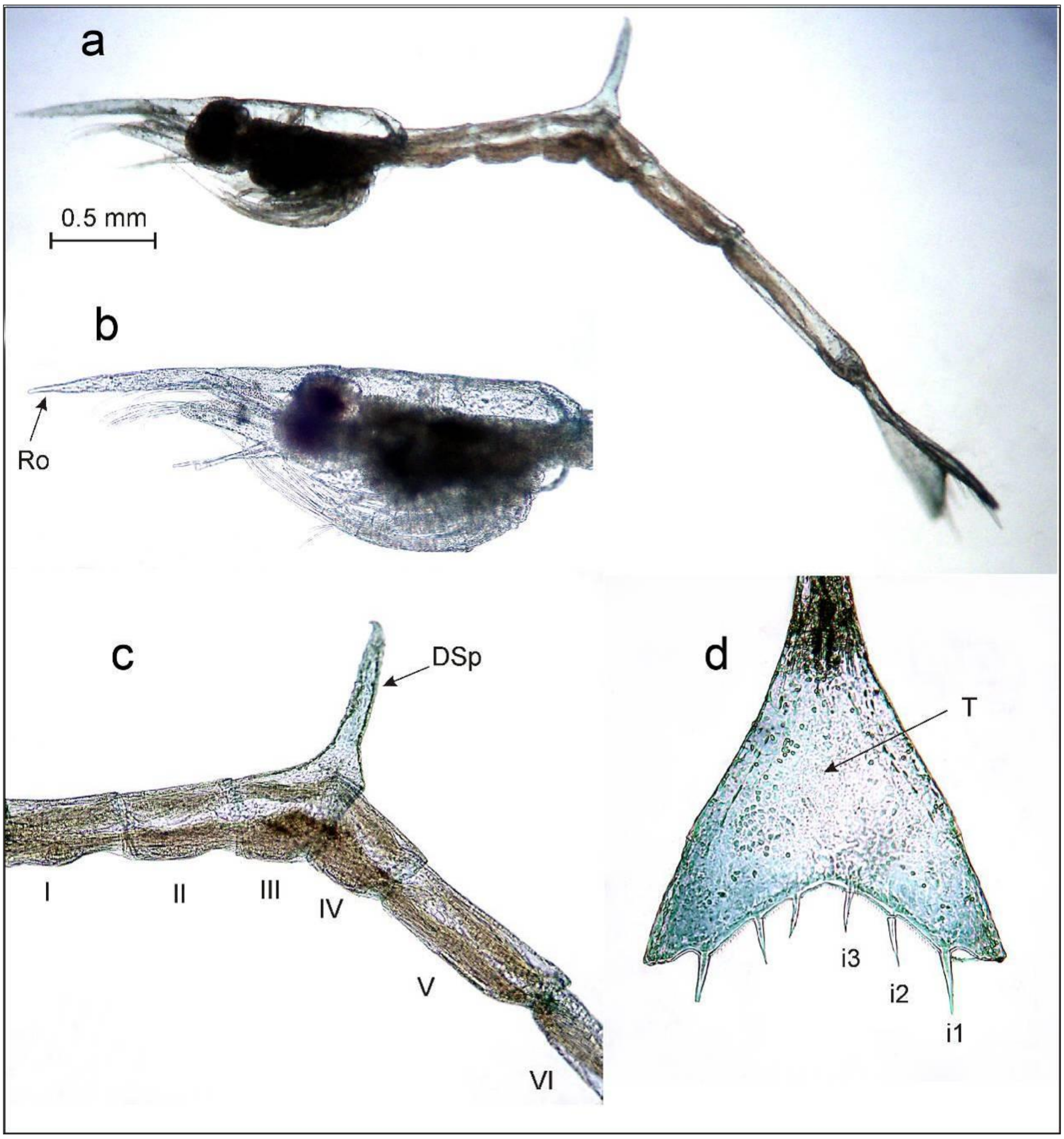
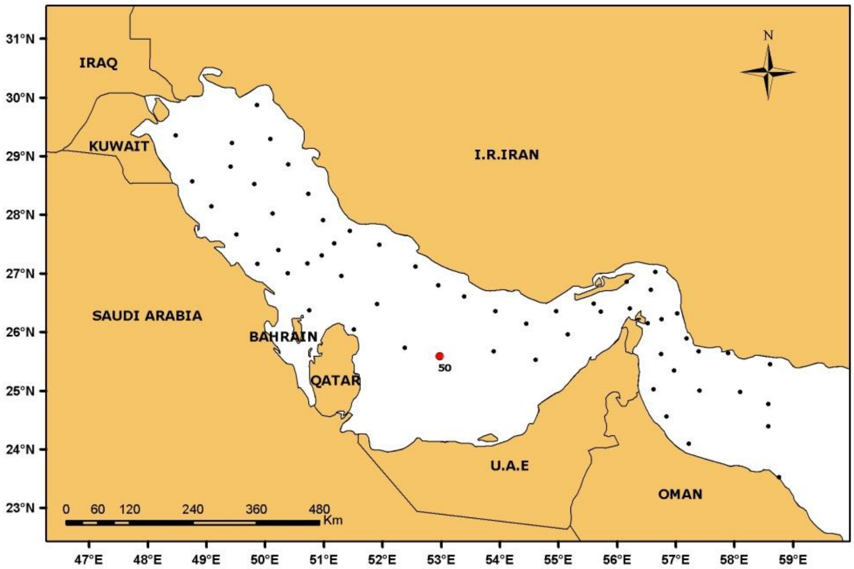


Figure 14. *Stenopus* sp., zoea I. a. lateral view; b. anterior part; c. posterior part; d. telson (T).

Ro. rostrum; DSp. dorsal spine; I – V. 1^{st} - 5^{th} abdominal somites; i1 - i3. 1^{st} - 3^{rd} spines.

Site of Occurrence in RSA: Inner RSA: Station 50.



Site of occurrence of *Stenopus* sp., zoea I in RSA

Infraorder Caridea Dana, 1852

Family Thalassocarididae Bate, 1888

Genus *Thalassocaris* Stimpson, 1860

Thalassocaris obscura Menon and Williamson, 1971

Zoea XI (Figure 15 a-b)

Reference: Menon and Williamson. 1971

Description: Larvae of *T. obscura* are most easily distinguished from those of the other two species by the comparatively narrow antennal scale (An2 in Figure 15 b).

Measurements: Total length 6.4 mm; length of carapace 1.9 mm.

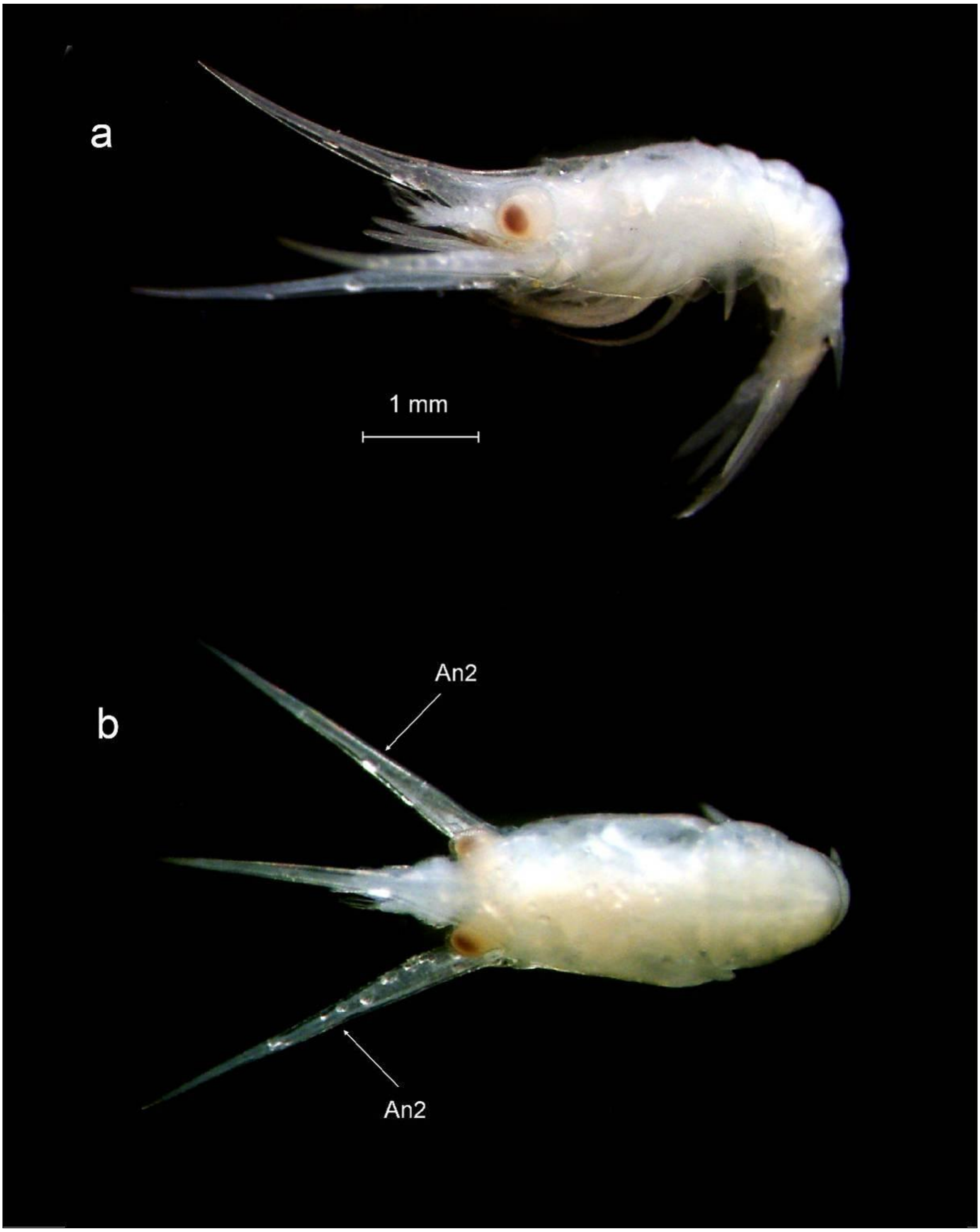
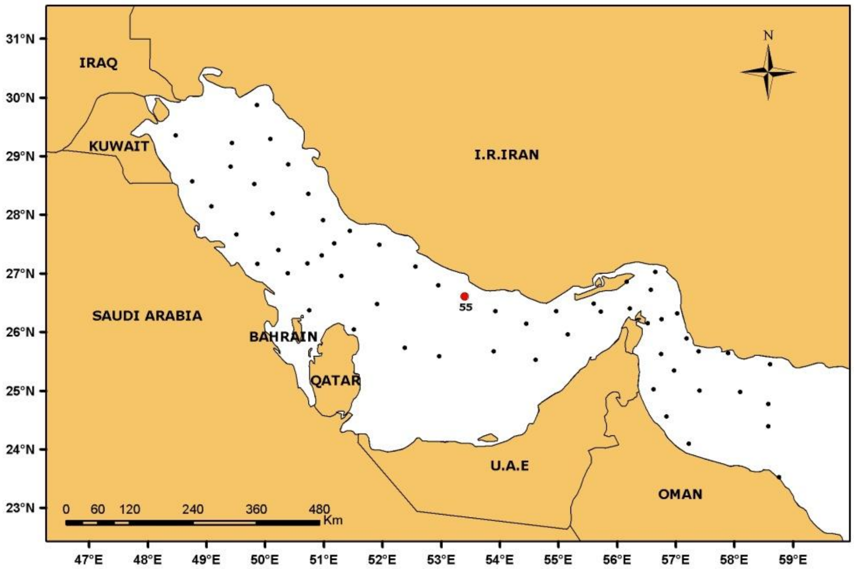


Figure 15. *Thalassocaris obscura*, zoea XI. a. lateral view; b. dorsal view.

An2. antennal scale.

Geographical Distribution: Indian Ocean.

Site of Occurrence in RSA: Inner RSA: Station 55.



Site of occurrence of *Thalassocaris obscura*, zoea XI in RSA

Family Oplophoridae, Dana, 1852

Genus *Acanthephyra* A. Milne Edwards, 1881

***Acanthephyra* sp.**

Zoea IV (Figure 16 a-b)

References: Williamson, 1957a; Williamson, 1962.

Description: Abdominal somite. 3 of zoeal stages with conspicuous fat-filled hump (H in Figure 16 a) rounded in lateral view but forming a dorsal carina. Cornea of eye wider than stalk in zoeal stages (E in Figure 16 a). Rostrum with a few dorsal teeth in late zoeal stages (Ro in Figure 16 a). Pair of lateral spines on posterior margin of abdominal somite 5 from stage II or III. Number of telson processes 6 + 6 (T, i1 - i6 in Figure 16 b).

Measurements: Total length 3.4 mm; length of carapace 0.6 mm.

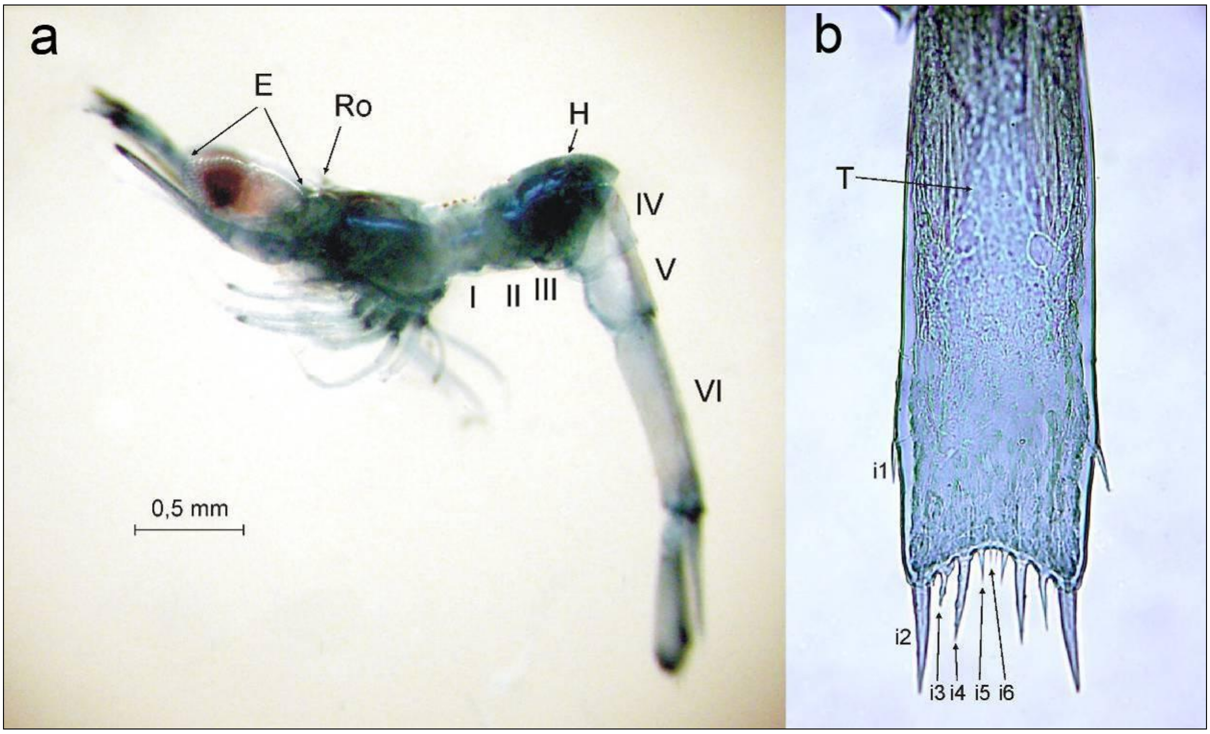
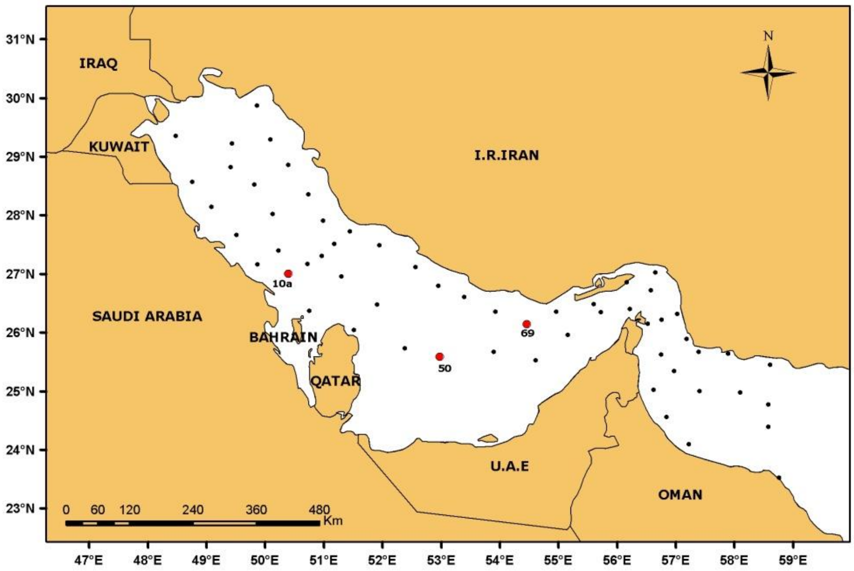


Figure 16. *Acanthephyra* sp., zoea IV. a. lateral view, b. telson (T).

E. eyes; Ro. rostrum; H. hump; I – VI. abdominal somites; i1 - i6. 1st - 6th - telson spines.

Sites of Occurrence in RSA:

Inner RSA: Stations 10a, 50 and 69.



Sites of occurrence of *Acanthephyra* sp., zoea IV in RSA

Family Palaemonidae Rafinesque, 1815

Genus *Palaemon* Weber, 1795

***Palaemon* sp.**

Zoea IV (Figure 17 a, b)

References: Williamson, 1957a; Fincham, Williamson, 1978; Shy *et al.*, 2005.

Description: Carapace with 1 -3 dorsomedian teeth on the anterior part (DT in Figure 17 a, b). Dactylus of fifth pereiopod armed by four curved spines (D, 1-4 in Figure 17 c).

Measurements: Total length 4.0 mm; length of carapace 0.6 mm.

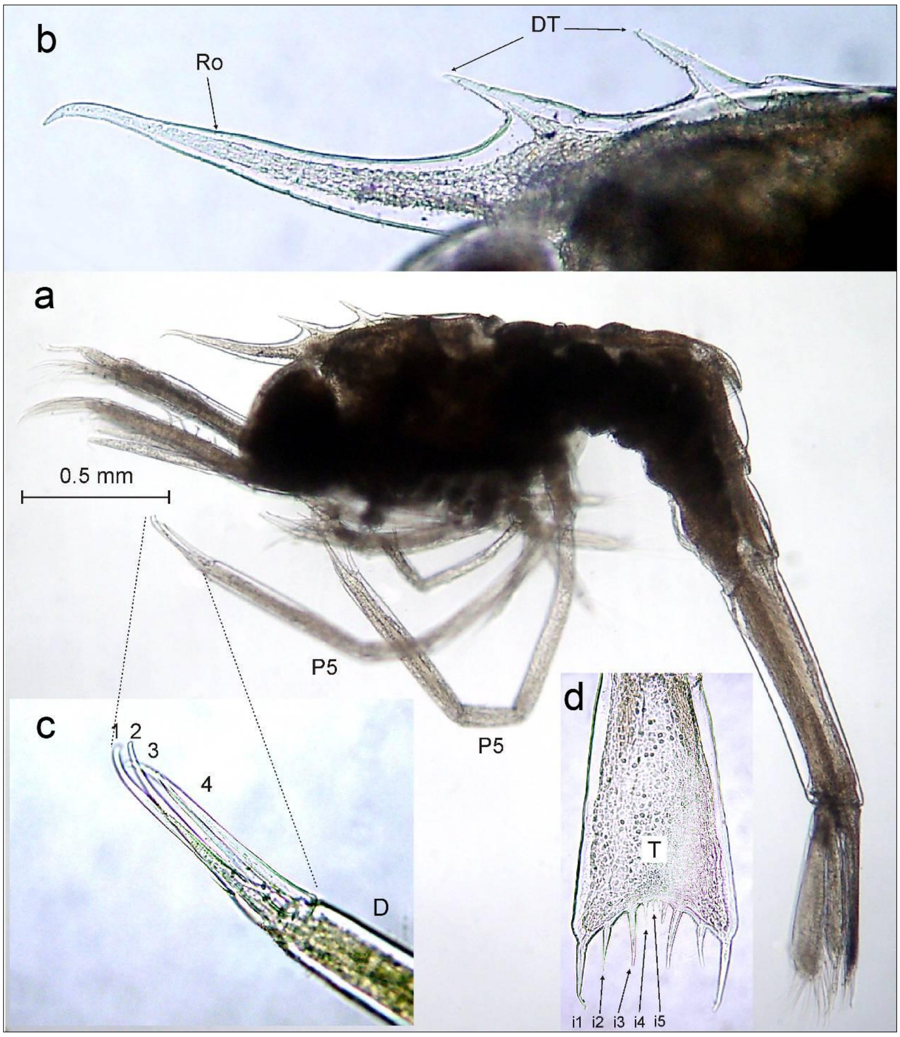


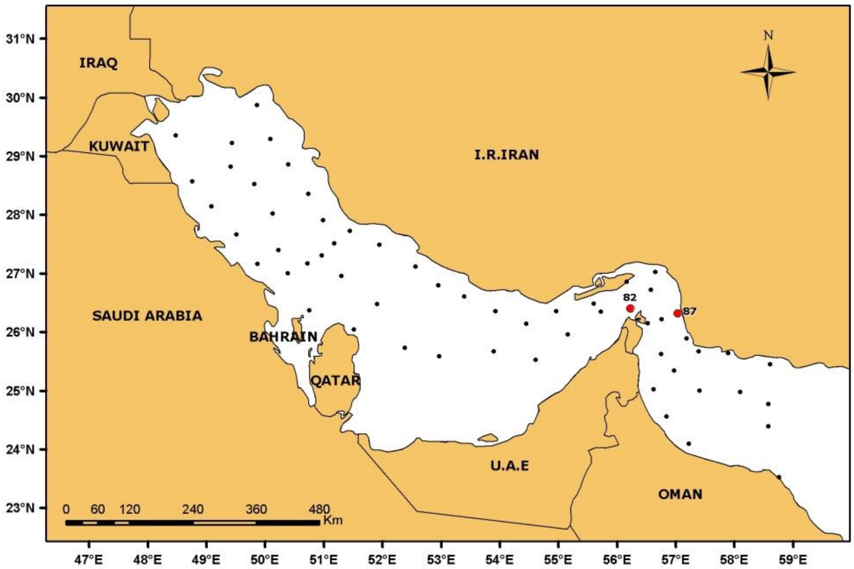
Figure 17. *Palaemon* sp., zoea IV. a. lateral view, b. anterior part of carapace; c. distalmost part of 5th pereopod; d. teson (T).

P5. fifth pereopod; Ro. rostrum; DT. dorsomedian teeth; D. dactylus, 1-4. spines of 5th pereopod; i1 - i4. 1st - 4th telson spines.

Sites of Occurrence in RSA:

Sea of Oman: Station 87.

Strait of Hormuz: Station 82.



Sites of occurrence of *Palaemon* sp., zoea IV in RSA

Family Palaemonidae Rafinesque, 1815

Subfamily Pontoniinae Kingsley, 1878

Genus *Periclimenes* Costa, 1844

***Periclimenes* sp.**

Zoea IV (Figure 18 a-d)

References: Williamson,1957a; Fincham and Williamson, 1978; Wear, 1976.

Description: Body with double bend (mesocaris form), acutely angled or “humped” (Figure 18 a, b). Rostrum short (Ro in Figure 18 b, c). Carapace with supraorbital spines only (SSp in Figure 18 c).

Measurements: Total length 2.7 mm; length of carapace 0.4 mm.

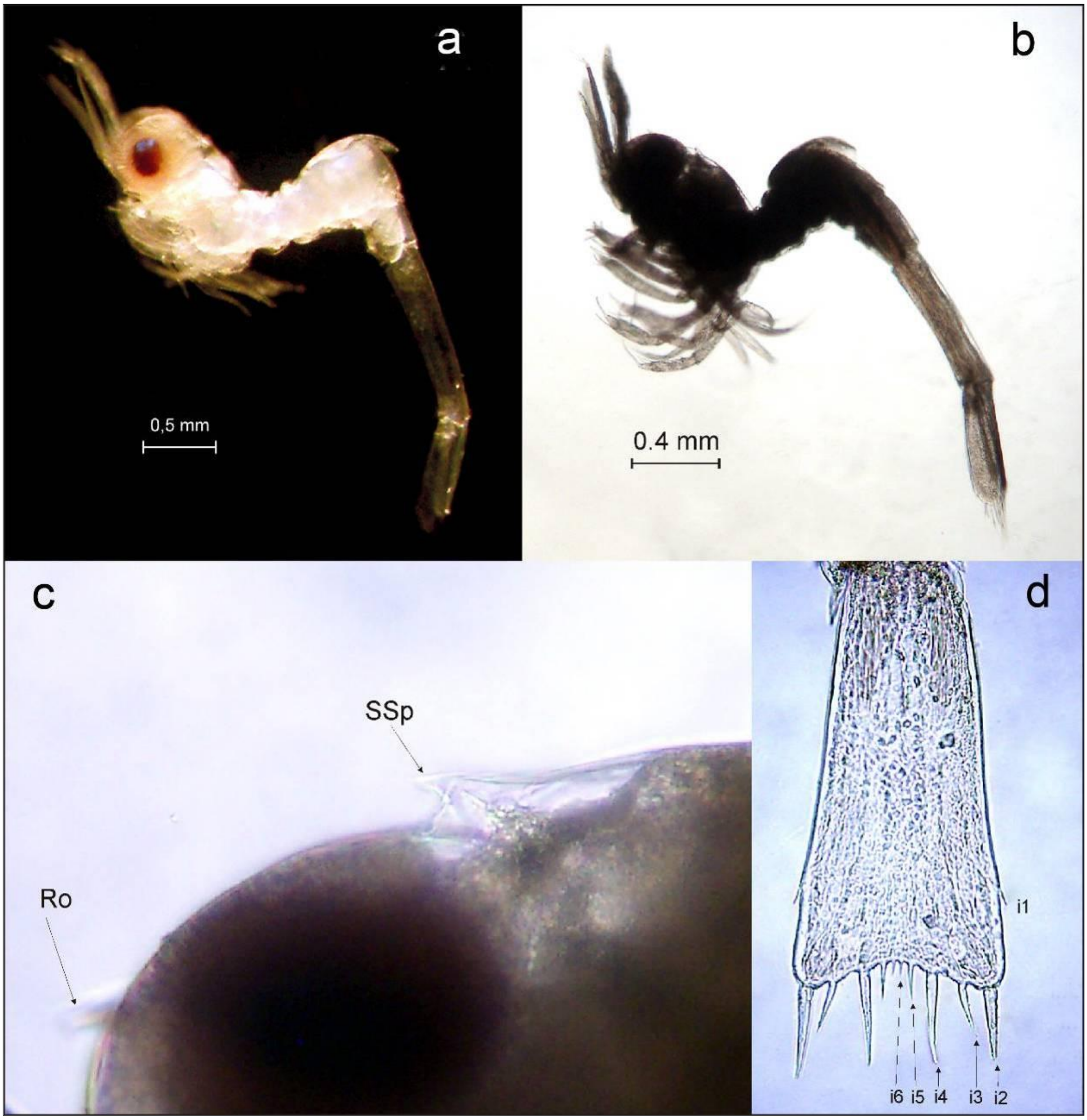


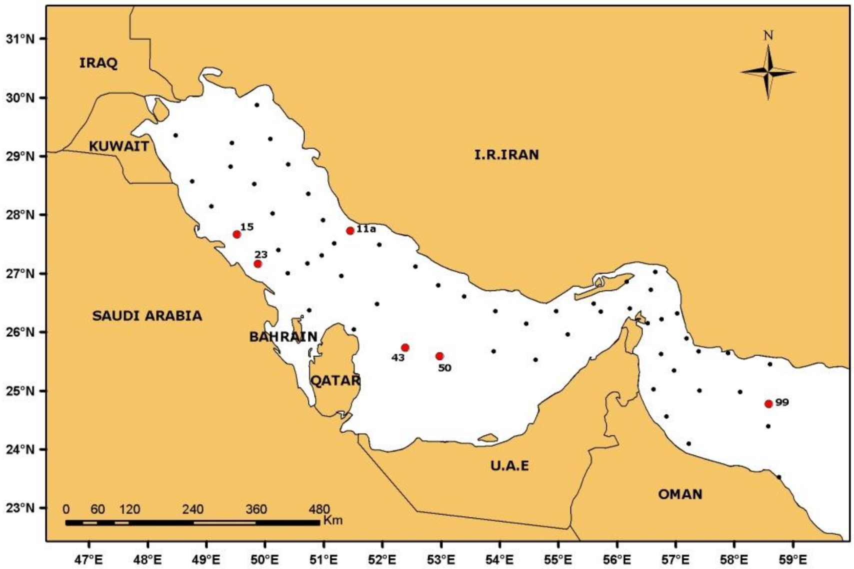
Figure 18. *Periclimenes* sp., zoea IV. a, b. lateral view; c. anterior part of carapace; d. telson.

Ro. rostrum; SSp. supra-orbital spine; i1 - i6 - 1st - 6th telson spines.

Sites of Occurrence in RSA:

Sea of Oman: Station 99.

Inner RSA: Stations 11a, 15, 23, 43 and 50.



Sites of occurrence of *Periclimenes* sp., zoea IV in RSA

Family Alpheidae Rafinesque, 1815

Genus *Alpheus* Fabricius, 1798

***Alpheus* sp.**

Zoea IV (Figure 19 a-c)

References: Dos Santos, Gonzales-Cordillo, 2004; Williamson, 1967

Description: Eyes stalked, rounded. Leg 5 uniramous and much longer than leg 4. Leg 5 reaching anterior part of carapace (P5 in Figure 19 a, b). Telson widest in anterior half (T in Figure 19 c). Telson with 4 + 4 setae (i1 - i4 in Figure 19 c).

Measurements: Total length 3.5-3.7 mm; length of carapace 0.8-0.9 mm.

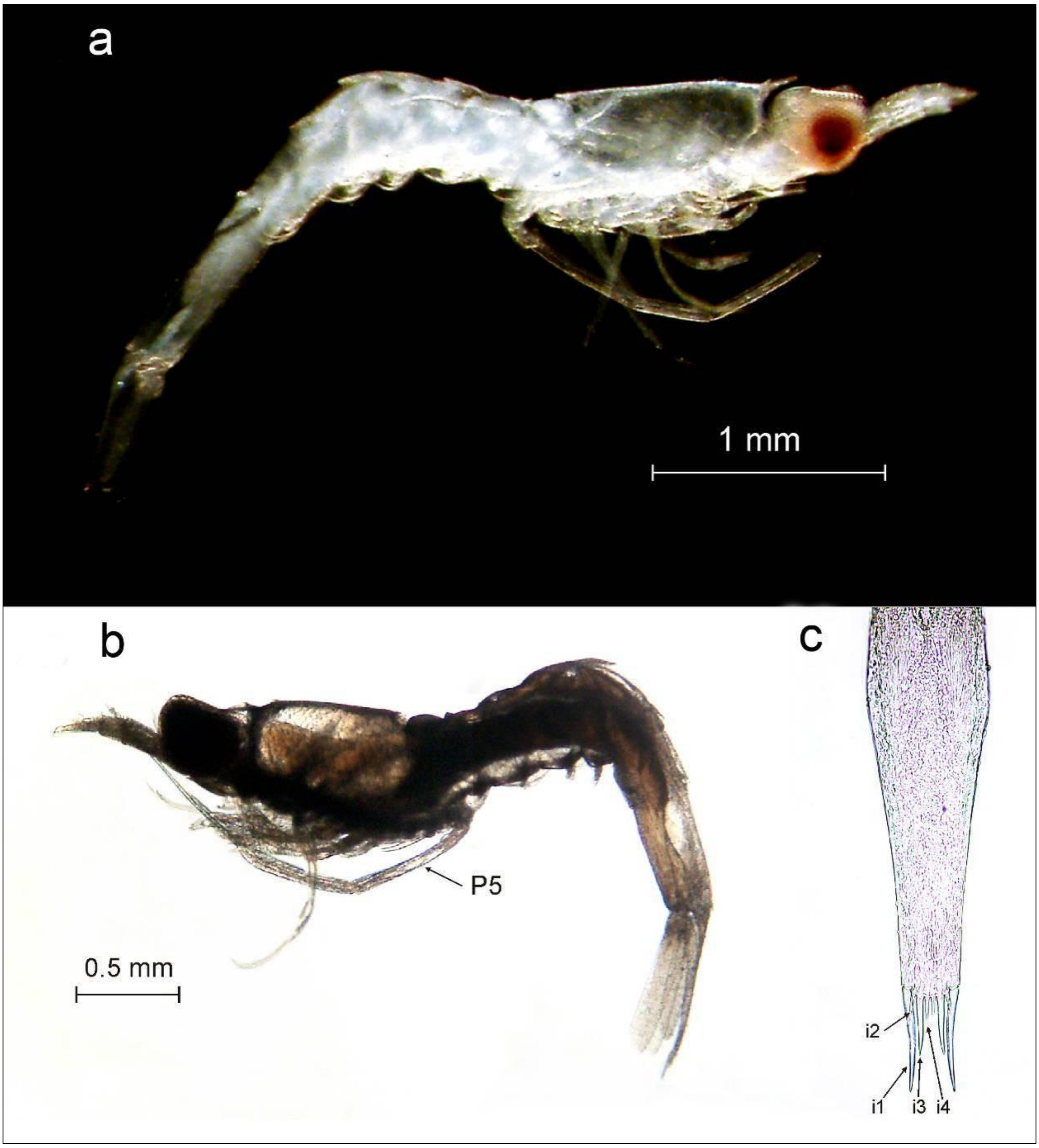


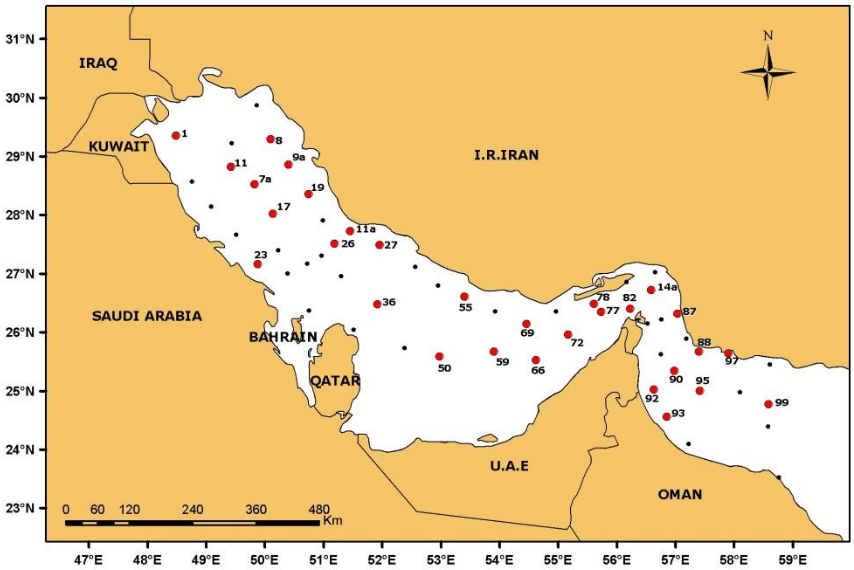
Figure 19. *Alpheus* sp., zoea IV. a, b. lateral view; c. telson.

i1 - i4. 1st - 4th telson spines.

Sites of Occurrence in RSA:

Sea of Oman: Stations 14a, 87, 88, 90, 92, 93, 95, 97 and 99.

Inner RSA: Stations 1, 7a, 8, 9a, 11, 11a, 17, 19, 23, 26, 27, 36, 50, 55, 59, 66, 69, 72, 77, 78 and 82.



Sites of occurrence of *Alpheus* sp., zoea IV in RSA

Family Hippolytidae, Dana, 1852

Genus *Latreutes* Stimpson, 1860

***Latreutes* sp.**

Zoea IX (Figure 20 a-e)

References: Williamson,1957a; Williamson, 1957b; Yang, 2005; 2007.

Description: Eye-stalks cylindrical (Figure 20 a). Telson flat without a median spine (Figure 20 e). Rostrum prominent, slender, and tapering in early stages, deep and most oblong in later stages (Figure 20 c); carapace with anterior and posterior dorsomedian papillae (DP in Figure 20 b); ventral margin of carapace with anterior, middle, and posterior denticles in first zoea and series of anterior and strong posterior denticles in late zoea (Figure 20 d).

Measurements: Total length 4.0 mm; length of carapace 0.8 mm.

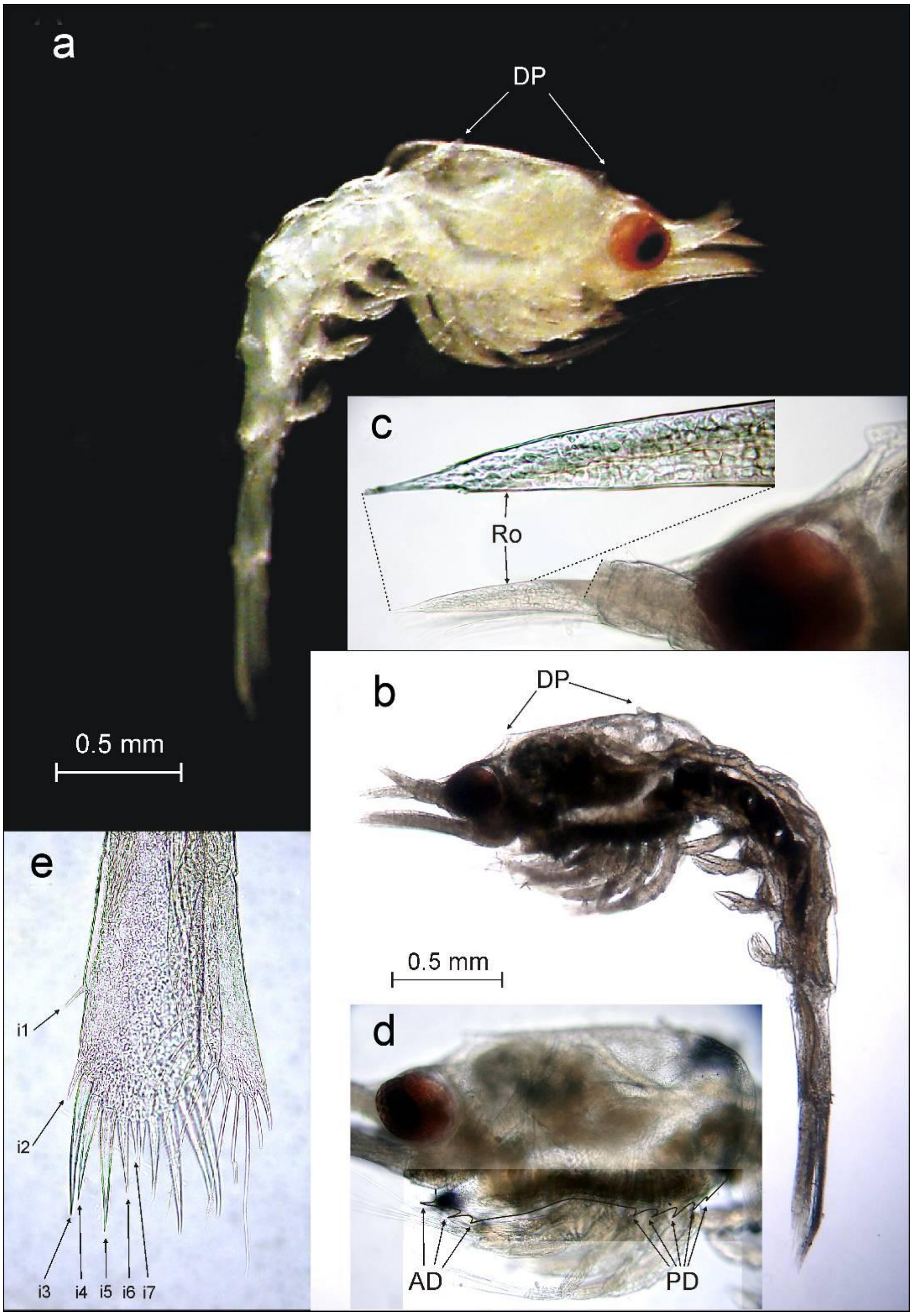
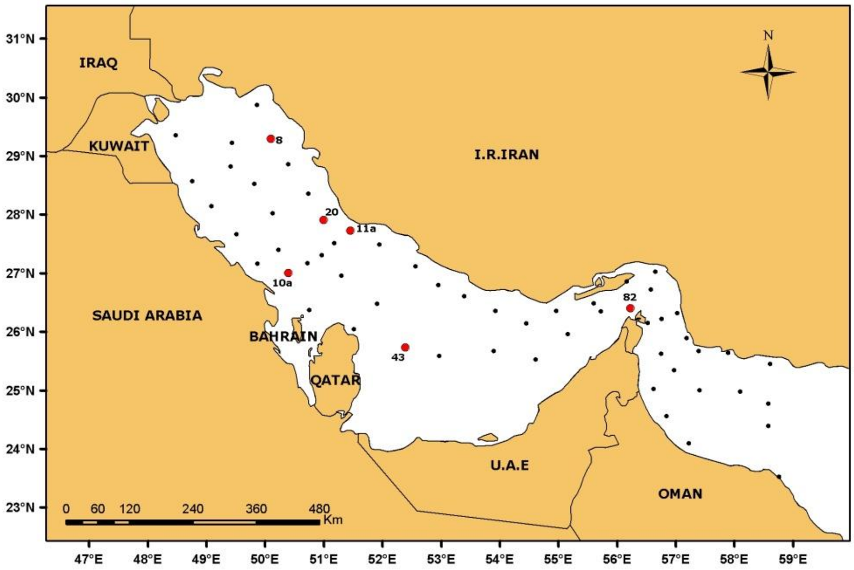


Figure 20. *Latreutes* sp., zoea IX. a, b. lateral view; c. anterior part; d. carapace; e. telson.

DP. dorsomedian papillae; Ro. rostrum; AD. anterior denticles, PD. posterior denticles; i1 - i7. 1st - 7th telson spines.

Sites of Occurrence in RSA: Inner RSA: Stations 8, 10a, 11a, 20, 43 and 82.



Sites of occurrence of *Latreutes* sp., zoea IV in RSA

Family Hippolytidae, Dana, 1852

Genus *Lysmata* Stimpson, 1866

***Lysmata* sp.**

Zoea IV (Figure 21 a-h)

References: Williamson, 1957a; Williamson, 1957b.

Description: Eye-stalk very long (F, E in Figure 21 a).

Measurements: Total length 4.0-7.5 mm; length of carapace 0.6-1.3 mm.

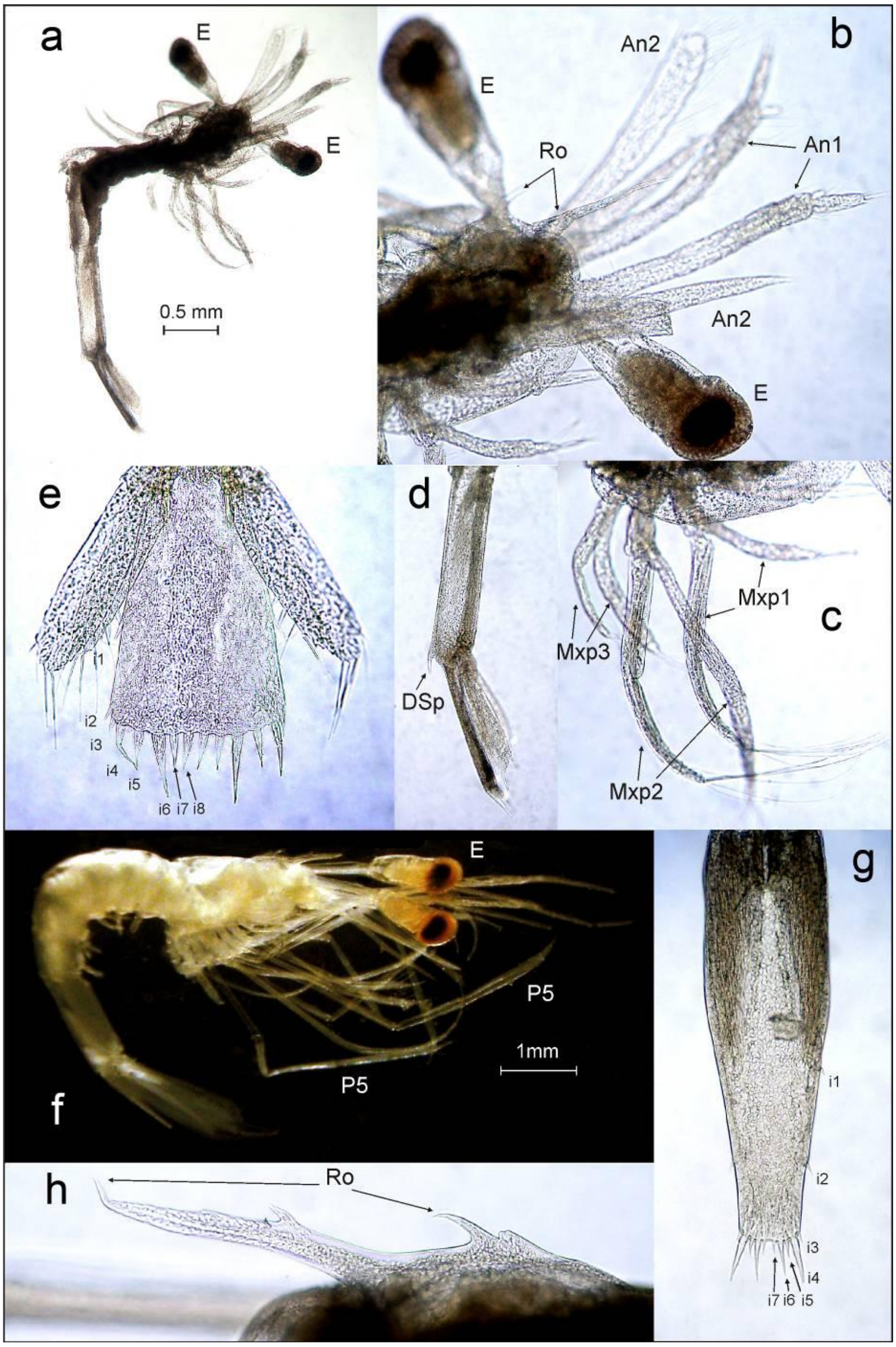
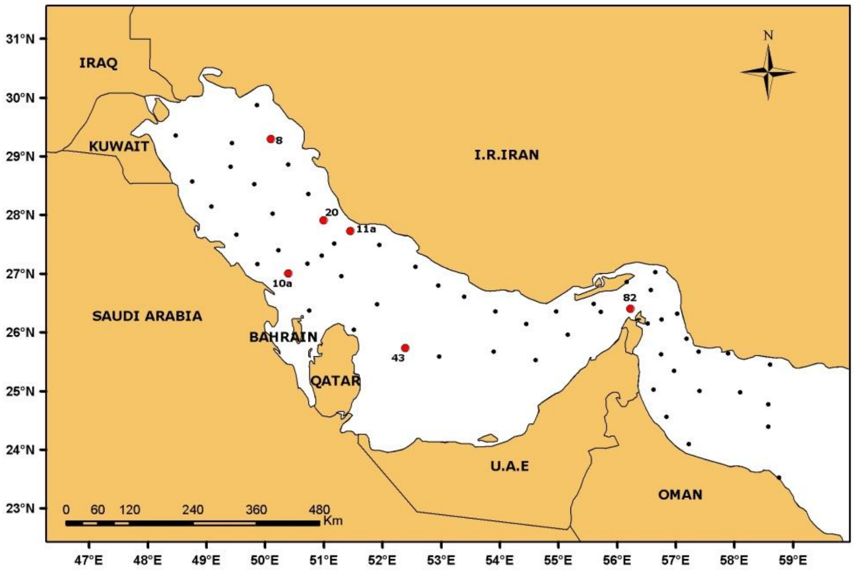


Figure 21. *Lysmata* sp., zoea IV. a, f. lateral view; b. anterior part; c. ventral part of carapace and maxillipeds; d. distal part of abdomen and telson; e. telson; g. anterior part; h. rostrum.

E. eyes; An1. antennule, An2. antenna; Ro. rostrum; Dsp. dorsal spine; E. telson; i1-i8. 1st-8th telson spines; P5. 5th pereopod; Ro. rostrum; Mxp1-3. maxillipeds.

Sites of Occurrence in RSA: Inner RSA: Stations 8, 10a, 11a, 20, 43 and 82.



Sites of occurrence of *Lysmata* sp., zoea IV in RSA

Infraorder Thalassinidea Latreille, 1831

Family Callianassidae Dana, 1852

Genus *Callianassa* Leach, 1814

***Callianassa* spp.**

Zoea I (Figure 22 a-e)

References: Gurney, 1938; Sandifer, 1973.

Description: Anterolateral carapace margin toothed (Figure 22 a). Rostrum narrow, pointed (Figure 22 a, b, c, d). Eyes sessile (Figure 22 a, b). Abdomen (Figure 22 a, b) of 5 somites; 6th somite fused with telson (Figure 22 a, b, e). Somite 2 with very large dorsal spine overlapping all of somite 3 (DSp in Figure 22 a, b); somites 3 to 5 with small medial spines on posterodorsal border (MSp in Figure 22 a, b). Telson (Figure 22 e) triangular with 7 + 1 + 7 terminal processes (i1-i7 in Figure 22 e); unpaired medial spine large and unarticulated (USp in Figure 22 e); 2nd processes hair-like (i2 in Figure 22 e).

Measurements: Total length 3.20-3.25 mm; length of carapace 0.6 mm.

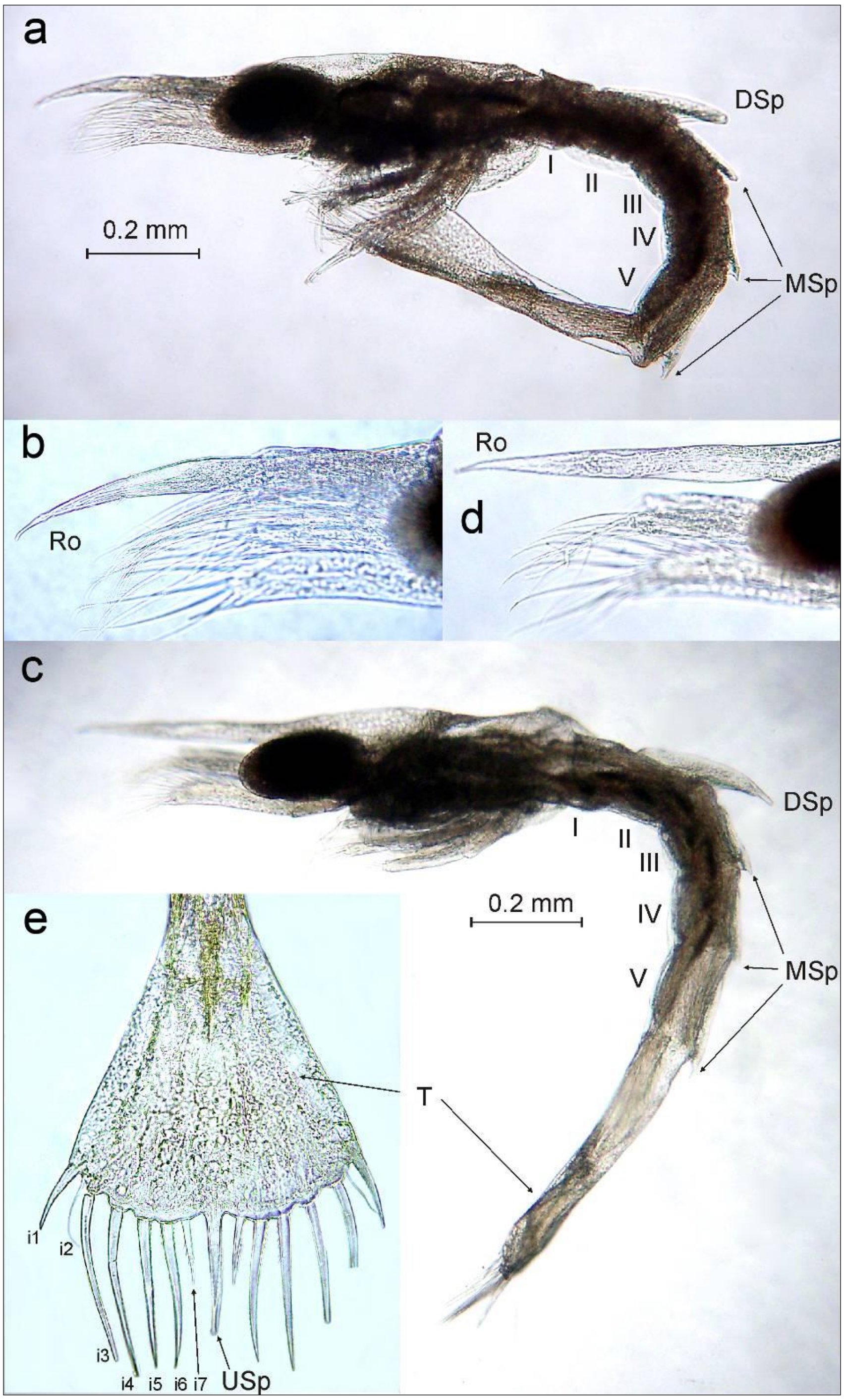
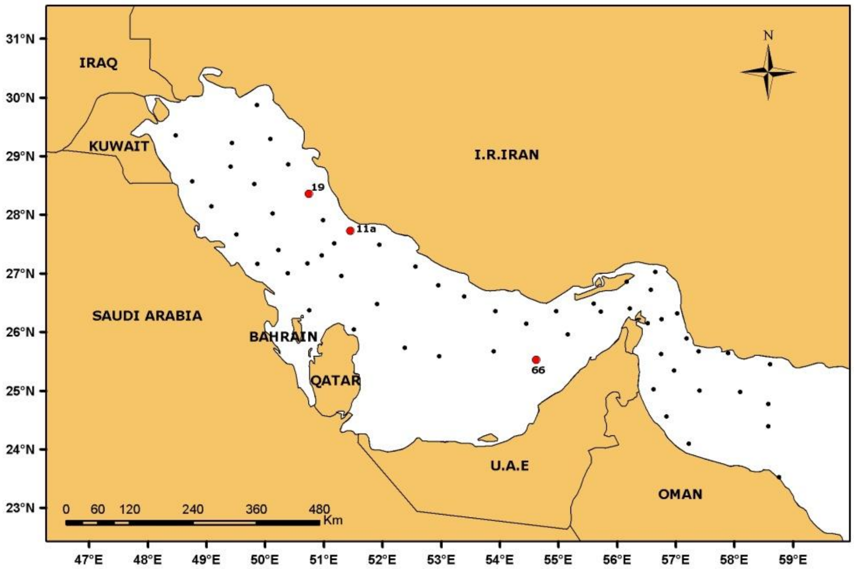


Figure 22. *Callianassa* spp., zoea I. a, c. lateral view; b, d. anterior part; e. telson.

DSp. dorsal spine; MSp. medial spines; I-V. abdominal somites; Ro. rostrum; i1-i7. 1st-7th terminal processes; USp - unpaired medial spine.

Sites of Occurrence in RSA: Inner RSA: Stations 11a, 19 and 66.



Sites of occurrence of *Callianassa* spp., zoea I in RSA

Family Laomediidae Dana, 1852

Genus *Laomedia* De Haan, 1841

***Laomedia* sp.**

Zoea IV (Figure 23 a-e)

Reference: Yaldwin and Wear, 1972.

Description: Rostrum slender and unarmed, tapering to a point and extending well beyond the level of the unstalked eyes (Figure 23 a, b, c); region between mouth and antennae not lengthened, and there is no evidence of a “neck”. Abdomen (Figure 23 a, b, d) consists of five segments and a telson; abdominal segments unarmed and lacking pro-curved pleural hooks. Telson (Figure 23 e) almost straight, the posterior margin with temperate posterior cleft. Posterior telson margin armed with eigth pairs of setae: first (outer) seta very short and stout, articulating with telson plate, and finely serrated along its inner margin; second seta reduced to a fine hair as is usual among thalassinid larvae; third setae prominent, fourth to eigth setae about equal in length, finely serrated along their inner and outer margins, and with scattered fine lateral hairs; eighth (inner) seta smaller than fourth to seventh pairs, but otherwise similar to these. Unpaired medial spine (USp) small.

Measurements: Total length 4.6-5.0 mm; length of carapace 1.4 mm.

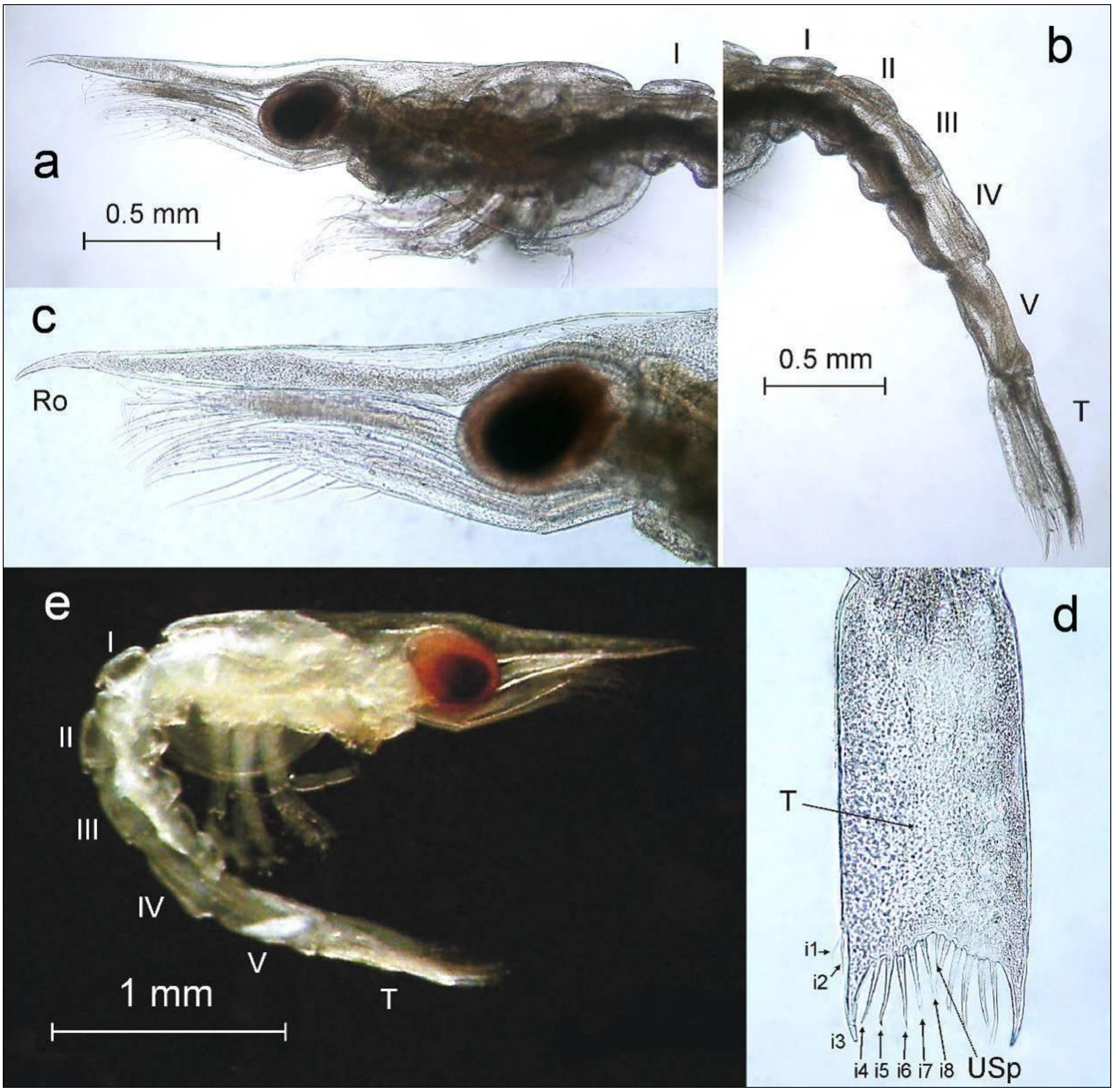


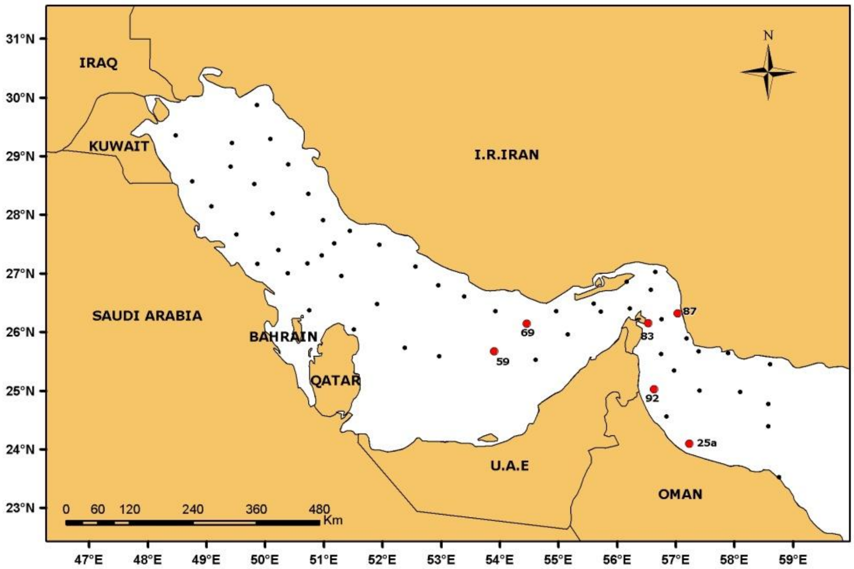
Figure 23. *Laomedia* sp., zoea IV. a. lateral view of anterior part; b. lateral view of posterior part; c.anterior part of carapace; d; telson; e. general lateral view.

I-V. 1^{st}-5^{th} abdominal somites; T. telson; Ro. rostrum; i1-i8. 1^{st}-8^{th} telson spines; USp. unpaired medial spine.

Sites of Occurrence in RSA:

Sea of Oman: Stations 25a, 83, 87 and 92

Inner RSA: Stations 59 and 69.



Sites of occurrence of *Laomedia* sp., zoea IV in RSA

Family Upogebiidae Borradaile, 1903

Genus *Upogebia* Leach, 1814

***Upogebia* sp.**

Zoea I and zoea III (Figure 24 a-f)

References: Ngoc-Ho, 1981; Andryszak, 1986.

Description: one pair of large lateral spines (LSp in Figure 24 b, c) on the 5th abdominal segments. These spines constitute the main features of interest. The presence of abdominal spines can be considered as an important distinguishing character. Telson formula for zoea I 7+7. No unpaired medial spine. Telson formula for zoea III 8+1+8. Small unpaired medial spine.

Measurements: Total length 3.0-3.6 mm; length of carapace 1.0-1.2 mm.

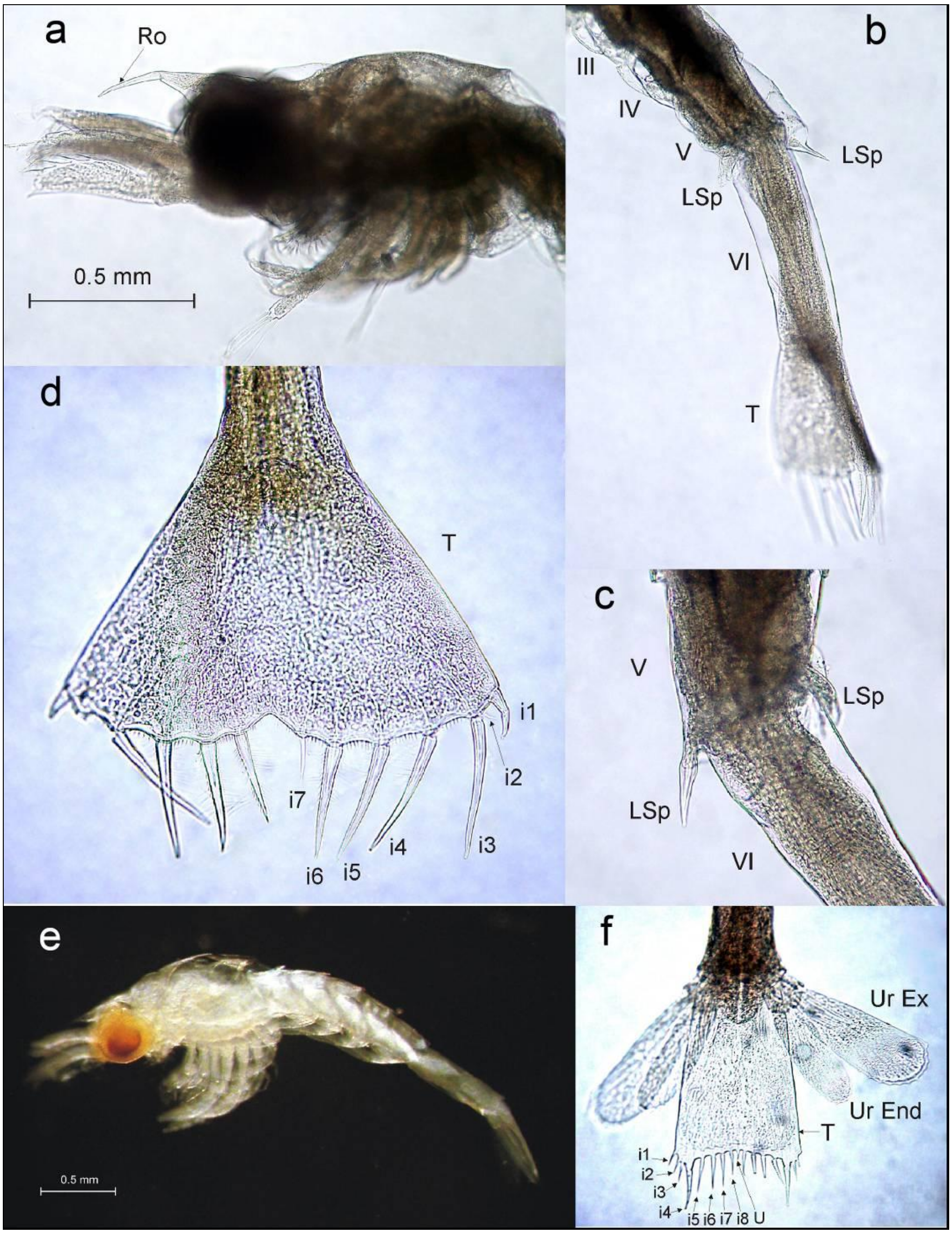
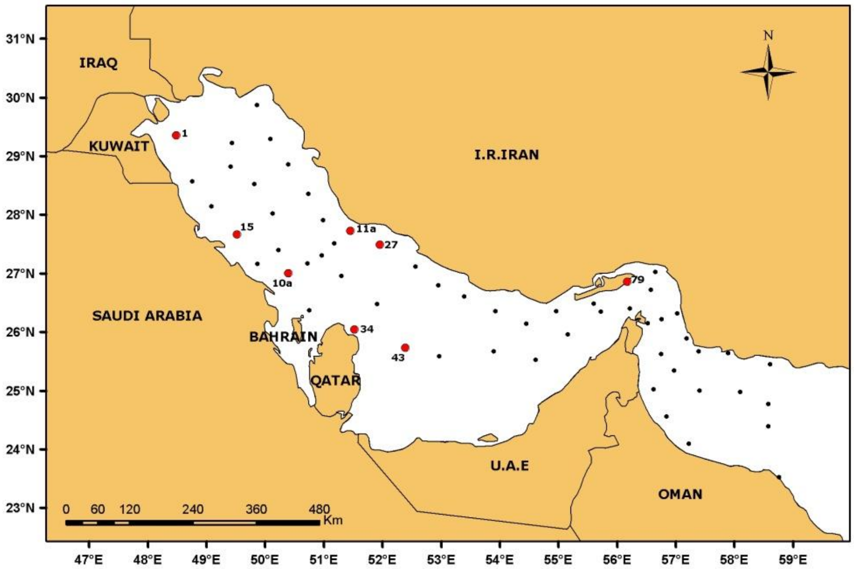


Figure 24. *Upogebia* sp., zoea I (a-d) and zoea III (e-f). a. lateral view of anterior part of zoea I; b. lateral view of posterior part of zoea I; c. dorsal view of 5th and 6th abdominal somites; d. telson of zoea I; e. lateral view of zoea III; e. telson of zoea III.

Ro. rostrum; III-VI. 3rd-6th abdominal somites; LSp. lateral spines; i1-i7. 1st-8th terminal spines; T. telson.

Sites of Occurrence in RSA: Inner RSA: Stations 1, 10a, 11a, 15, 27, 34, 43 and 79.



Sites of occurrence of *Upogebia* sp., zoea I in RSA

Infraorder Anomura MacLeay, 1838

Family Galatheidae Samouelle, 1819

Genus *Galathea* Fabricius, 1793

***Galathea* sp.**

Zoea III (Figure 25 a-e)

References: Pike and Williamson, 1972; Dos Santos and Gonzales-Cordillo, 2004

Description: Carapace laterally flattened (Figure 25 b). Each posterolateral margin of carapace extended into a spinous process (Figure 25 a, d). Rostrum shorter than body (Figure 25 a). Posterolateral margin process of carapace never extending beyond the end of telson. Posterolateral margins of carapace denticulate (Figure 25 d). Antennal exopod flattened (Figure 25 b). Rostrum narrower than diameter of eye (Figure 25 b).

Measurements: Total length 2.0 mm; length of carapace 0.4 mm.

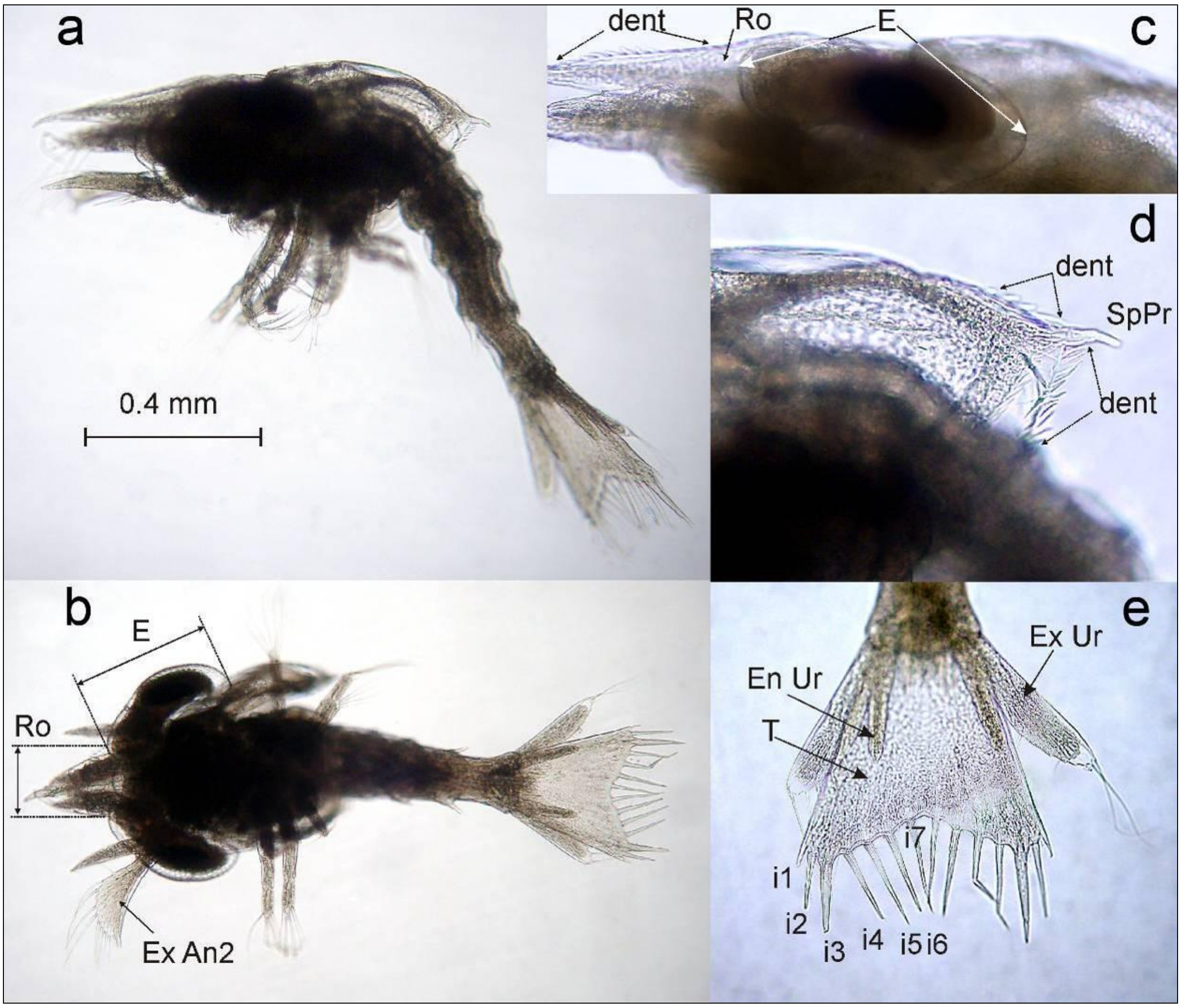


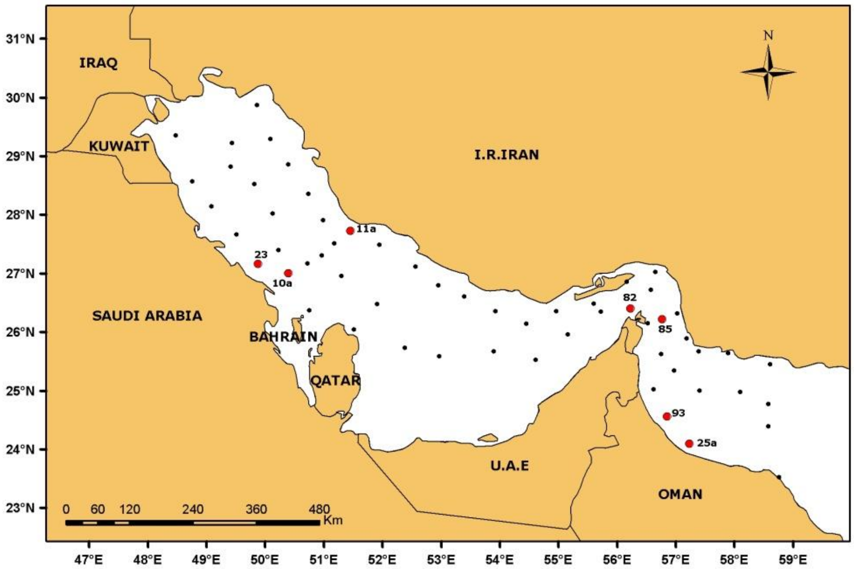
Figure 25. *Galathea* sp., zoea III. a. lateral view; b. dorsal view; c. dorsal portion of carapace; d. posterior portion of carapace; e. telson.

Ro. rostrum; E. eye; Ex An2. antennal exopod; dent. denticles; SpPr. spinous process; Ex Ur. exopod of uropod; En Ur. endopod of uropod.

Sites of Occurrence in RSA:

Sea of Oman: Stations 25a, 85 and 93.

Inner RSA: Stations 10a, 11a, 23, and 82.



Sites of occurrence of *Galathea* sp., zoea III in RSA

Family Porcellanidae Haworth, 1825

Genus *Pachycheles* Stimpson, 1858

***Pachycheles* sp.**

Zoea I (Figure 26 a-d)

References: Dos Santos and Gonzales-Cordillo, 2004; Tirmizi and Yaqoob, 1979; Wear, 1965; Konishi, 1987.

Description: carapace laterally flattened, typically porcellanid (Figure 26 a). Each posterolateral margin of carapace extended into a spinous process (PSp in Figure 26 a, c). Rostrum much longer than body (4 times carapace length) armed overall with spinules to its tip (Sp in Figure 26 a, b). Posterio-lateral margin process of carapace extended beyond the end of telson (1.4 times carapace length). Both posterior spines bearing ventral pointed spinelets near their basal portion (Sp in Figure 26 a, c). Lower margin of carapace smooth (Ca in Figure 26 a, c). Abdomen with lateral spines increasing in size posteriorly (LSp in

Figure 26 d). Telson bearing 7 pairs of posterior processes, long and plumose except for first and second (i1 - i7 in Figure 26 d).

Measurements: Length of carapace 1.4 mm; rostral spine length 5.5 mm; posterior spine length 2.0 mm.

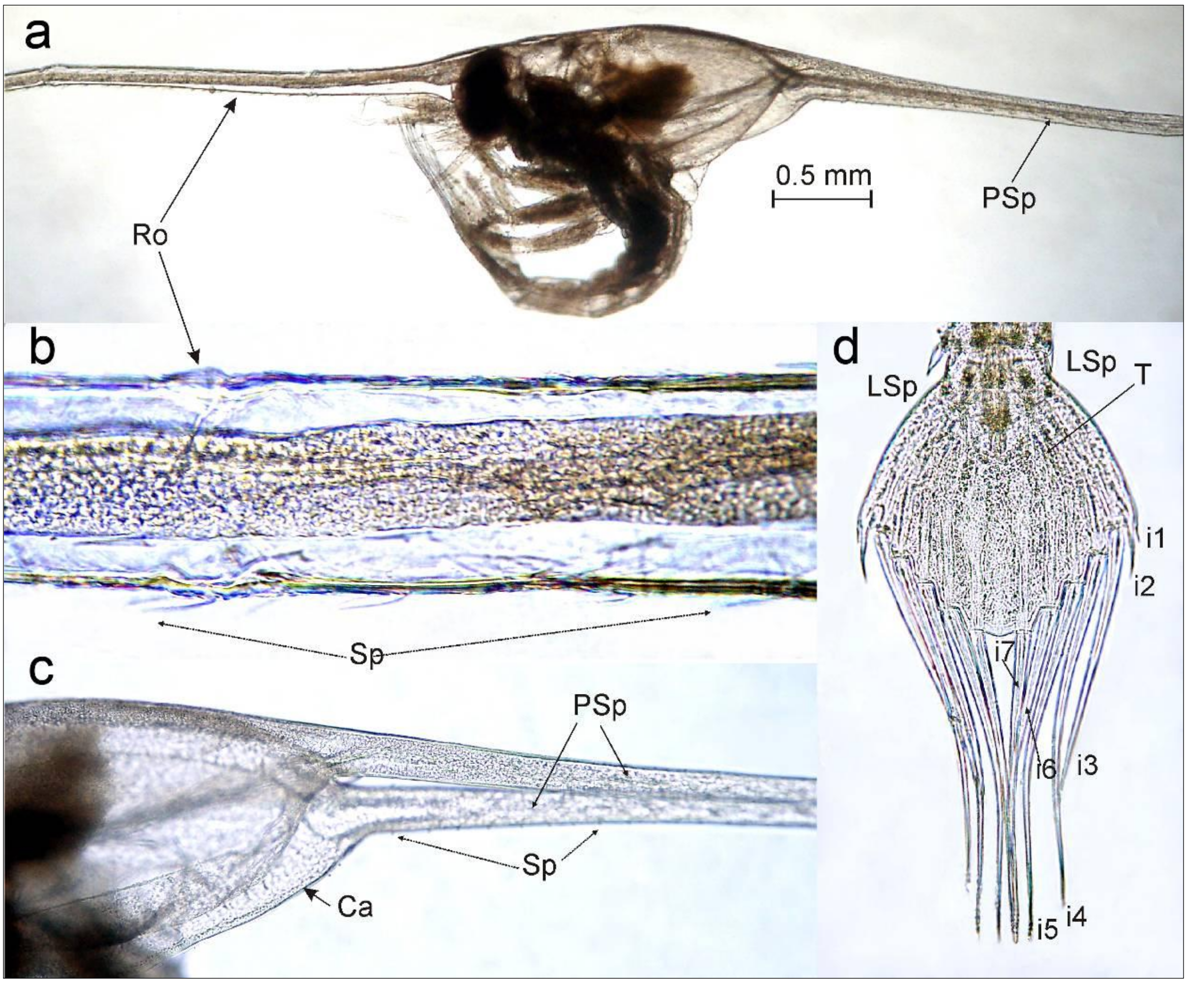


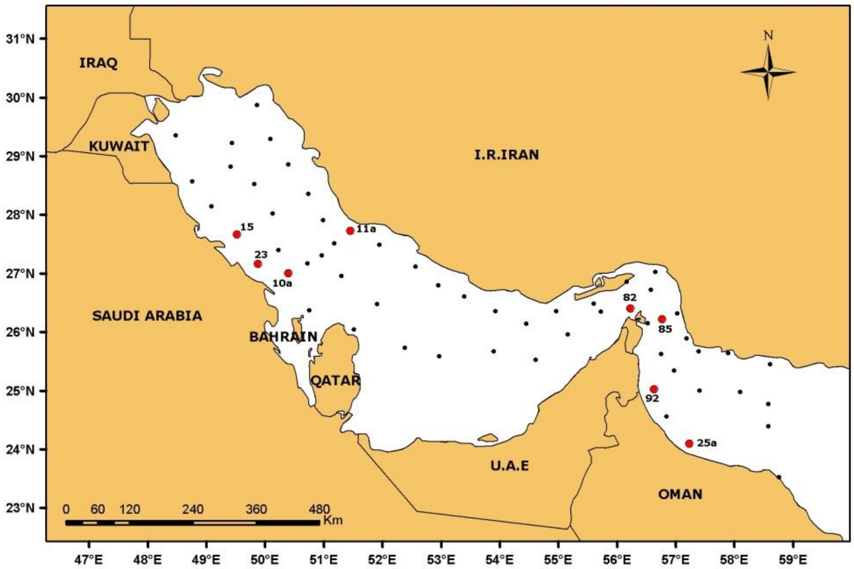
Figure 26. *Pachycheles* sp., zoea I. a. lateral view; b. fragment of rostrum; c. posterior portion of carapace; d. telson.

Ro. rostrum; PSp. posterio-lateral margin process; Sp. spinulets; LSp. lateral spines; i1-i7. 1^{st}-7^{th} posterior processes; T. telson; Ca. carapace.

Sites of Occurrence in RSA:

Sea of Oman: Stations 25a, 85 and 92.

Inner RSA: Stations 10a, 11a, 15, 23 and 82.



Sites of occurrence of *Pachycheles* sp., zoea I in RSA

Family Diogenidae Ortmann, 1892

Genus *Diogenes* Dana, 1851

***Diogenes* sp.**

Zoea III (Figure 27 a-e).

Reference: Dos Santos and Gonzales-Cordillo, 2004.

Description: Carapace laterally flattened, smooth with small swellings behind eyes. Each posterolateral margin of carapace rounded (Figure 27 c). Rostrum large with pointed end, longer than antenna length (Figure 27 b). Eye stalk relatively short. 5th somite of abdomen bears dorsal spine (Figure 27 d). Telson flattened (Figure 27 e). Posterior margin without median spine and slightly concave. Each half of telson bears six spines. Small setules between 2nd - 6th spines. Uropods with exopod and rudimentary endopod.

Measurements: Total length 2.5 mm; length of carapace 0.8 mm.

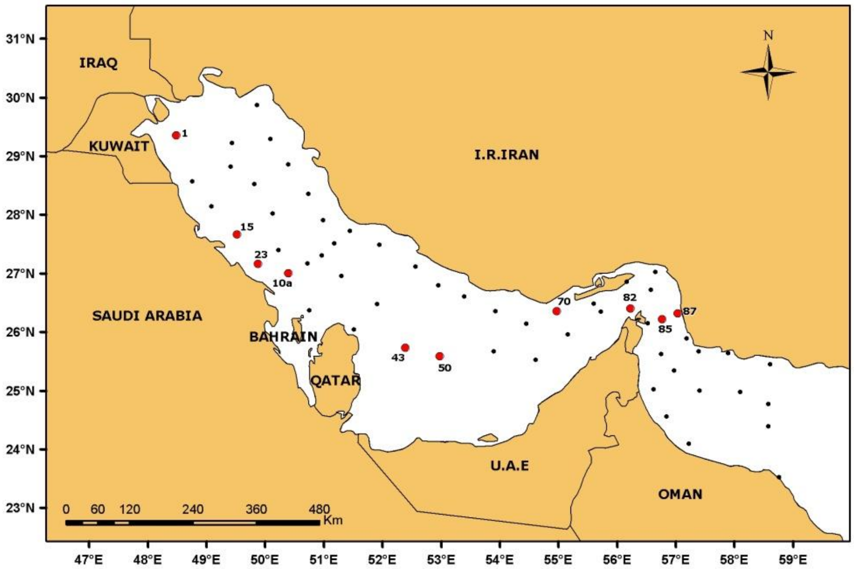
Figure 27. *Diogenes* sp., zoea III. a. lateral view; b. anterior fragment; c. posterior part of carapace; d. fragment of abdomen; e. distal fragment of abdomen.

Ro. rostrum; An2. antenna; DSp. dorsal spine on 5th somite; III-VI. 3rd-6th somite; Ca. carapace; T. telson; Ex Ur. exopod of uropod; En Ur. endopod of uropod; i1-i6. 1st-6th caudal spines.

Sites of Occurrence in RSA:

Sea of Oman: Stations 85 and 87.

Inner RSA: Stations 1, 10a, 15, 23, 43, 50, 70 and 82.



Sites of occurrence of *Diogenes* sp., zoea III in RSA

Family Diogenidae Ortmann, 1892

Genus *Dardanus* Paulson, 1875

***Dardanus* sp.**

Zoea I (Figure 28 a-c)

Reference: Pike and Williamson, 1960.

Description: Carapace without posterior spine (Figure 28 a). Antennal scale without terminal spine. Rostrum broad narrowing more abruptly near tip (Figure 28 b). No dorsal spine on 5th abdominal somite (Figure 28 a). Lateral spines on 5th abdominal somite. Rostrum reaching well beyond antennal scale (Figure 28 b). Carapace with small dorsal carina (DC in Figure28 c).

Measurements: Total length 1.9 mm; length of carapace 0.6 mm.

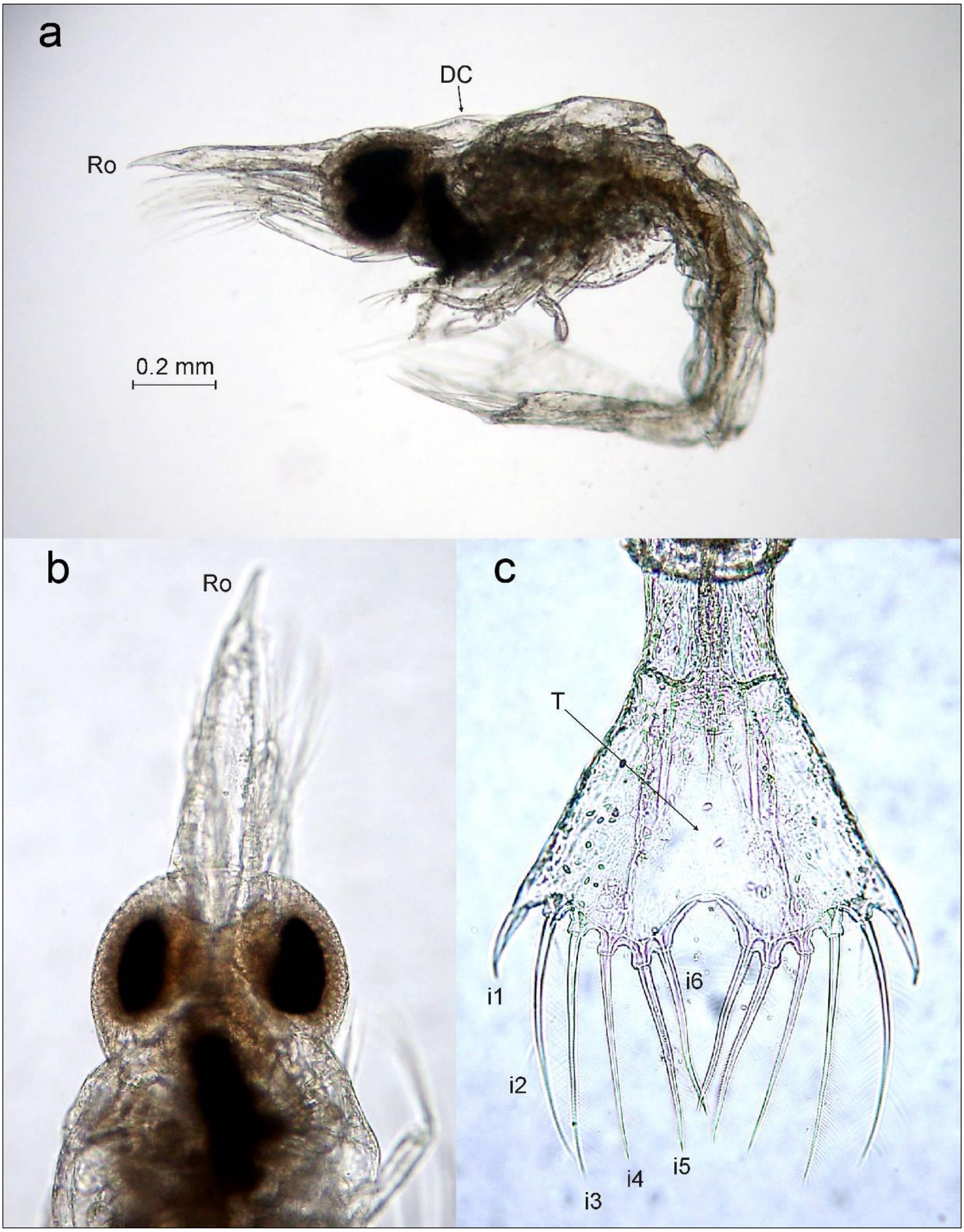
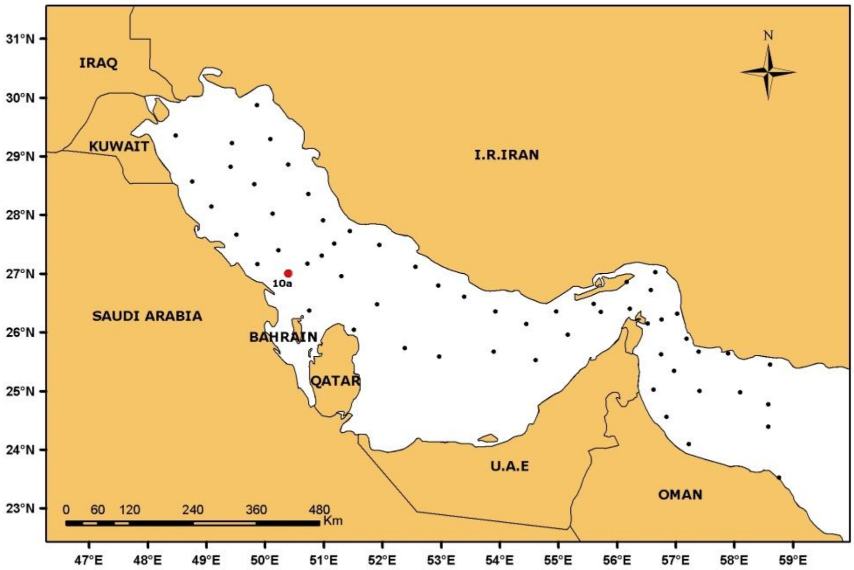


Figure 28. *Dardanus* sp., zoea I. a. lateral view; b. dorsal view of anterior part; c. telson.

Ro. rostrum; DC. dorsal carina; i1-i6. 1st-6th telson spines; T. telson.

Site of Occurrence in RSA: Inner RSA: Station 10a.



Site of occurrence of *Dardanus* sp., zoea I in RSA

Family Diogenidae Ortmann, 1892

Genus *Paguristes* Dana, 1852

***Paguristes* sp.**

Zoea I (Figure 29 a-d)

References: Pike and Williamson, 1958; Roberts, 1971; Dos Santos and Gonzales-Cordillo, 2004.

Description: Carapace laterally flattened. Eyes are sessile. Posterior margins of carapace is rounded. Rostrum reaches (in smaller specimen) or not reaches (in bigger specimen) the apex of antennule (Figure 29 a, c). Eight pairs of caudal spines (i1-i8 in Figure 29 b, d).

Measurements: Total length 1.8-2.6 mm; length of carapace 0.6-1.0 mm.

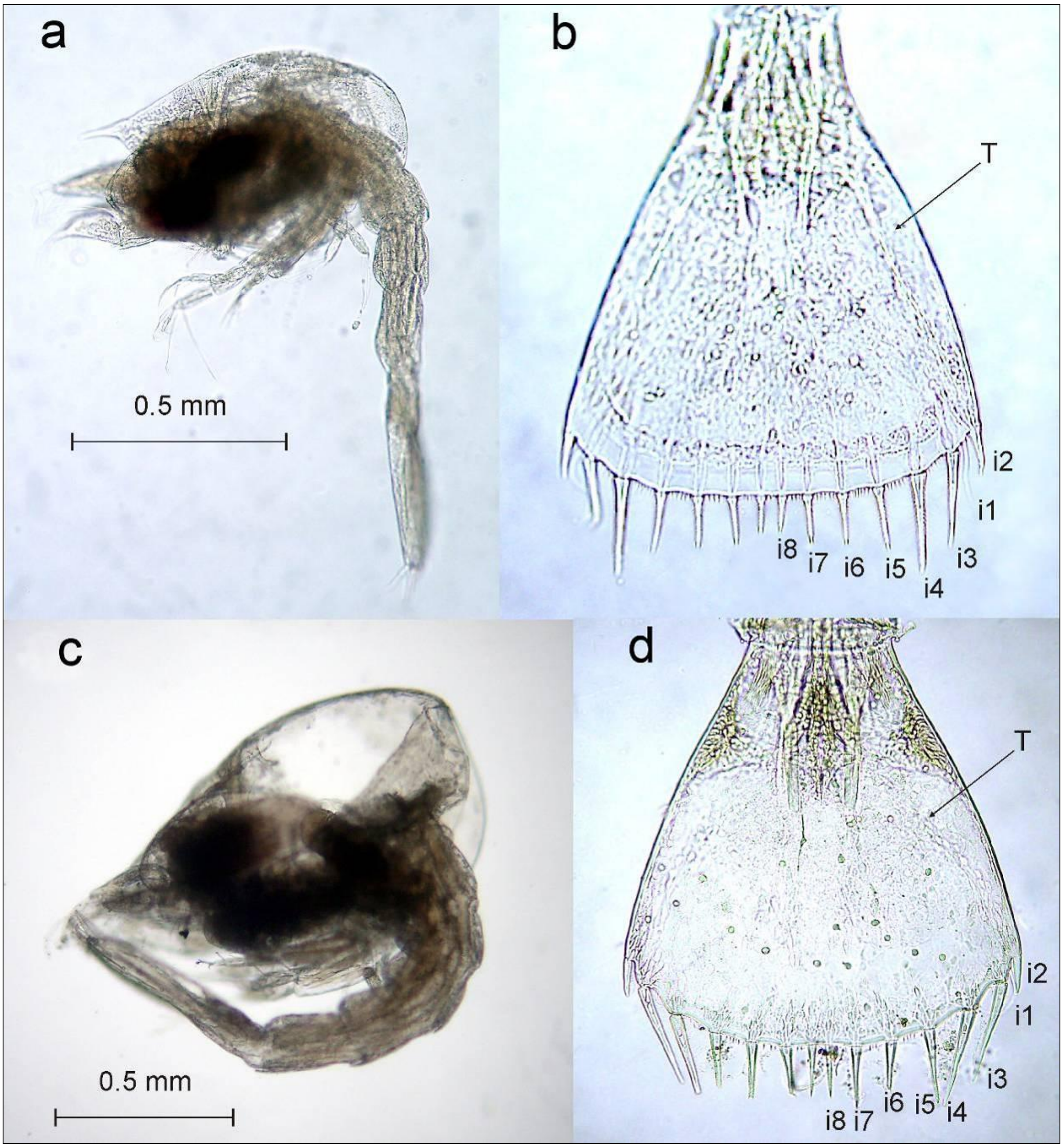
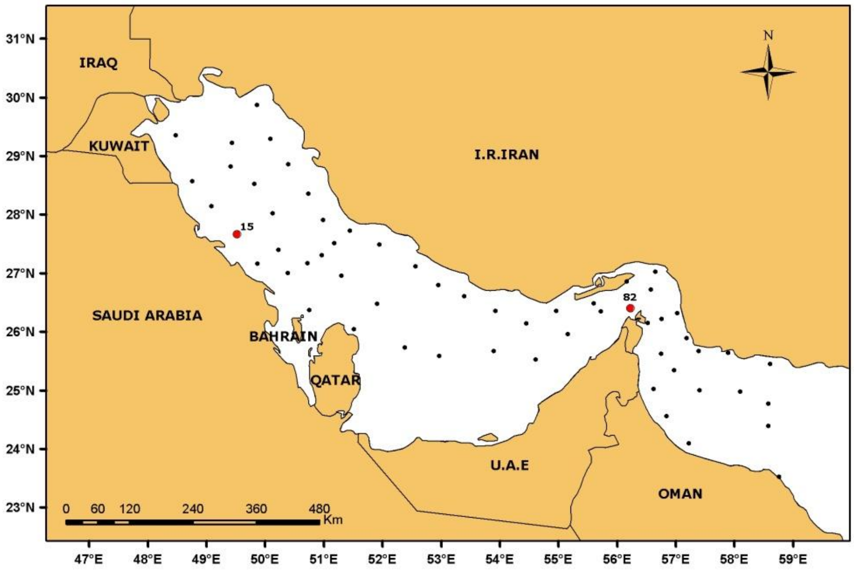


Figure 29. *Paguristes* sp., zoea I. a, c. lateral view; b, d. telson.

T. telson; i1-i8. 1st-8th telson spines.

Sites of Occurrence in RSA: Inner RSA: Stations 15 and 82.



Sites of occurrence of *Paguristes* sp., zoea I in RSA

Family Paguridae Latreille, 1802

Genus *Pagurus* Fabricius, 1775

***Pagurus* sp.**

Zoea III (Figure 30 a-c)

References: Pike and Williamson, 1958; Roberts, 1971; Dos Santos and Gonzales-Cordillo, 2004.

Description: Carapace laterally flattened (Figure 30 a). Eyes sessile. Biramous uropods present. Each posterolateral margin of carapace extended into a spinous process (SpPr in Figure 30 a, b). Rostrum shorter than body (Figure 30 a, b). Posterolateral margins of carapace smooth (Figure 30 a, b). Eight pairs of telson spines (i1-i8 in Figure 30 c).

Measurements: Total length 3.4 mm; length of carapace 1.1 mm.

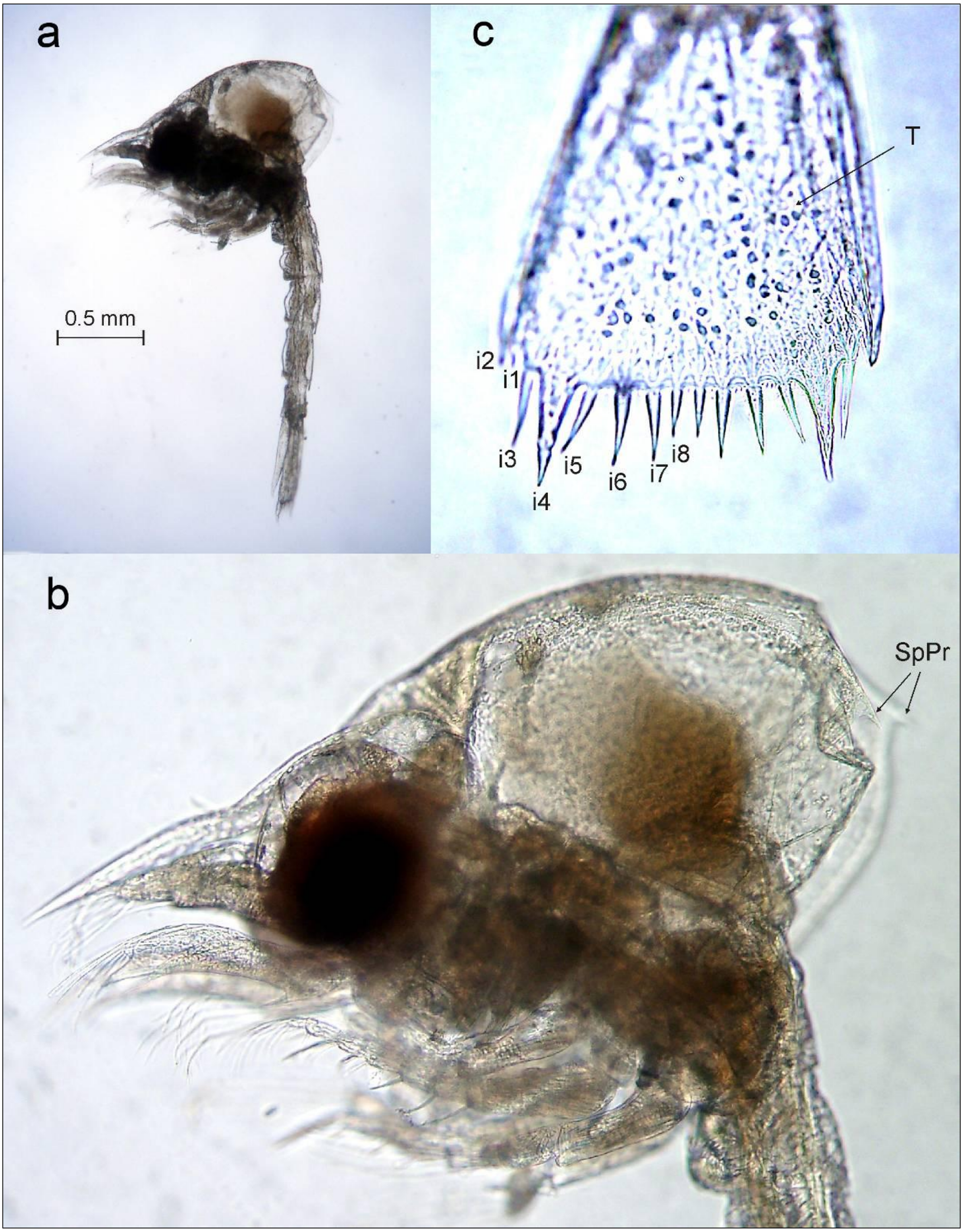


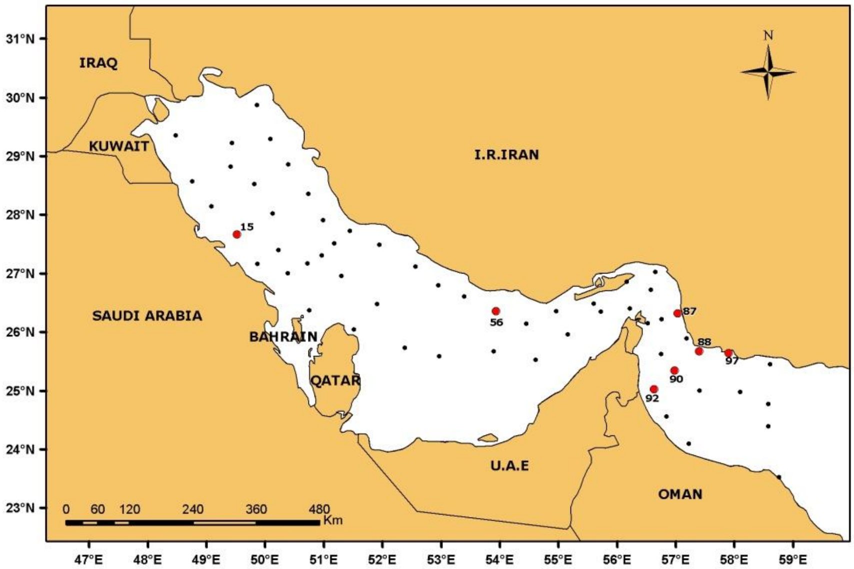
Figure 30. *Pagurus* sp., zoea III. a. lateral view; b. lateral view of carapace; c. telson.

SpPr. spinous process; T. telson; i1-i8. 1^{st}-8^{th} telson spines.

Sites of Occurrence in RSA:

Sea of Oman: Stations 87, 88, 90, 92 and 97.

Inner RSA: Stations 15 and 56.



Sites of occurrence of *Pagurus* sp., zoea III in RSA

Infraorder Brachyura Latreille, 1802

Family Leucosiidae Samouelle, 1819

Genus *Ebalia* Leach, 1817

***Ebalia* sp.**

Zoea I (Figure 31 a-b)

References: Dos Santos and Gonzales-Cordillo, 2004; Ingle, 1992; Pohle *et al*., 1999.

Description: Telson with triangular shape and short furcal spines lacking medial arch. Five pairs of furcal spines (Figure 31 b). Carapace without dorsal spine (Figure 31 a).

Measurements: Length of carapace 0.6 mm.

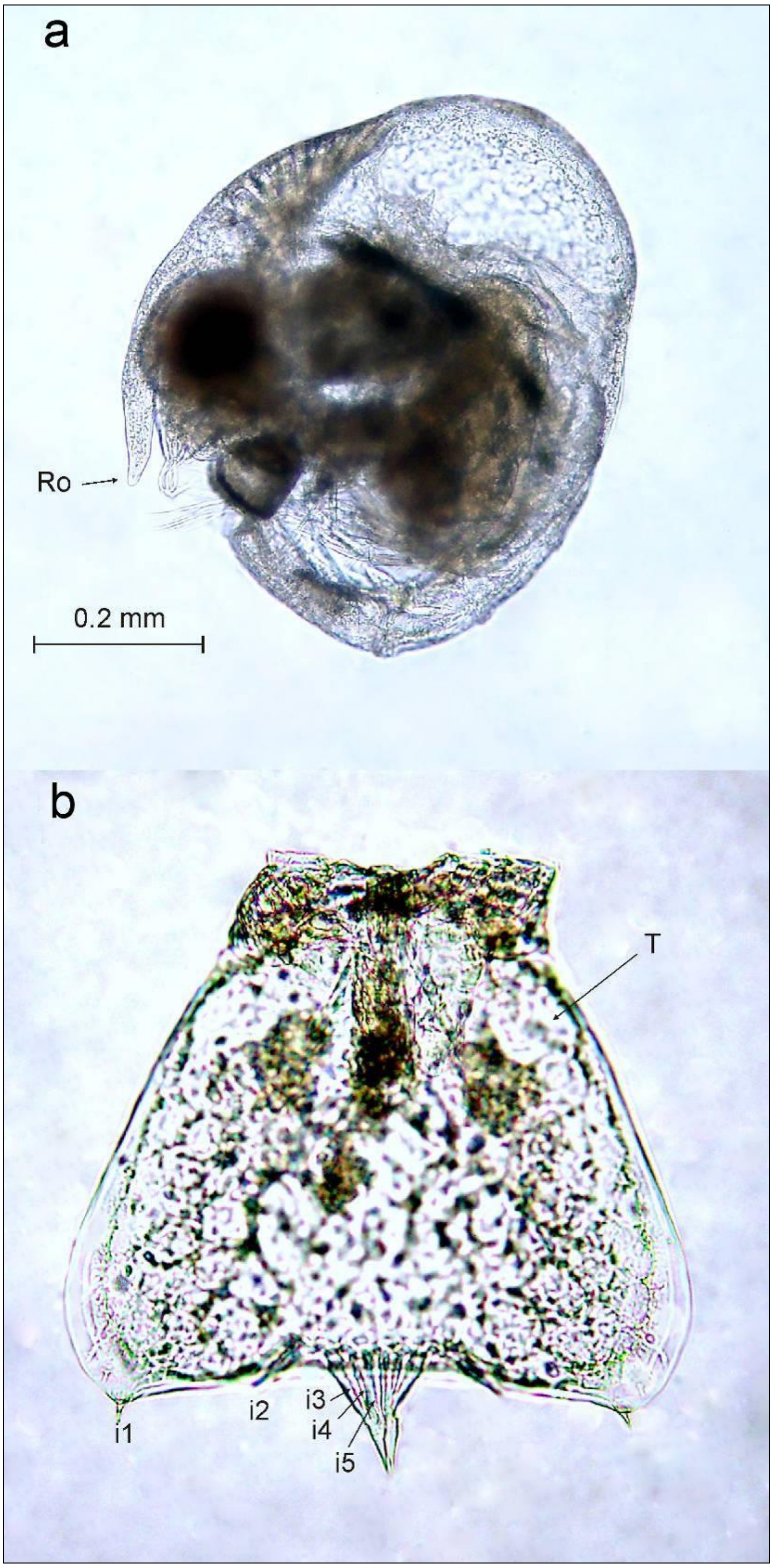


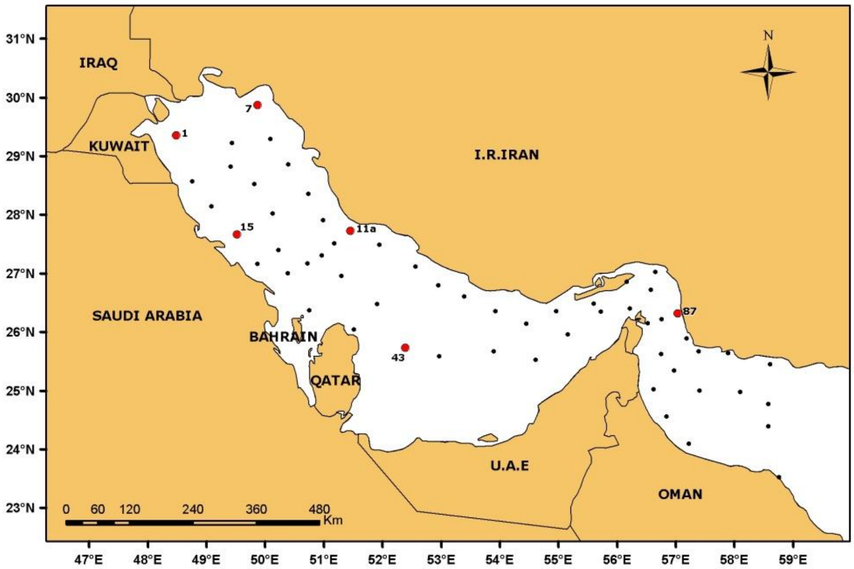
Figure 31. *Ebalia* sp., zoea I. a. lateral view; b. telson

Ro. rostrum; T. telson; i1-i5. 1st-5th telson spines.

Sites of Occurrence in RSA:

Sea of Oman: Station 87.

Inner RSA: Stations 1, 7, 11a, 15 and 43.



Sites of occurrence of *Ebalia* sp., zoea I in RSA

Family Leucosiidae Samouelle, 1819

Genus *Leucosia* Weber, 1795

***Leucosia* sp.**

Zoea I (Figure 32 a-b)

References: Dos Santos and Gonzales-Cordillo, 2004; Ingle, 1992; Pohle *et al*., 1999.

Description: Telson with triangular shape and short furcal spines lacking medial arch. Four pairs of furcal spines (Figure 32 b). Carapace with long rostral, dorsal and lateral spines (Figure 32 a).

Measurements: Total length 3.8 mm; length of carapace 0.8 mm.

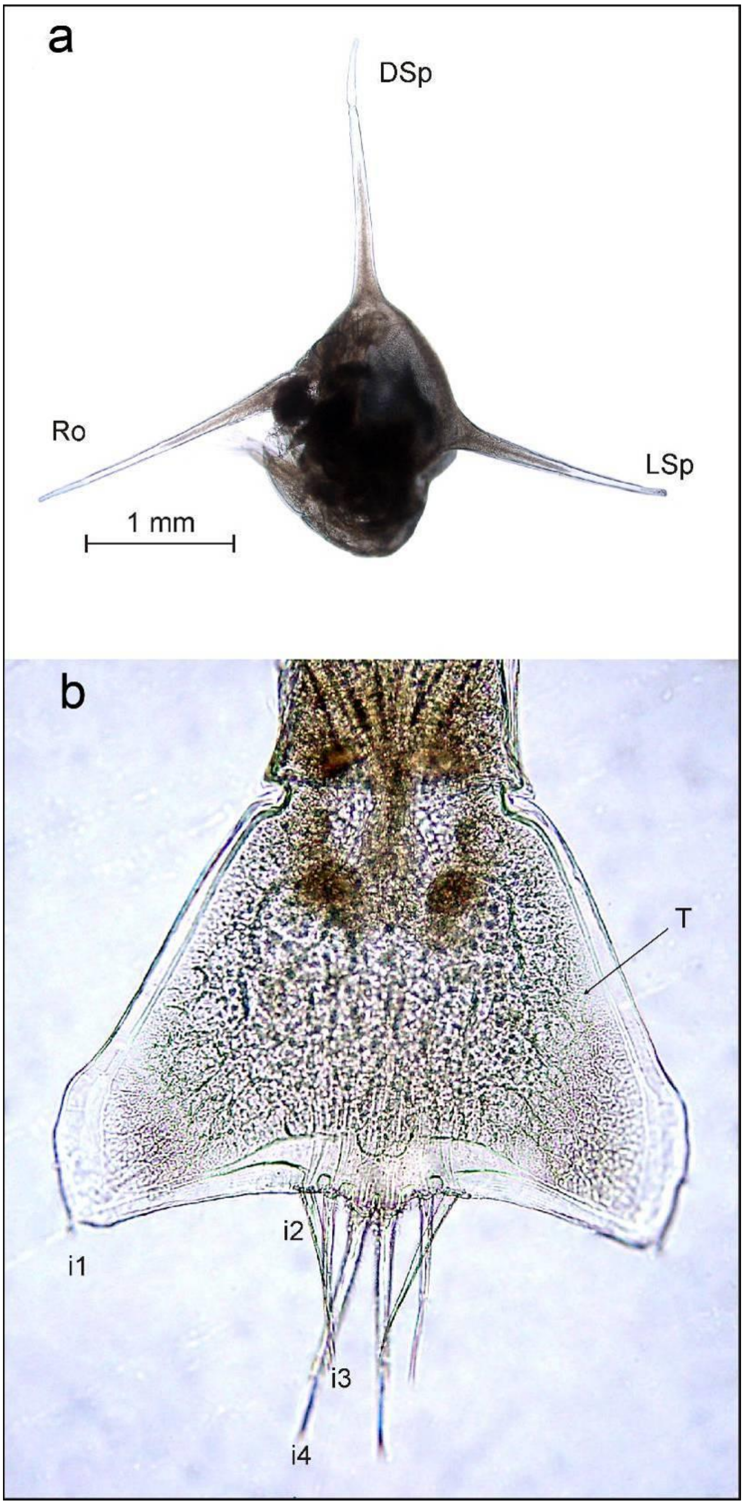


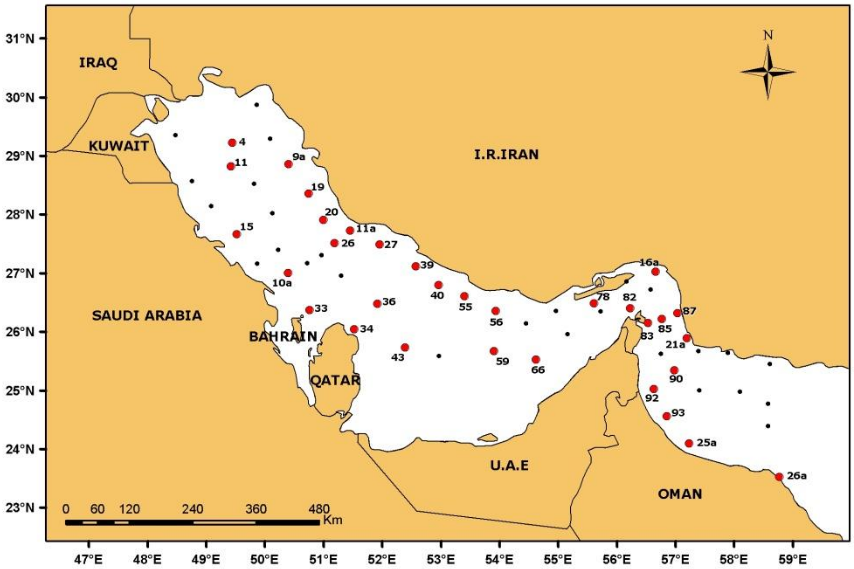
Figure 32. *Leucosia* sp., zoea I. a. lateral view; b. telson

Ro. rostrum; DSp. dorsal spine; LSp. lateral spine; T. telson; i1-i4. 1^{st}-4^{th} spines.

Sites of Occurrence in RSA:

Sea of Oman: Stations 16a, 21a, 25a, 26a, 83, 85, 87, 90, 92 and 93.

Inner RSA: Stations 4, 9a, 10a, 11, 11a, 15, 19, 20, 26, 27, 33, 34, 36, 39, 40, 43, 55, 56, 59, 66, 78 and 82.



Sites of occurrence of *Leucosia* sp., zoea I in RSA

Family Parthenopidae MacLeay, 1838

Genus *Parthenope* Weber, 1795

***Parthenope* sp.**

Zoea IV (Figure 33 a-e)

References: Yang W. T., 1971; Guerao and Abello, 1999.

Description: Carapace globose with the full complement of dorsal, rostral and lateral spines but without conspicuous projection (Figure 33 a, b). Abdominal somites 3-5 with prominent posterolateral spines, about as long as length of somite (PLSp in Figure 33 c, d); telson furca arched (T in Figure 33 e).

Measurements: Total length 3.5 mm; length of carapace 1.1 mm.

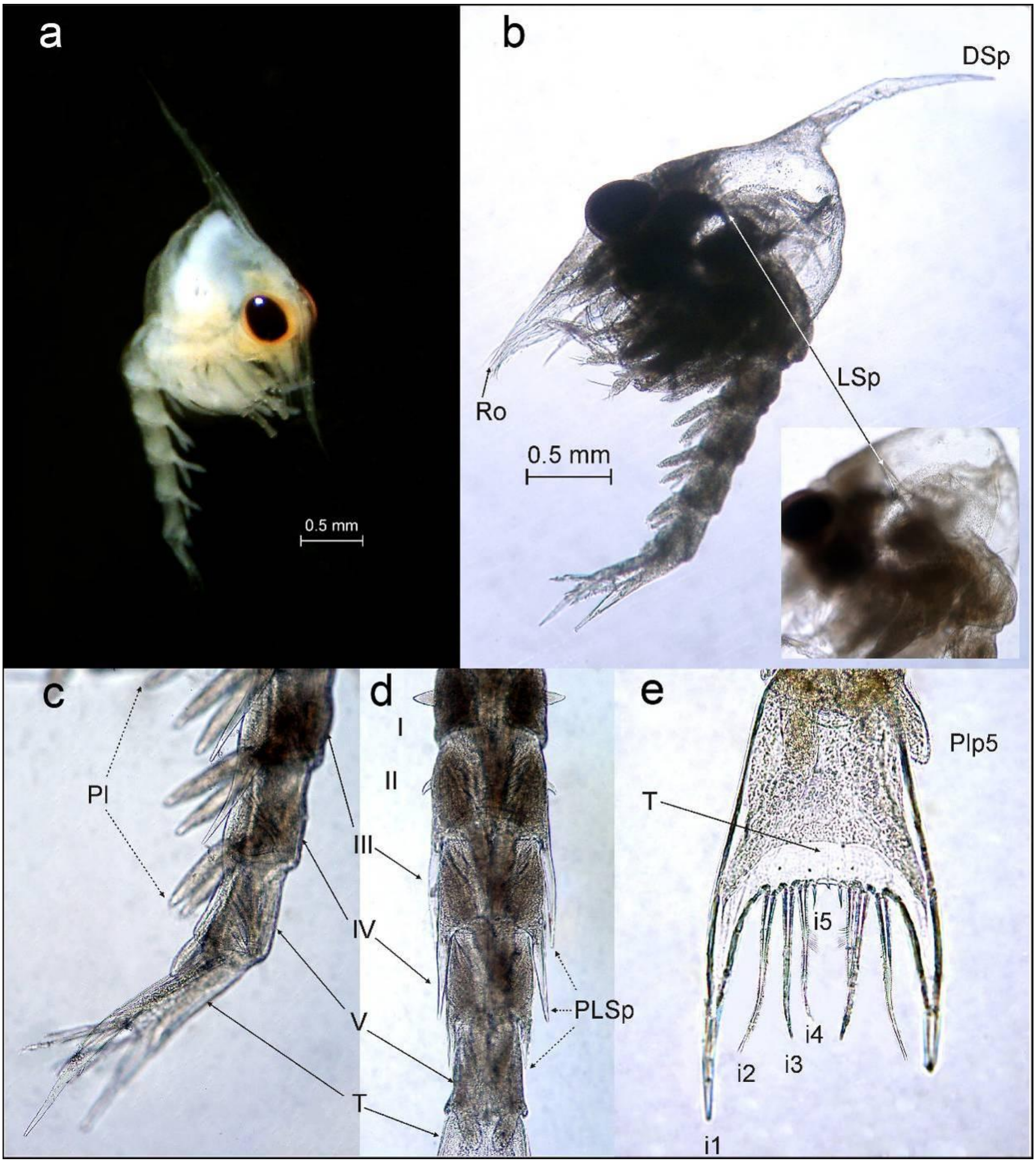


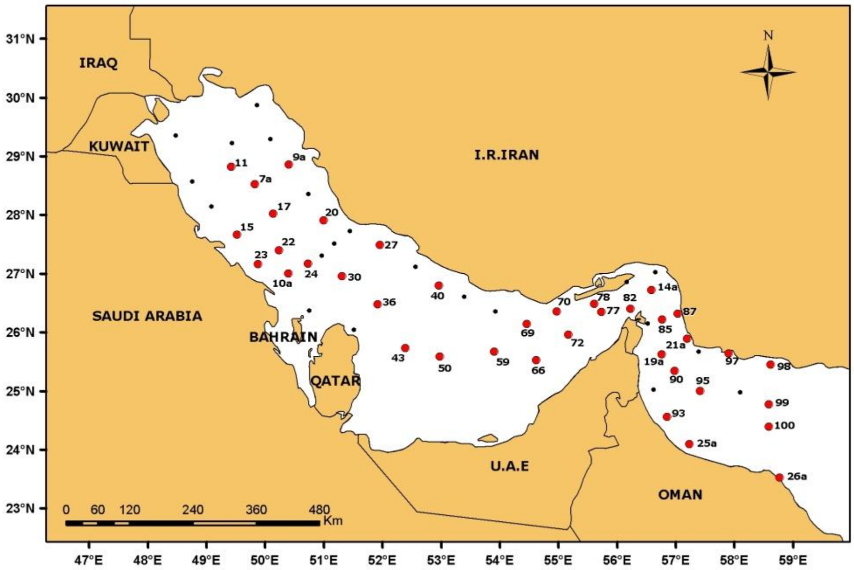
Figure 33. *Parthenope* sp., zoea IV. a, b. general lateral view; c. lateral view of abdomen; d. dorsal view of abdomen; e. dorsal view of telson.

Pl. pleopod buds; I-V. abdominal somites; T. telson; PLSp. posterolateral spines; i1-i5. 1^{st}-5^{th} furcal spines.

Sites of Occurrence in RSA:

Sea of Oman: Stations 14a, 19a, 21a, 25a, 26a, 85, 87, 90, 93, 95, 97, 98, 99 and 100.

Inner RSA: Stations 7a, 9a, 10a, 11, 15, 17, 20, 22, 23, 24, 27, 30, 36, 40, 43, 50, 59, 66, 69, 70, 72, 77, 78 and 82.



Sites of occurrence of *Parthenope* sp., zoea IV in RSA

Family Ocypodidae Rafinesque, 1815

Genus *Macrophthalmus* Desmarest, 1823

***Macrophthalmus* sp.**

Zoea III (Figure 34 a-b)

References: Fielder and Greenwood, 1986; Hashmi, 1969; Pasupathi and Kannupandi, 1988.

Description: Carapace smooth and globose (Figure 34 a). Dorsal and lateral spines absent. Rostrum very short and evenly tapered (Figure 34 a). Eyes immobile. Telson slightly wider than last abdominal somite (Figure 34b). Telson posterior margin transverse with 3 + 3 subequal biplumose setae (i2-i4 in Figure 34 b). Telson rami short (i1 in Figure 34 b).

Measurements: Length of carapace 0.7 mm.

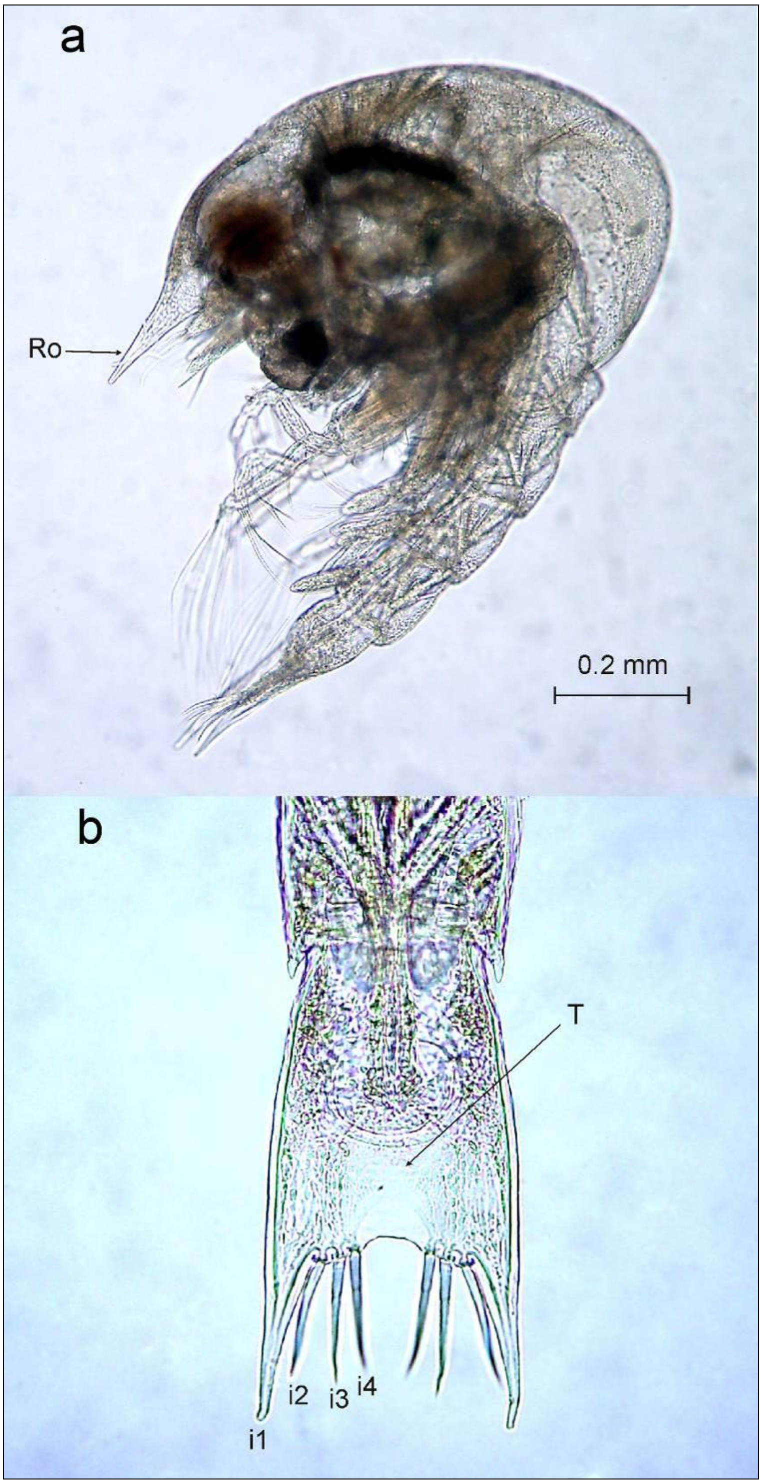
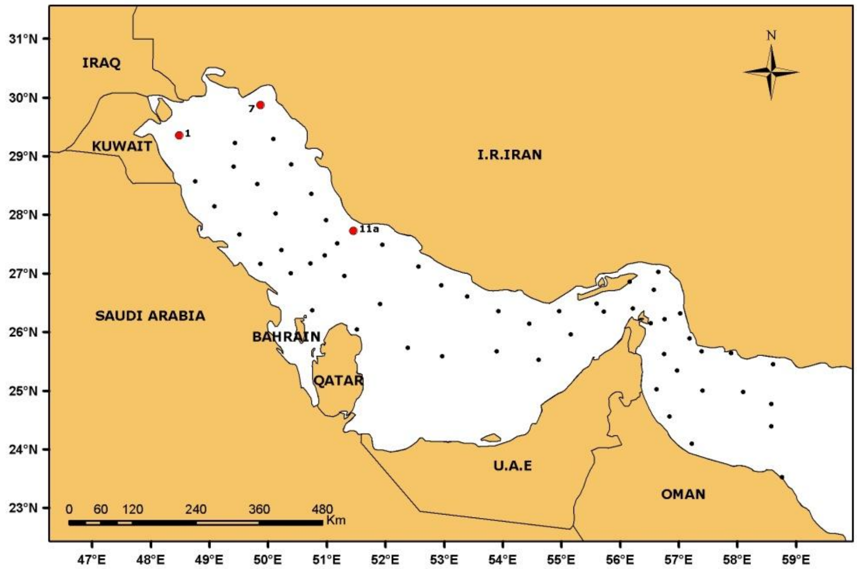


Figure 34. *Macrophthalmus* sp., zoea III. a. lateral view; b. telson.

Ro. rostrum; T. telson; i1-i4. 1st-4th telson spines.

Sites of Occurrence in RSA: Inner RSA: Stations 1, 7 and 11a.



Sites of occurrence of *Macrophthalmus* sp., zoea III in RSA

Family Ocypodidae Rafinesque, 1815

Genus *Ilyoplax* Stimpson

Ilyoplax frater (Kemp, 1919)

Synonym: *Tympanomerus frater* Kemp, 1919

Zoea VI (Figure 35 a-c)

References: Al-Khayat and Jones, 1996.

Description: Carapace wider than long. Dorsal spine longer than length of carapace. Rostral spine approximately two thirds length of dorsal spine (Figure 35 a). Pair of lateral spines on both sides of carapace. Eyes rounded (Figure 35 b). Five subequal abdominal somites. Telson elongate with posterior margin with deep median cleft and 3 + 3 plumose setae (i1 - i3); long furca without rows of spinules (T in Figure 35 c).

Measurements: Total length 4.50 mm, length of carapace 0.75 mm.

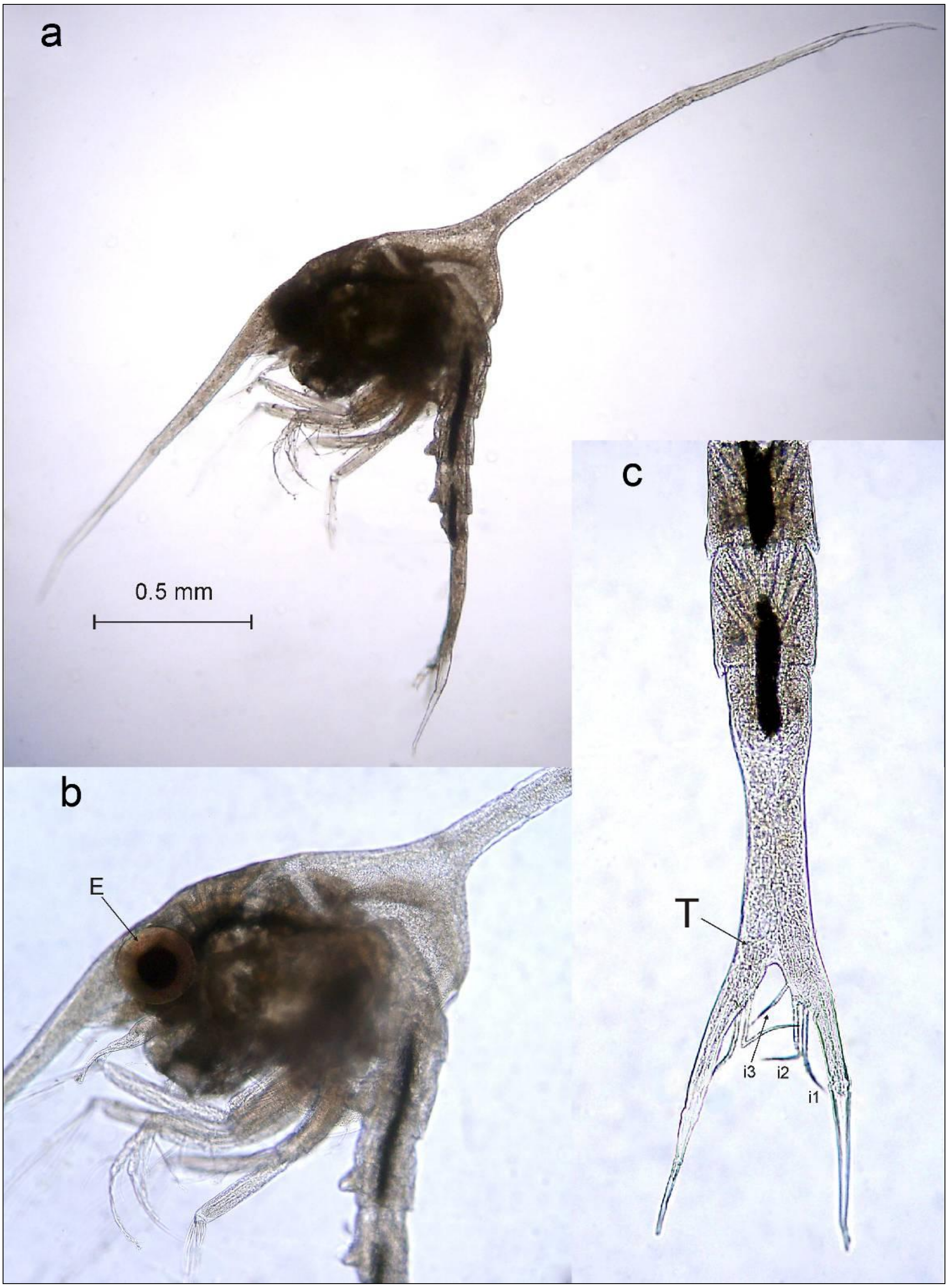
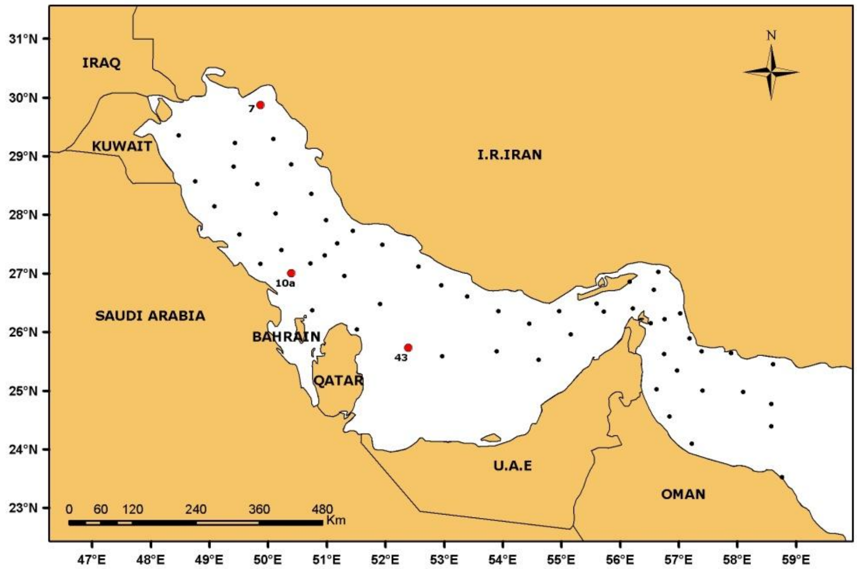


Figure 35. *Ilyoplax frater*, zoea VI. a. lateral view; b. lateral view of carapace; c. distal part of abdomen and telson.

E. eye; T. telson; i1-i3. 1st-3rd setae.

Geographical Distribution: Indian Ocean.

Sites of Occurrence in RSA: Inner RSA: Stations 7, 10a and 43.



Sites of occurrence of *Ilyoplax frater*, zoea VI in RSA

3.2 Spatial Occurrence and Abundance of Decapod Larvae

Seven morphotypes, 23 families, 27 genera and 10 species of planktonic and larval decapods were identified within the RSA plankton collection (Table 2). Several larval decapods remained unidentified. Among the planktonic and larval decapods collected from ROPME Sea Area during the winter season, the sergestid shrimps (comprised of *Luciferidae* and *Sergestidae*) were the most abundant group (87.3%, Figure 36). Other recorded groups were considerably less in percentage composition of the total decapods assemblage - Brachyura (8.3%), Caridea (2.1%), Anomura (0.9%), Penaeoidea (0.7%), and Thalassinidea (0.2%).

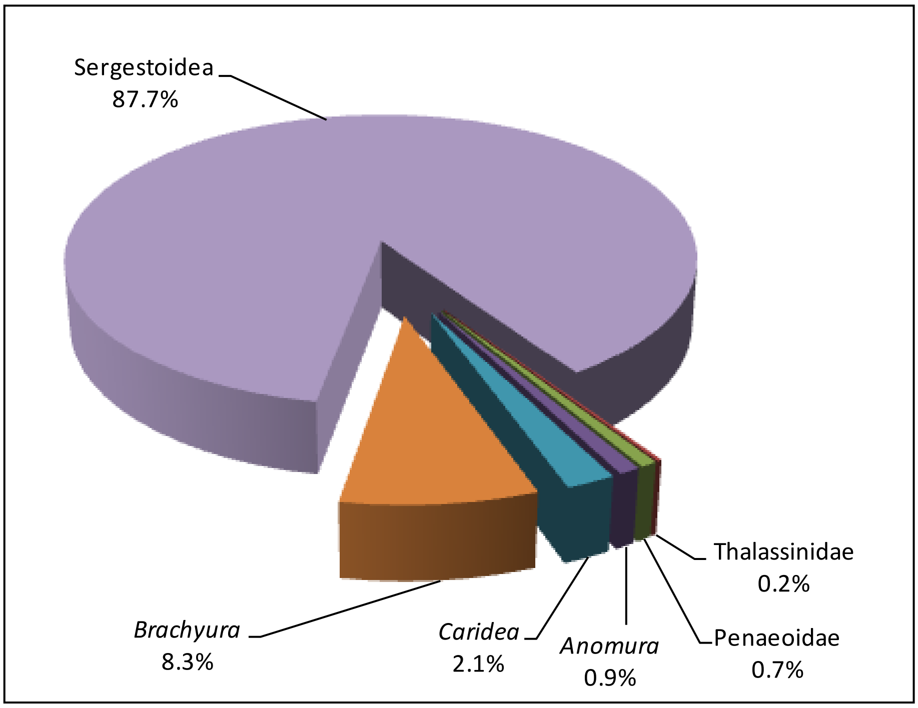


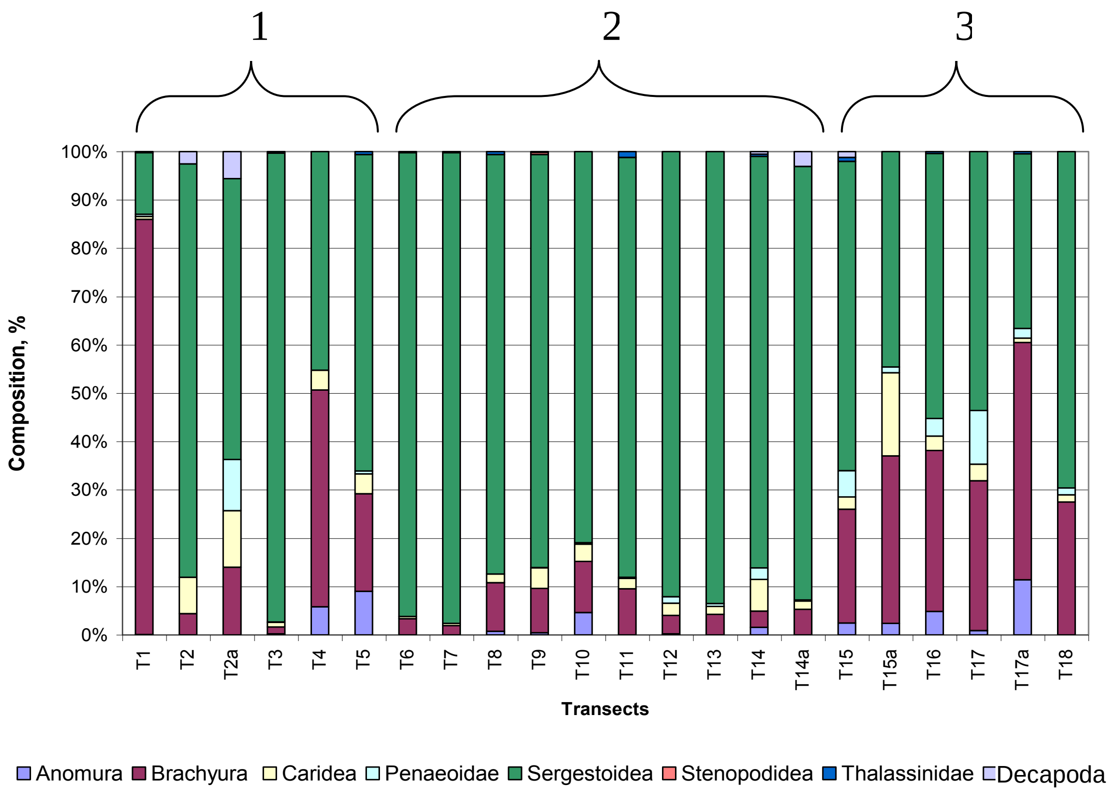
Figure 36. Percentage composition of planktonic decapods in the RSA during the Winter Cruise of 2006.

3.2.1 Composition along the RSA Axis

Composition of decapods assemblage along the RSA axis varied considerably (Figure 37). Decapod larval assemblages of the RSA differed remarkably in terms of the dominance of Sergestoidea. The dominance can be tentatively classified into three major groups as follows:

1. Northern inner RSA T1-T5 (13 - 97% Sergestoidea);
2. Central and Southern inner RSA T6-T14a (81-98% Sergestoidea);
3. Sea of Oman T15-T18 (36-70% Sergestoidea).

Al-Aidaroos (1993) reported that the decapod larvae in the ROPME samples collected from the western coast of the inner RSA (the Mt. Mitchell Cruise) during the spring season belonged to the following major groups: Penaeidae, Caridea, Anomura and Brachyura.



1. Northern Inner RSA T1-T5; 2. Central and Southern Inner RSA T6-T14a; 3. Sea of Oman T15-T18.

Figure 37. Percentage composition of planktonic decapoda in the RSA.

3.2.2 Composition of Planktonic Decapods from Previously Conducted Studies

Grabe and Lees (1992; 1995) observed in Kuwait Bay two species of sergestids and at least six species of penaeids during their one year of study. Brachyuran zoeae comprised 43% of all decapod larvae collected during their study. Larvae of 23 Caridea, one Stenopodidea, eight Anomara and 15 Thalassinidea were identified.

Al-Yamani and Khvorov (2007) ascertained that brachyuran larvae were the most abundant group among the decapods off Bubiyan Island (69.3%) in the NIG. Also representatives of Caridea (7.6%), Thalassinidae (7.0%), Anomura (5.6%), Penaeidae (5.5%) and Sergestidae (4.2%) were observed in the plankton. Larvae of Luciferidae and *Palinura* were recorded off Bubiyan Island, but in single numbers.

3.2.3 Abundance and Distribution of the Major Taxa Encountered in the RSA during Winter 2006

3.2.3.1 Dendrobranchiata

3.2.3.1.1 Sergestoidea

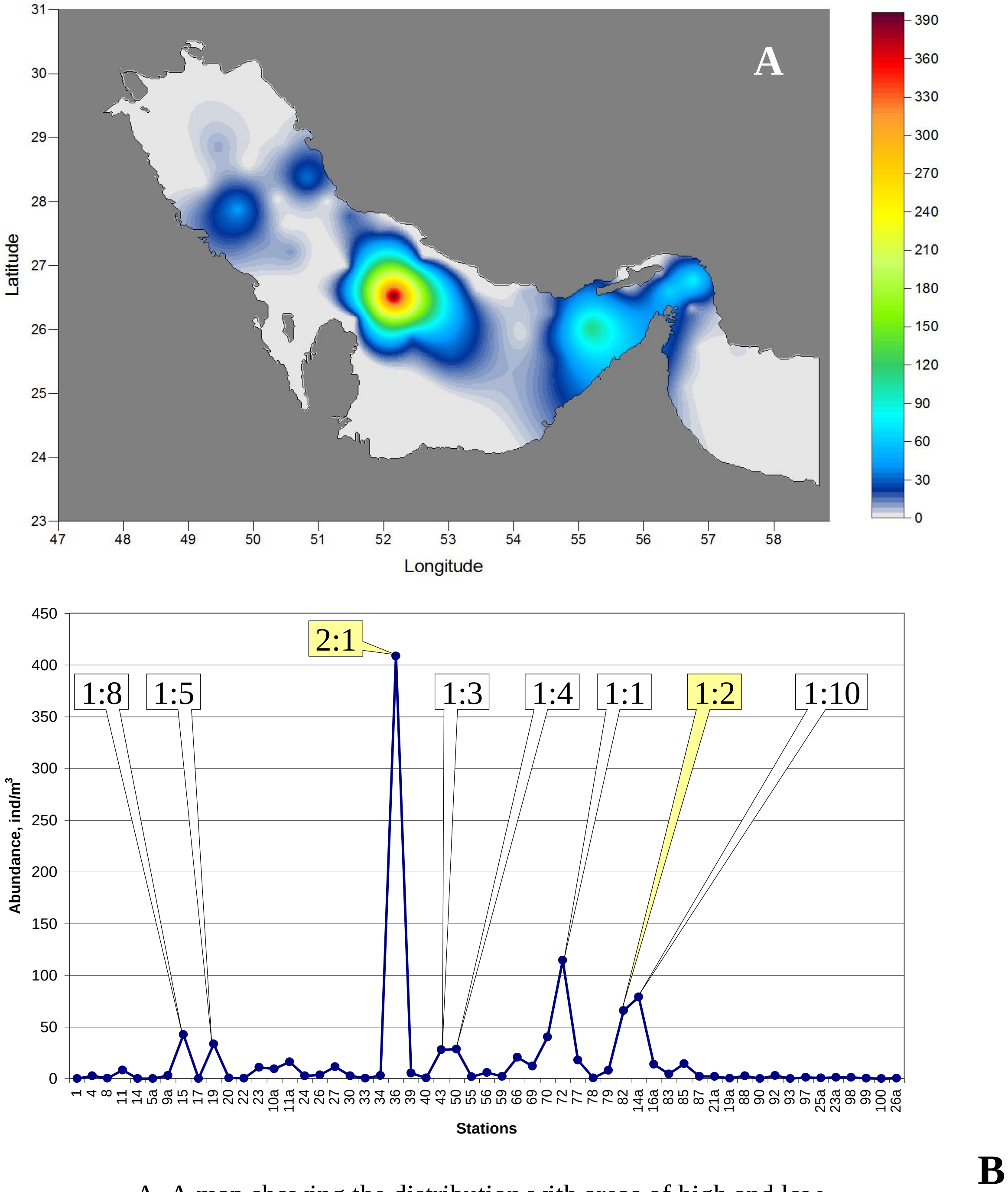
Luciferid Shrimp: The holoplanktonic neritic species – the luciferid shrimp *Lucifer hanseni* (belonging to Sergestoidea) was found to be the most abundant decapods in the ROPME Sea Area during February-March 2006. It comprised 89.9% of all the planktonic decapods.

The spatial extent of the populations of *L. hanseni* in the RSA was recorded from northern waters of the inner RSA to the northern part of the Sea of Oman (Figure 38).

Highest abundances (409 ind/m^3) were found on St. 36 located almost in the geographic center of the inner RSA (depth 52 m) (Figures 38 A, B). Second abundance peak of *L. hanseni* (114 ind/m^3) was observed on St. 72 (towards the southern part of the inner RSA). Relatively sparse swarms of *L. hanseni* were observed in the Strait of Hormuz at Stations 82 (65.6 ind/m^3) and 14a (78.9 ind/m^3). Two low-density swarms were recorded on transect 3 off the Saudi coast (Station 15: 42.5 ind/m^3) and off the Iranian coast (Station 19: 33.4 ind/m^3).

The mean and variance of abundance, as well as the dispersion index (I) for the RSA are presented in Table 3. The spatial distribution of *L. hanseni* as shown from the value of the index of dispersion (I = 176.23) indicates that the species is highly aggregated.

Population abundance for *L. hanseni* ranged from 0.03 to 409 ind/m^3 with a mean population density of 18.9 ind/m^3 (Table A2, Appendix A).



A. A map showing the distribution with areas of high and low concentrations; B. Spatial pattern of abundance (Individuals/m^3) and sex ratio (male: female) for several swarms (high concentrations).

Figure 38. Spatial distribution of abundance (Individuals/m^3) of luciferid shrimp *Lucifer hanseni* in the RSA during the winter season.

Table 3. Abundance Distribution Statistics for the RSA Populations of Planktonic Decapoda

Species	N	Mean	Variance	Index of dispersion (I)	Distribution
Lucifer hanseni	55	18.85	3321.82	176.23	aggregated
Lucifer typus	5	0.39	0.11	0.28	regular
Sergestes seminudus	6	1.11	2.47	2.23	aggregated
Penaeus semisulcatus	6	0.07	0.00	0.03	regular
Parapenaeopsis stylifera	8	0.24	0.10	0.43	regular
Solenocera sp.	12	0.25	0.35	1.40	aggregated
Parthenope sp.	39	1.25	2.62	2.10	aggregated
Leucosia sp.	32	0.15	0.02	0.16	regular
Portunus sp.	16	0.78	2.44	3.14	aggregated
Ebalia sp.	6	0.92	1.11	1.20	aggregated
Macrophthalmus sp.	3	0.71	0.51	0.72	regular
Ilyoplax sp.	3	0.22	0.01	0.04	regular
Alpheus spp.	30	0.50	0.85	1.72	aggregated
Athanas sp.	5	0.26	0.04	0.14	regular
Crangon sp.	5	0.41	0.21	0.50	regular
Periclimenes	5	0.11	0.01	0.07	regular
Lysmata sp.	3	0.14	0.03	0.25	regular
Acanthephyra sp.	3	0.12	0.02	0.19	regular
Diogenes sp.	10	0.26	0.07	0.25	regular
Pachycheles sp.	8	0.70	1.78	2.56	aggregated
Galathea sp.	6	0.22	0.05	0.22	regular
Pagurus sp.	6	0.09	0.01	0.13	regular
Upogebia sp.	8	0.21	0.06	0.27	regular
Callianassa sp.	6	0.07	0.01	0.14	regular

(Based on raw data of abundance)

Distribution of *L. hanseni* abundance was tested for normality by visual method (Figure 39). Values of raw abundance data distributed on the plot by curved trajectory, which suggest anomalous distribution with high significance.

Plot of observed and expected distributions (Figure 40) indicated that abundance of *Lucifer hanseni* in the RSA during winter season was well described by the model of gamma distribution. There was a mosaic spatial variability of abundance; areas with high abundance can be combined with areas of zero abundance value (Puzachenko, 2004).

Sex Composition of *L. hanseni* population was analyzed (Figure 38b). It was established that the overall sex ratio (male: female) within the population extent varied considerably. Sex ratio in the area of highest abundance (St. 36) was 2:1, while on the northern section of the RSA ranged from 1:5 – 1:8 and on southern RSA was 1:100. Such variability of the sex ratio can be attributed by possible differential mortality, restricted nutrition, different levels of activity, emigration of one sex and the utilization of different habitats by the two sexes.

Age Structure: Among the *L. hanseni* population, the following stages were identified: protozoeae, mysises I-III, juveniles, adult females and adult males.

Low abundance (0.3 ind/m^3) of the protozoeae of *L. hanseni* was exclusively found in the northern part of the Strait of Hormuz (St. 16a) (Figure 38a). Since protozoeae have short period of development, the Strait region could be a nursery area for *L. hanseni*. Spatial pattern of *L. hanseni* mysises (Figure 41) indicated that its dispersal pattern was directed from the nursery area toward the inner RSA and the Sea of Oman. Mysises of *L. hanseni* observed in few numbers as well in Saudi and Iranian coastal waters in northwestern part of the inner RSA.

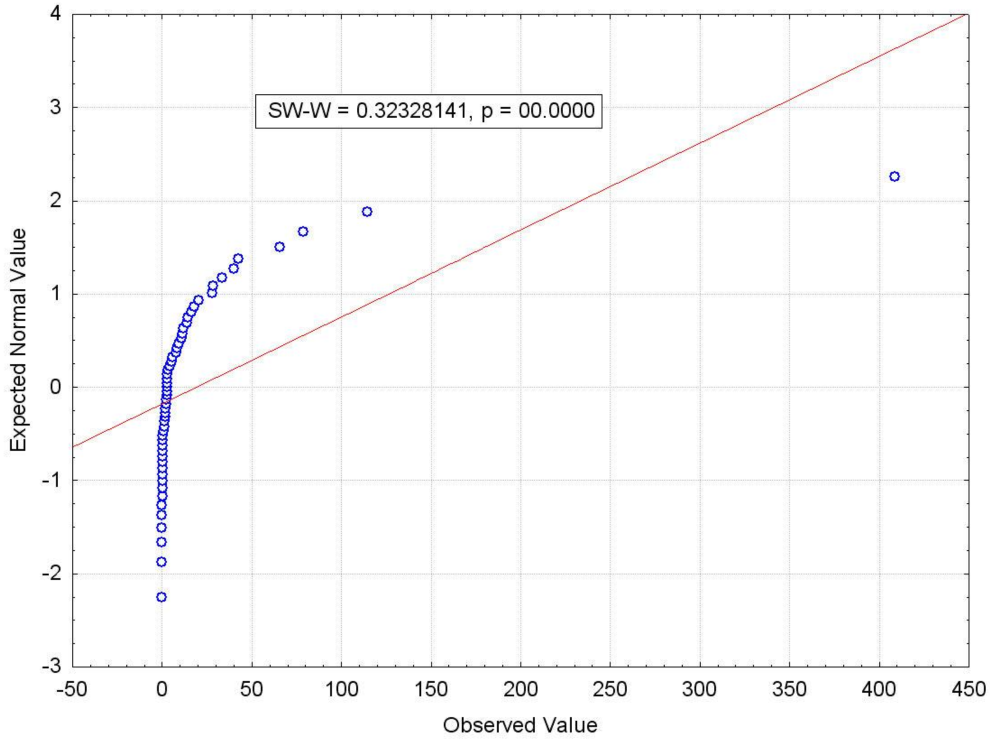


Figure 39. Normal probability plot of distribution of *Lucifer hanseni* abundance (raw data).

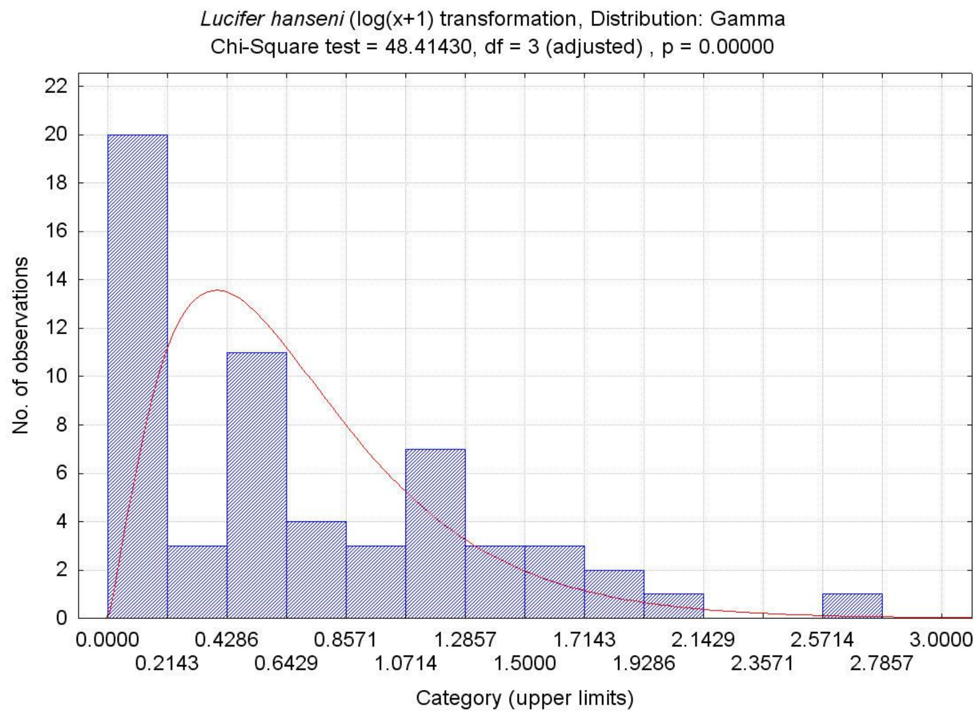


Figure 40. Frequency plot of log transformed abundance data of *Lucifer hanseni*.

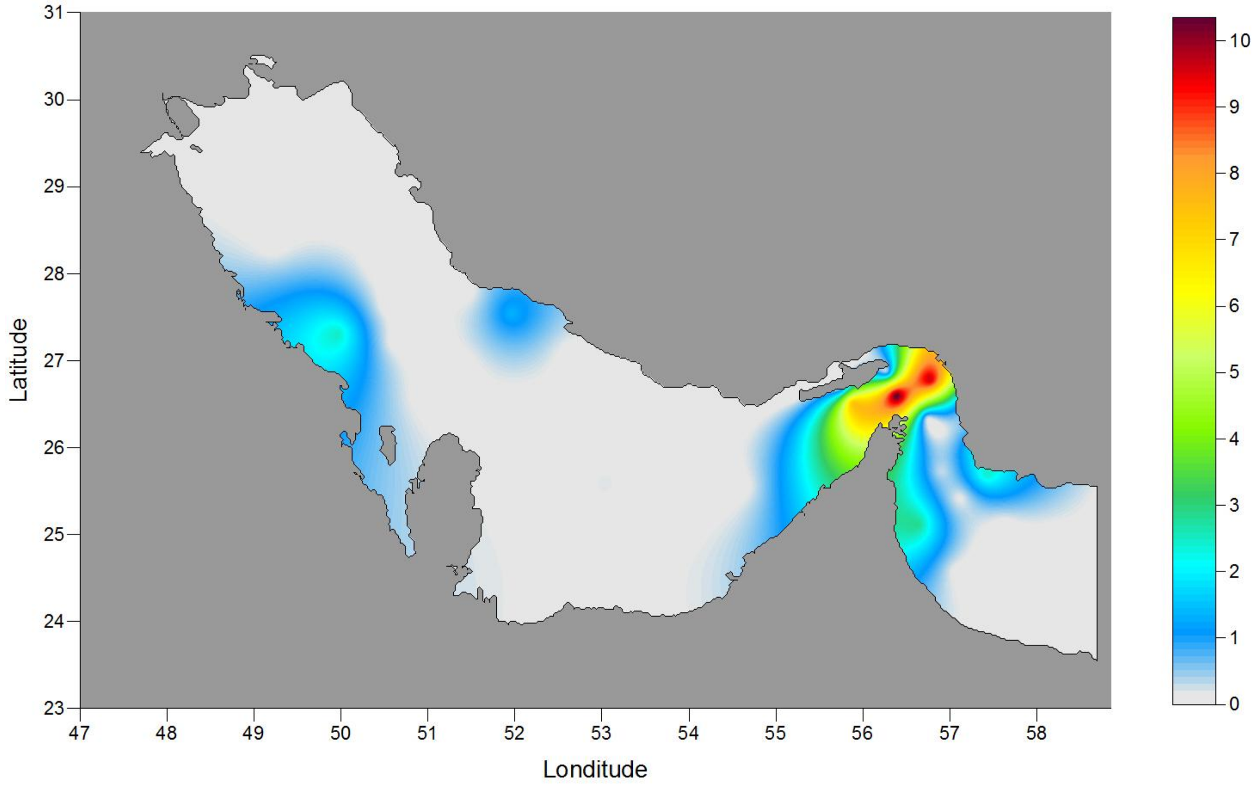


Figure 41. Spatial pattern of *Lucifer hanseni* mysises abundance.

Correlation between *L. hanseni* log transformed abundance and depth was calculated. The results indicated that there was no significant relationship between *L. hanseni* abundance and depth (r = - 0.2473, p = 0.0613) (Figure 42).

Species of the genus Lucifer occur commonly in the surface layers of tropical and subtropical waters, and they sometimes become a major component of surface-dwelling plankters (Omori, 1992). Since species of Lucifer are surface dwellers, the impact of surface currents in the region is strong as a segregation/limiting factor on their distribution.

Michel *et al*. (1986b) found that *L. hanseni* presented more than 70% of planktonic decapods in their collections from Kuwait waters. It was most abundant during summer and fall months. Grabe and Lees (1992) reported that *L. hanseni* protozoeae were collected during summer and early fall months generally in the west-central Kuwait Bay (>75%). Mysises were abundant during August and were widespread throughout Kuwait Bay. Adults were present throughout the year with 66% collected during August. The majority (52%) of the adults were found along the southern rim of Kuwait Bay, particularly during August.

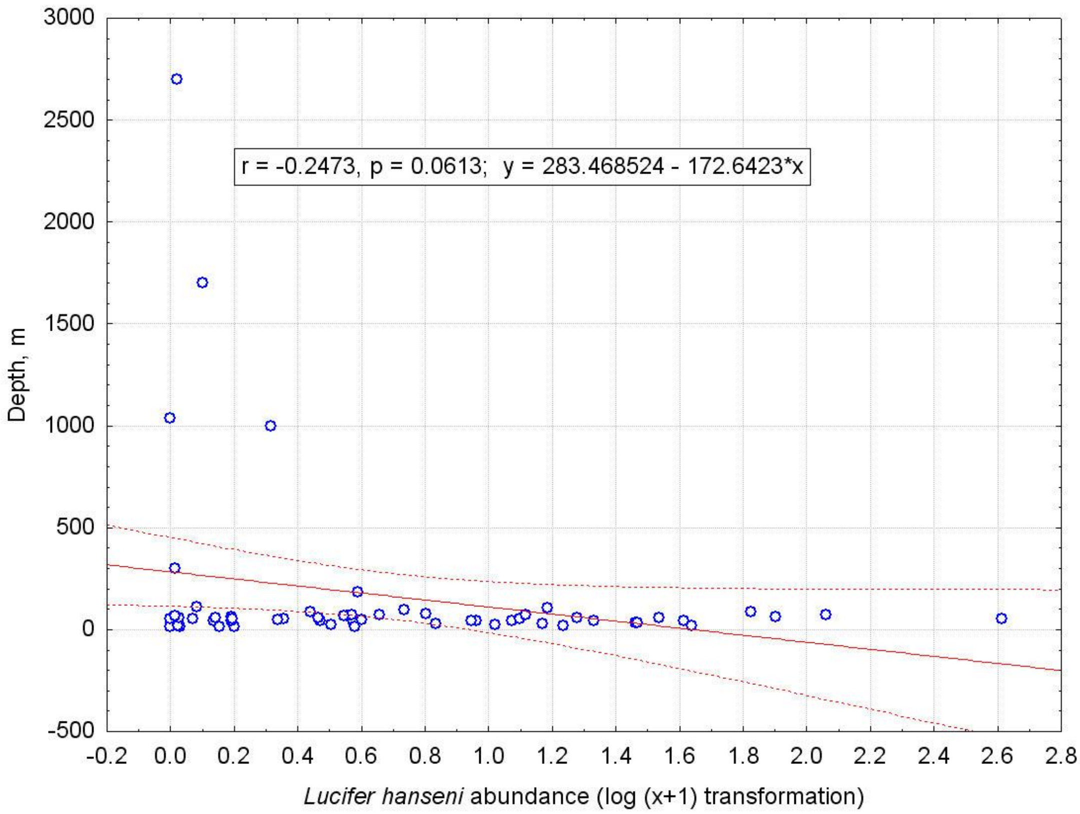


Figure 42. Correlation between *Lucifer hanseni* abundance and location depth.

Al-Aidaroos (1993) observed *Lucifer* spp. in few numbers at most sampled sites. The highest density recorded at Dawhat Abu Ali and Rennie Shoals were 18 and 13 ind/100 m^3, respectively.

Al-Yamani and Khvorov (2007) found a single specimen of *L. hanseni* offshore Bubiyan Island (in the northern inner RSA) at Khur Milh in June and Khor Abdullah in March.

Oceanic species of luciferid shrimp - *Lucifer typus* was found in the lower section of the Sea of Oman (Figure 43). Population abundance for *L. typus* ranged from 0.03 to 0.81 ind/m^3 (Table A2, Appendix A). Highest abundance was recorded at St.100 (depth 2700 m). *L. typus* population was mostly represented by adult male and females. Overall sex ratio of *L. typus* was 2:1 (male:female).

Frequency plot of log transformed abundance data of *Lucifer typus* is displayed in Figure 44.

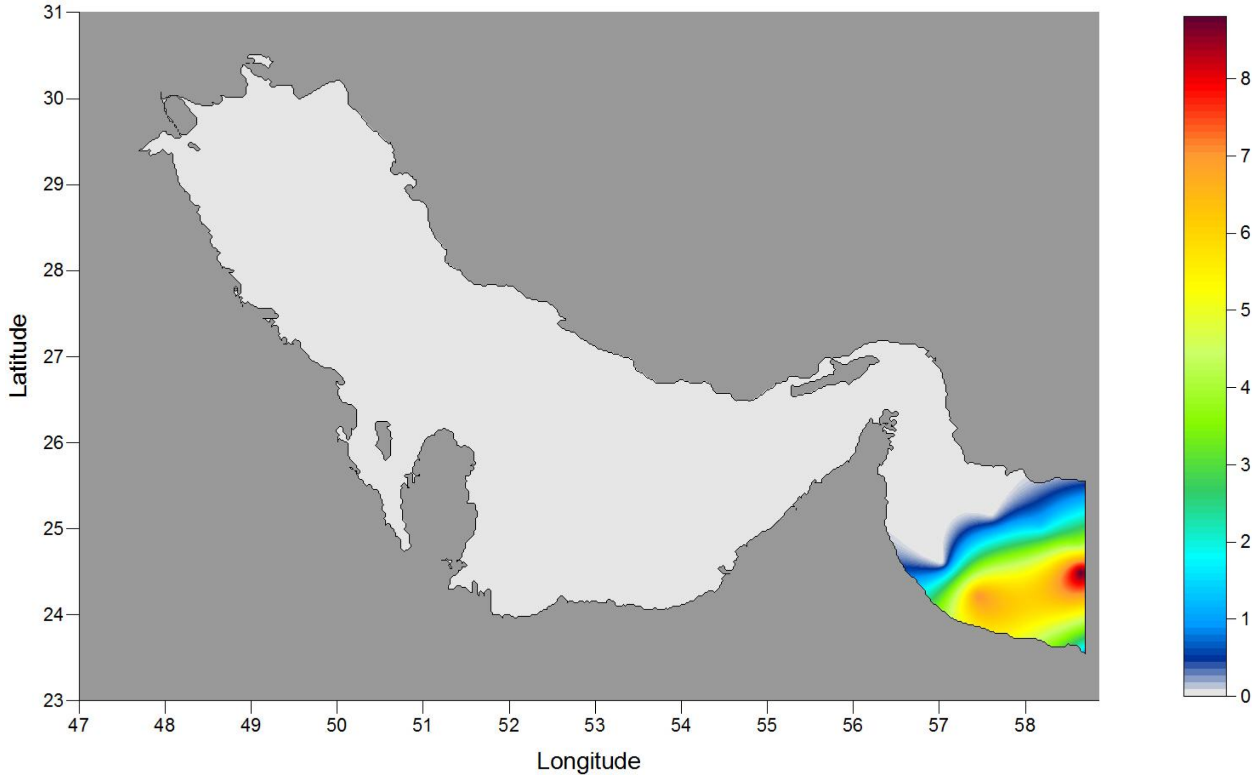


Figure 43. Distribution of *Lucifer typus* abundance.

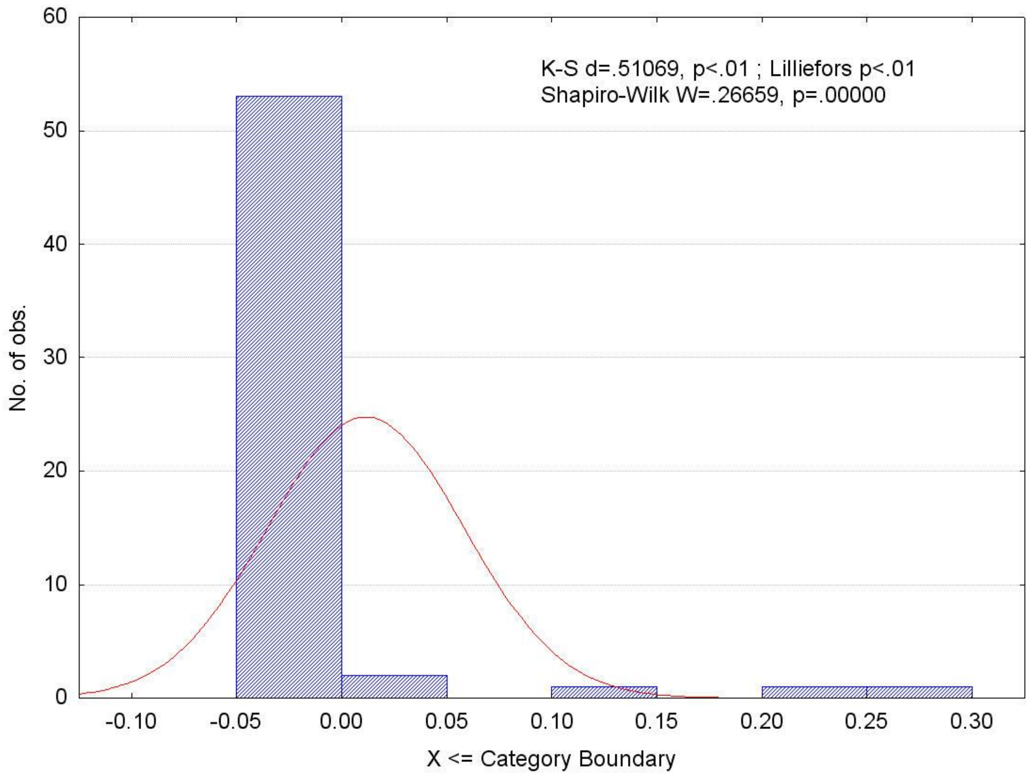


Figure 44. Frequency plot of log transformed abundance data of *Lucifer typus*.

There was a significant positive correlation between *L typus* abundance and station depth (r= 0.7435, p = 0.0000) (Figure 45). Occurrence of *L. typus* is an indicator of the influence of the Arabian Sea surface current. Populations of neritic species *L. hanseni* and oceanic *L. typus* in the Sea of Oman overlapped, although neritic pecies from St. 85 southeastward occurred in lower abundances.

L. typus is essentially an oceanic species, and the only species with circumglobal distribution in warm waters (Omori, 1992).

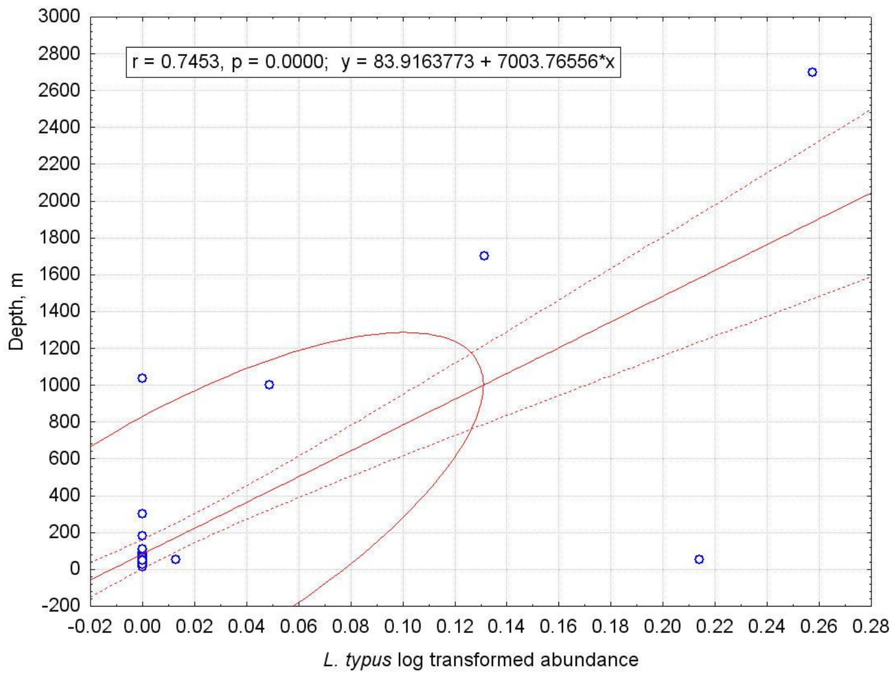


Figure 45. Correlation between *Lucifer typus* abundance and station depth.

Sergestid Shrimps: Other representatives of Sergestoidea were larvae of the holoplanktonic sergestid shrimp *Sergestes* sp**.** with an abundance that ranged from 0.03 to 3.28 ind/m^3. Highest values of abundance were recorded at St. 100 (3.28 ind/m^3) and St. 95 (2.97 ind/m^3) (Figure 46). Among the *Sergestes* sp. sampled, the following stages were identified: protozoeae, post-larvae and juveniles. Protozoeae were frequently encountered at St.100, whereas post-larvae were observed at St. 95.

Frequency plot of log transformed abundance data of *Sergestes* sp. is displayed in Figure 47. There was a significant positive correlation between *Sergestes* sp. abundance and station depth (r= 0.7539, p= 0.0000) (Figure 48). Occurrence of *Sergestes* sp. can be used as an indicator of the Arabian Sea surface current.

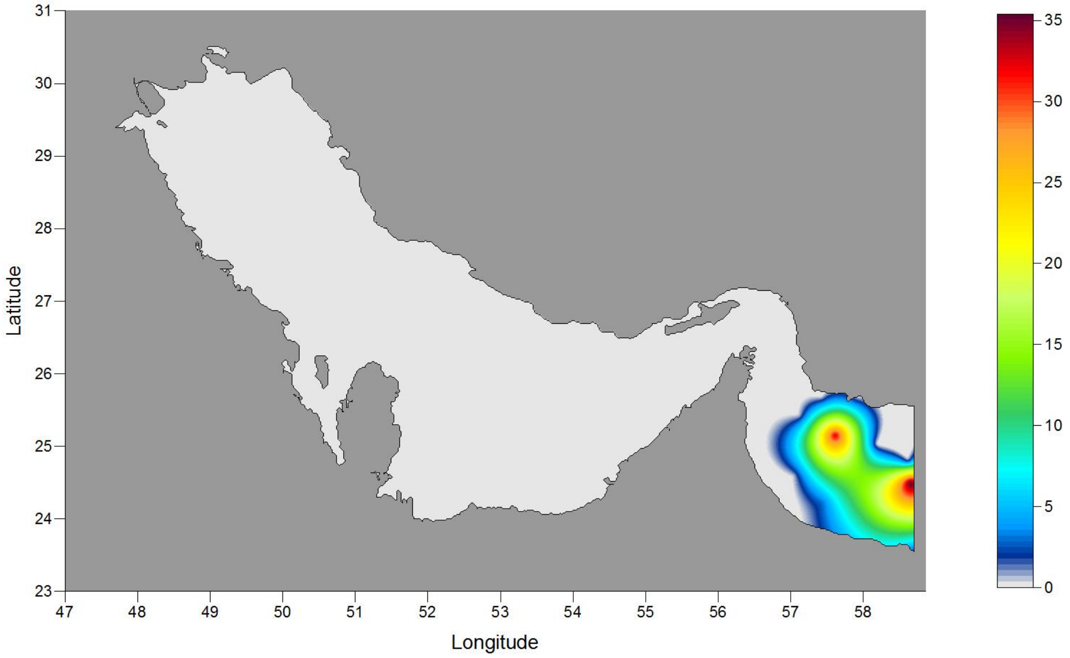


Figure 46. Spatial distribution of *Sergestes* sp. larvae.

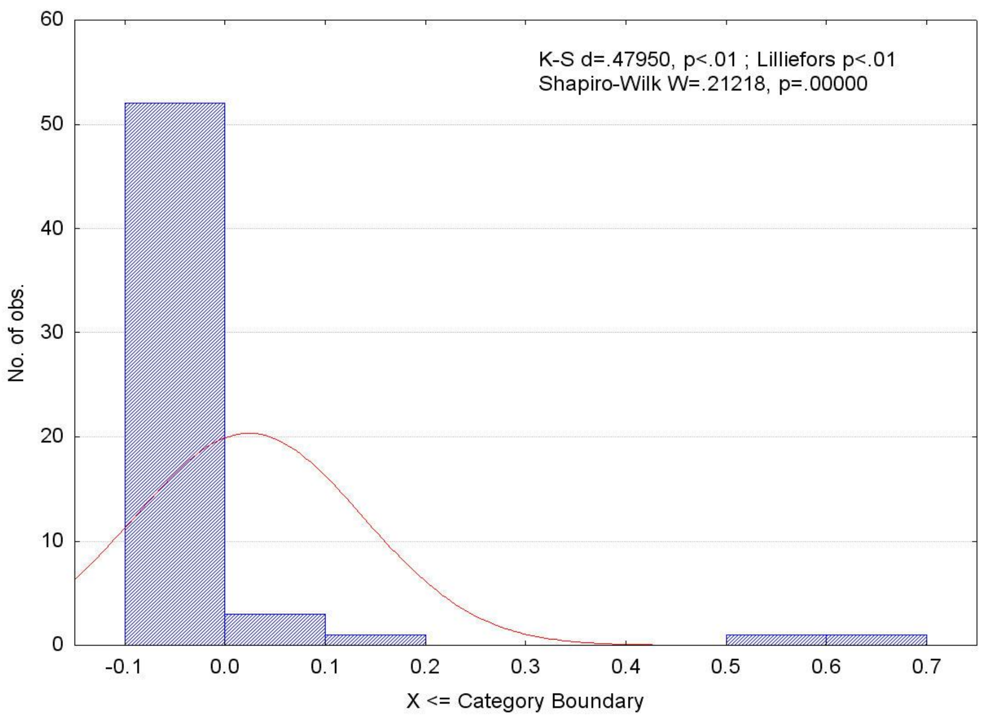


Figure 47. Frequency plot of log transformed abundance data of *Sergestes* sp.

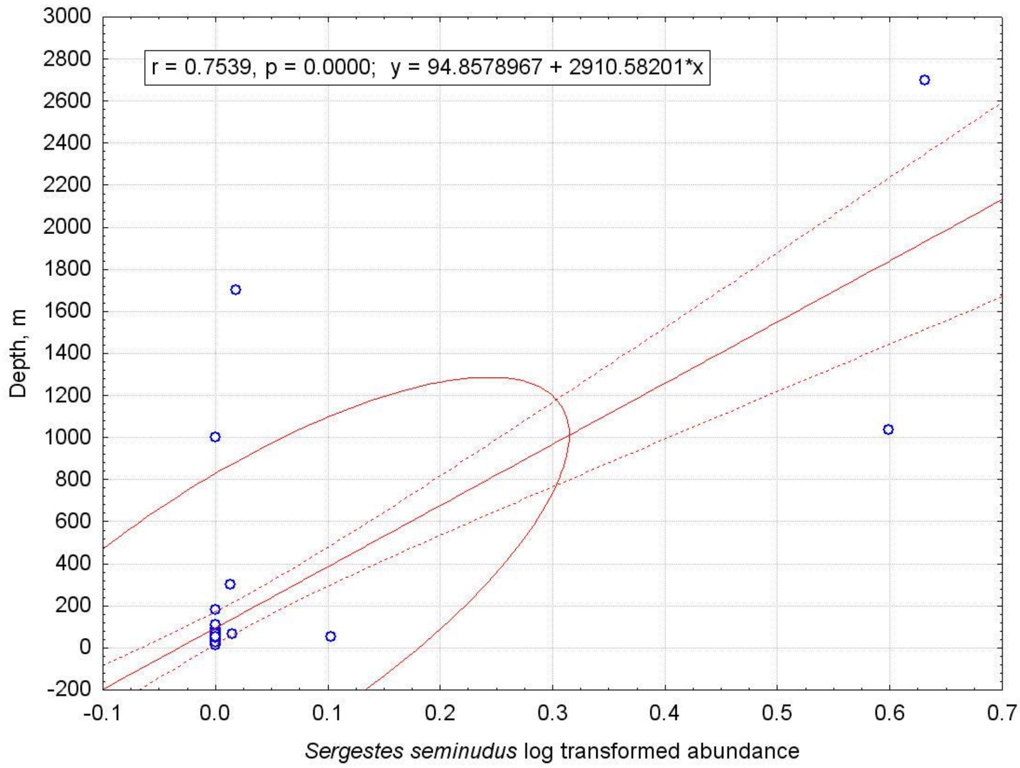


Figure 48. Correlation between *Sergestes* sp. abundance and station depth**.**

The importance of pelagic shrimps as sonic scatters, food for larger animals, and as agents in energy transfer to the deep sea is well-documented (Karuppasamy *et al*., 2006). The pelagic shrimps numerically form one of the major components of the micronekton. The pelagic shrimps of the Arabian Sea were comprised of 29 species belonging to 19 genera and 11 families. Shrimps belonging to genera *Oplophorus*, *Gennadas*, *Sergestes*, *Leptochela* and *Acanthephyra* were dominant. The species *Funchalia dana, Solenocera hextii*, *Acetes japonicus,* and *Nematocarcinus tenuirostris* were encountered only in the northern parts, and all the other species were distributed along the entire Arabian Sea. The swarming nature of pelagic shrimps was evident from the high concentrations that were often recorded. In the oceanic waters *Sergestes seminudus, Thallassocaris crinata* and *Leptochela robusta* occurred in swarms.

3.2.3.1.2 <u>Penaeiodea</u>

Penaeiodea larvae collected from the ROPME Sea Area comprised 0.7% of the total decapods composition (Figure 36). High commercial value of penaeid shrimps requires more attention to be paid to their life history stages and their spatial distribution. Penaeoid shrimps larvae, which were observed in the present collection were identified and summarized in Table 2. However, some penaeoid larvae remained unidentified.

Highest abundances of penaeid larvae in the RSA during February-March 2006 were observed in the Strait of Hormuz area– transect 14 (St. 82) (Figure 49). There is a distinct linear trend of increasing abundance of penaeid larvae towards the Indian Ocean (Figure 49, red dotted line).

Penaeid Shrimps: Larval abundance of Penaeus semisulcatus larvae ranged from 2 to 16 ind./100 m^3 (Table A2, Appendix A). Among the *P. semisulcatus* larvae sampled, the following stages were identified: protozoeae II, III; mysises I, III; and post-larvae.

P. semisulcatus protozoeae occurred exclusively in the northern part of the Sea of Oman at St. 97 (protozoeae III: 16 ind/100 m^3) and St. 87 (protozoeae II: 3 ind/100 m^3) (Figure 50).

P. semisulcatus mysises were observed at St. 87 (mysis I: 2 ind/100 m^3), in the northern part of the Strait of Hormuz (St. 16a) (mysis III: 4 ind/100 m^3) and in the open waters of the northern part of the inner RSA (St. 7a; mysis III: 3 ind/100 m^3).

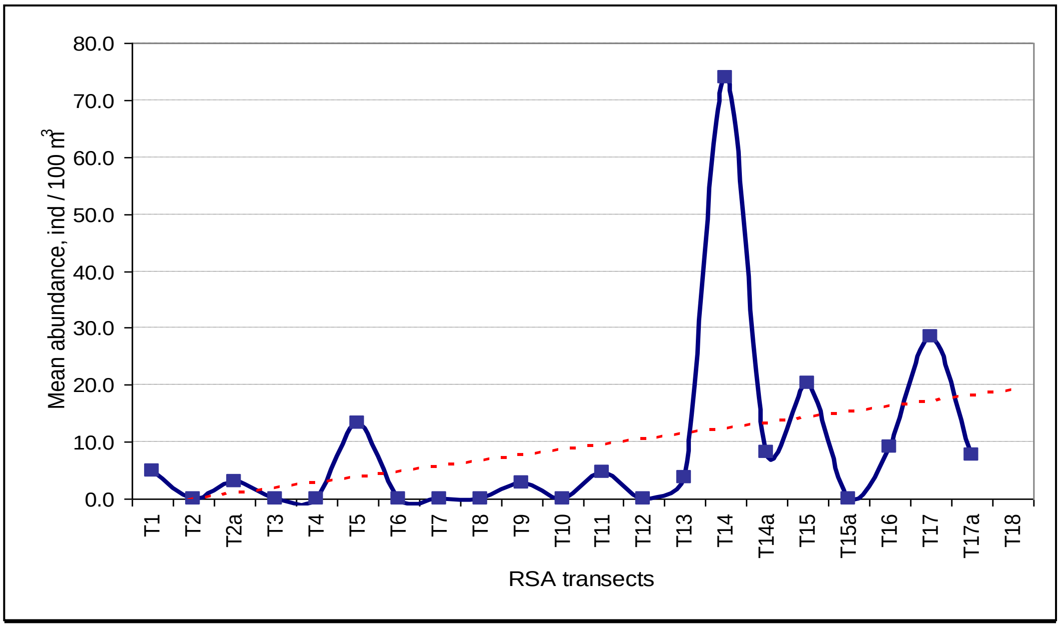


Figure 49. Spatial pattern of mean penaeid larval abundance (individuals/m^3) in the RSA (blue line). Red dotted line denotes linear increasing trend of mean abundance.

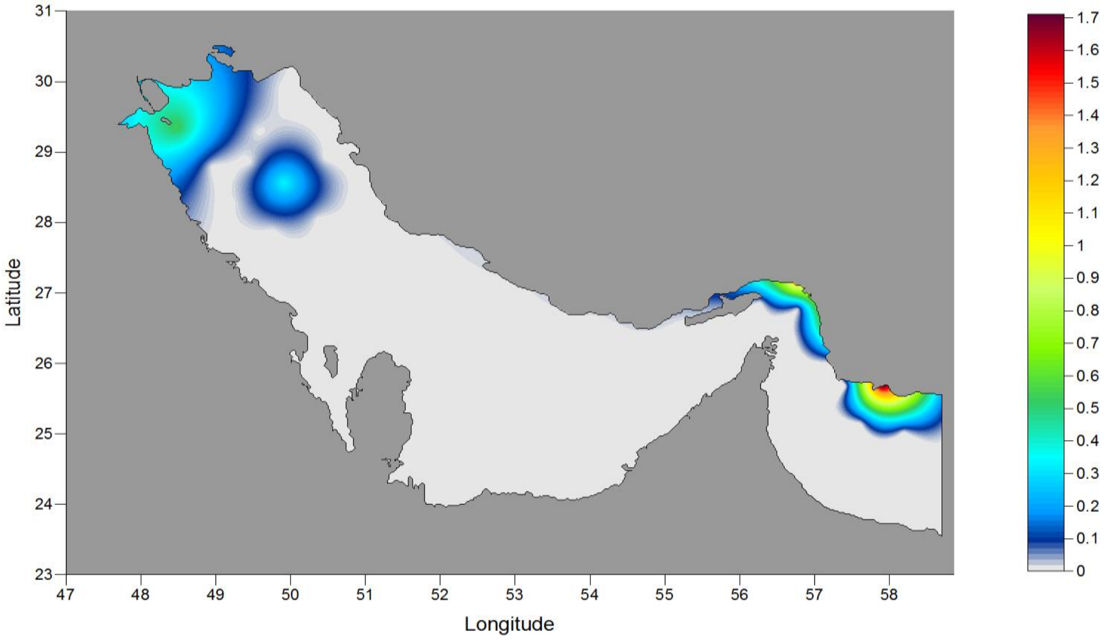


Figure 50. Spatial patterns of *Penaeus semisulcatus* larval abundance**.**

P. semisulcatus post-larvae were recorded at St.87 (3 ind/100m^3), in the northern part of the Hormuz Strait (St. 16a) (6 ind/100 m^3) and Kuwait waters (St.1) (5 ind/100 m^3). The frequency of occurrence of *Penaeus semisulcatus* larvae is displayed in Figure 51. Figure 52 shows the correlation between *Penaeus semisulcatus* larval abundance and station depth.

Parapenaeopsis stylifera larval abundance (Figure 53) ranged from 2 to 83 ind/100 m^3 (Table A2, Appendix A). Among the identified specimens were protozoeae and mysises stages. Ditsribution of *P. stylifera* protozoea in the Sea of Oman was very similar to the distribution of *P. semisulcatus* (Figure 50). Highest abundance value of *P. stylifera* protozoea III was observed at St.87 (66 ind/100 m^3). Mysises I were most abundant at the above station (83 ind/100 m^3). In general, mysises I were widely distributed within the RSA. Recorded abundances in Kuwait waters at St.1 was 5 ind/ 100 m^3, in the northern part of the inner RSA at St.17 it was 3 ind/100 m^3, in the central part of the inner RSA at St. 55, the abundance was 3 ind/100 m^3 and in the central part of the Sea of Oman at St. 23a, the abundance was 12 ind/100 m^3. Mysises II occurred in the northern part of the Strait of Hormuz at St.16a (15 ind/100 m^3). Frequency of distribution, as well as correlation with station depth is displayed in Figures 54 and 55.

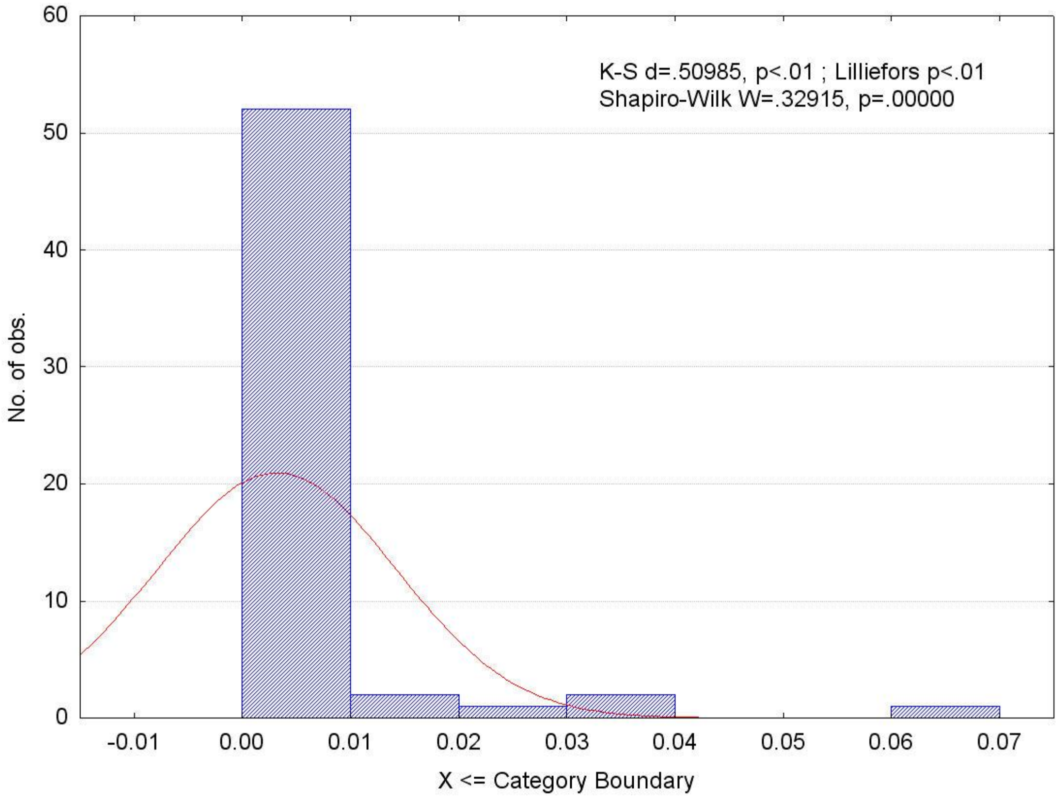


Figure 51. Frequency plot of log transformed abundance data of *Penaeus semisulcatus.*

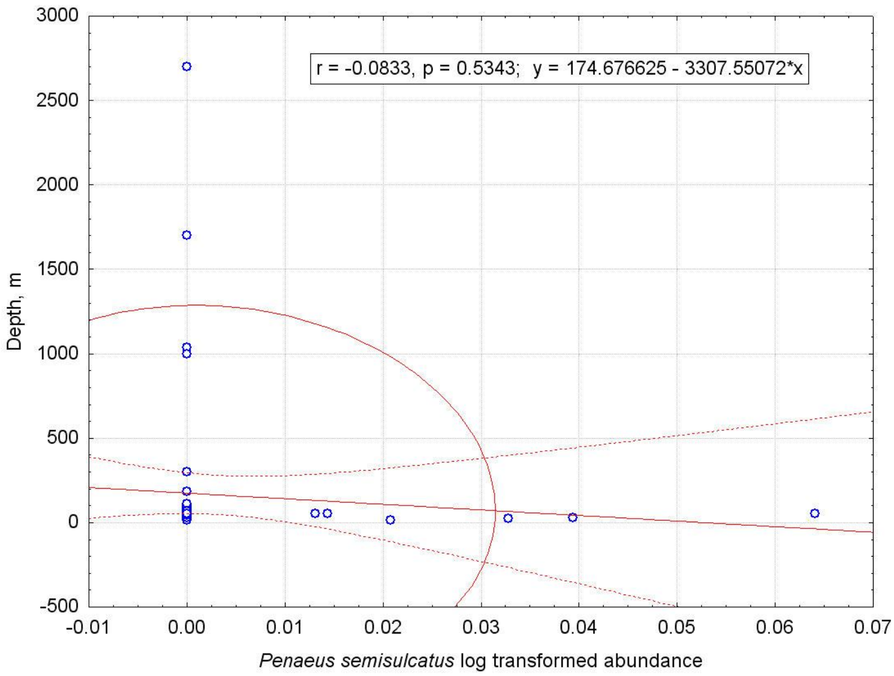


Figure 52. Correlation between *Penaeus semisulcatus* larval abundance and station depth.

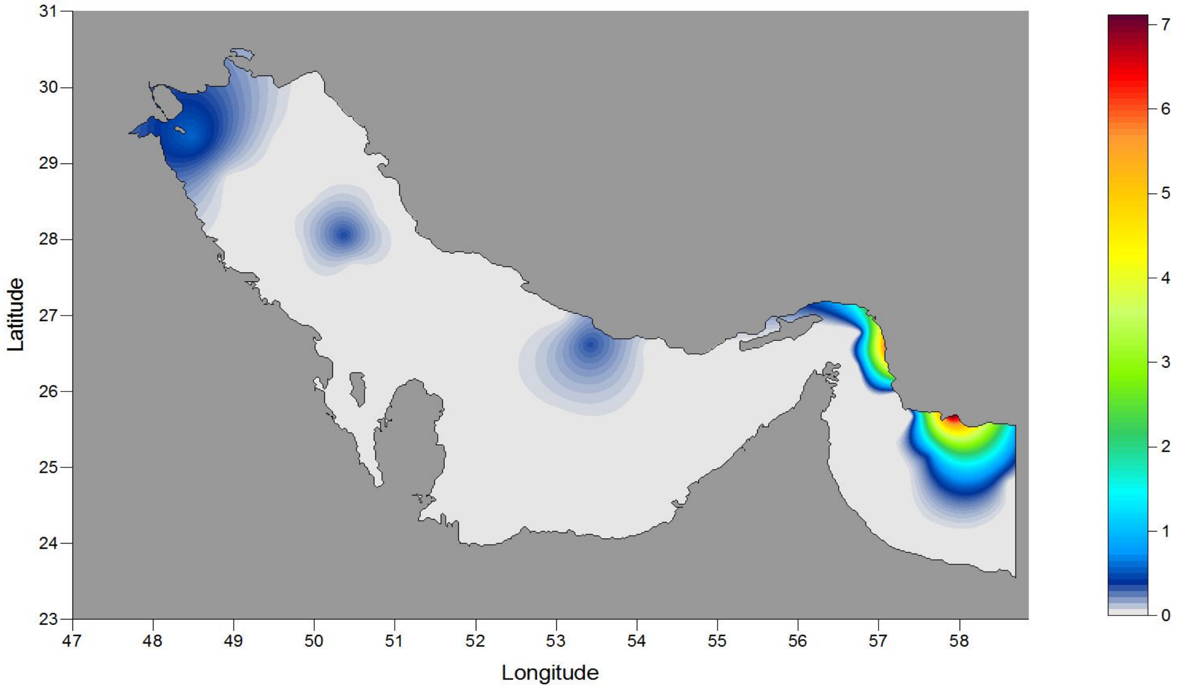


Figure 53. Spatial pattern of *Solenocera hextii* larval abundance.

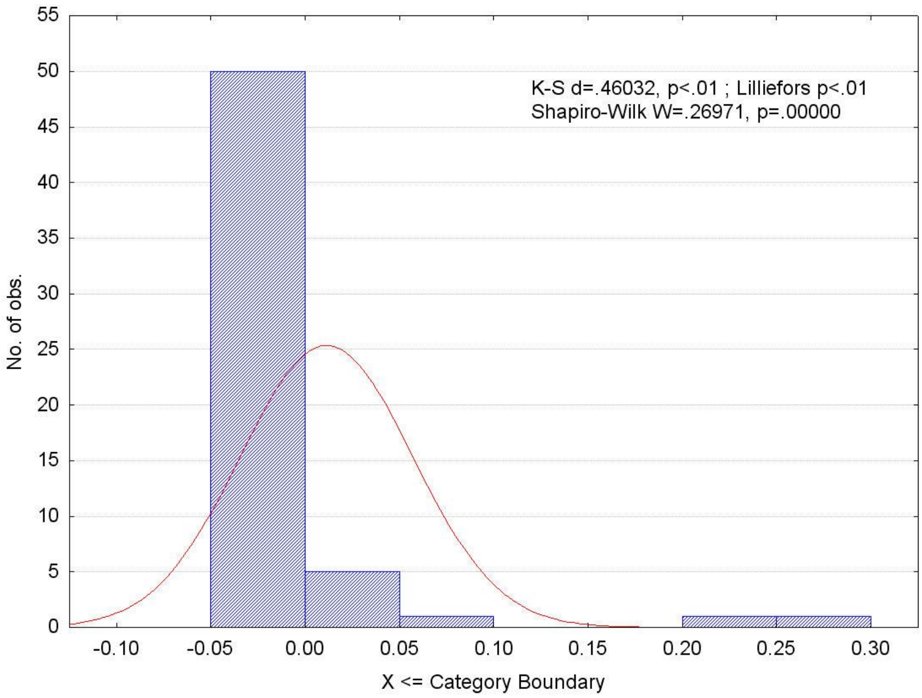


Figure 54. Frequency plot of log transformed abundance data of *Parapenaeopsis stylifera*.

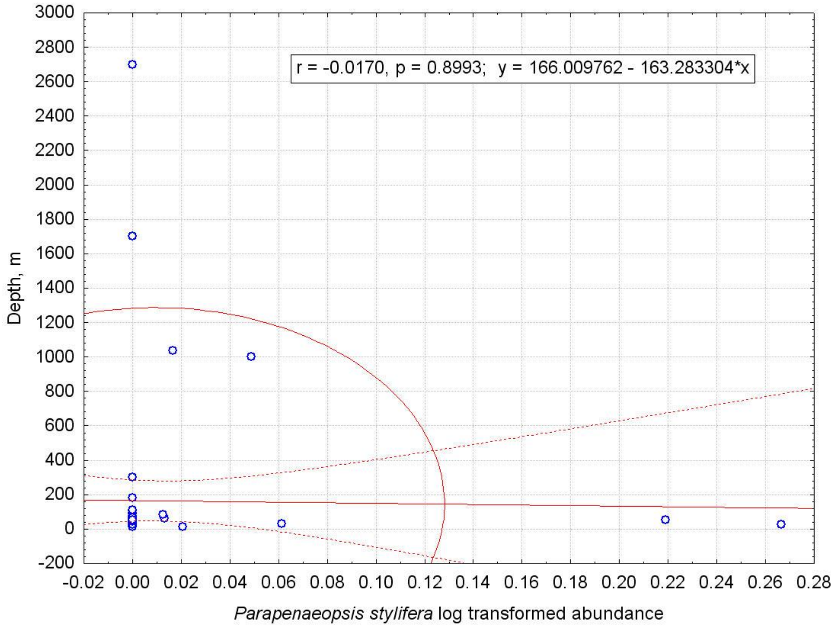


Figure 55. Correlation between *Parapenaeopsis stylifera* abundance and Station depth.

Metapenaeus ensis protozoeae II was found as a single specimen in the southern part of the Sea of Oman (St. 25a).

Solenocerid Shrimps: *Solenocera crassicornis* (coastal mud shrimp) and *S. hextii* (deep sea mud shrimp) larvae were identified within the RSA plankton collection.

Abundance of *S. hextii* ranged from 2 to 211 ind/100 m^3. Among the sampled specimens that were identified were the following stages: protozoea and mysises. Protozoeae of *S. hextii* were found in the northern (St. 98: 13 ind/100 m^3) and southern (St. 92: 15 ind/100 m^3) parts of the Sea of Oman (Figure 56). Highest abundance value of *S. hextii* mysises was recorded in the eastern part of the inner RSA near Qeshm Island (St. 70: 211 ind/100 m^3). Mysises of *S. hextii* were observed in the Strait of Hormuz (St. 77, and St. 82: 22 ind/100 m^3) and the western (Stations 87, 19a, and 90) and central (St. 95) parts of the Sea of Oman in low abundances. Frequency of distribution, as well as correlation with station depth are displayed in Figures 57 and 58.

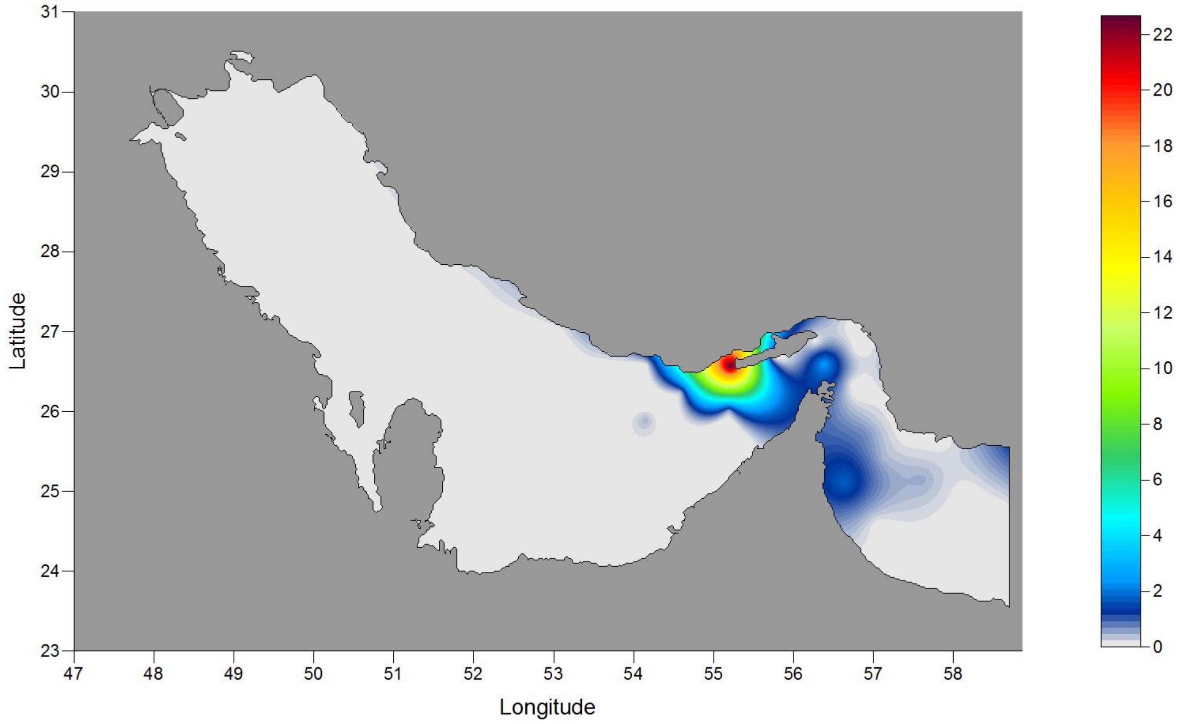


Figure 56. Distribution of the larvae of *Solenocera* sp.

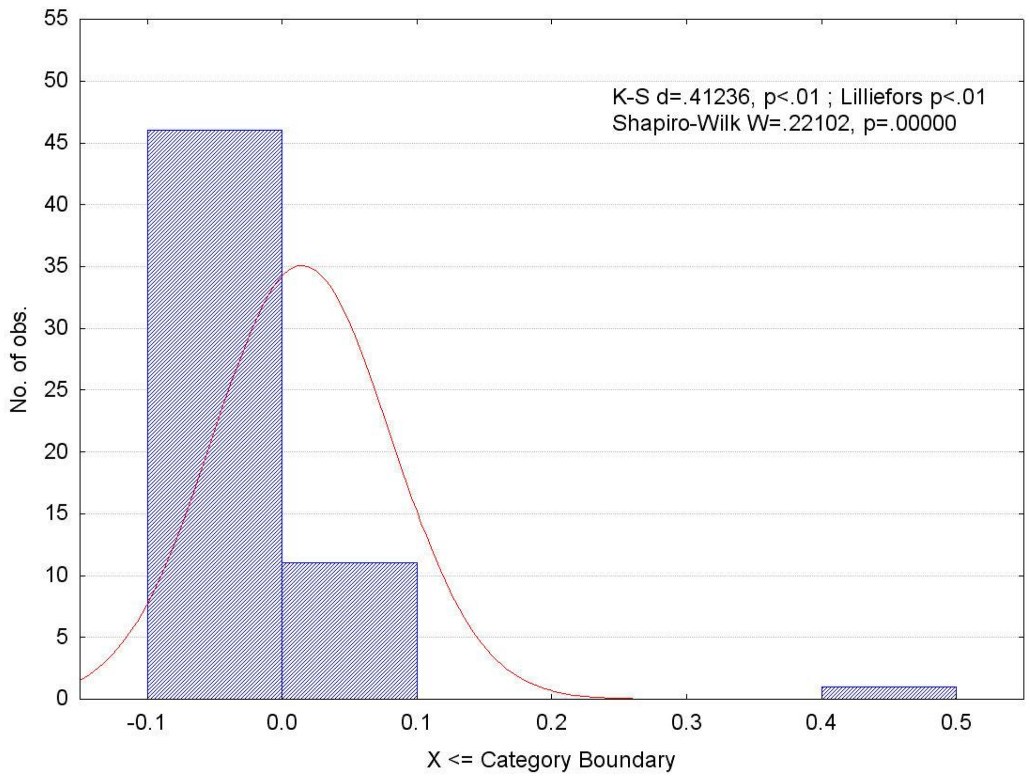


Figure 57. Frequency plot of log transformed abundance data of *Solenocera* sp.

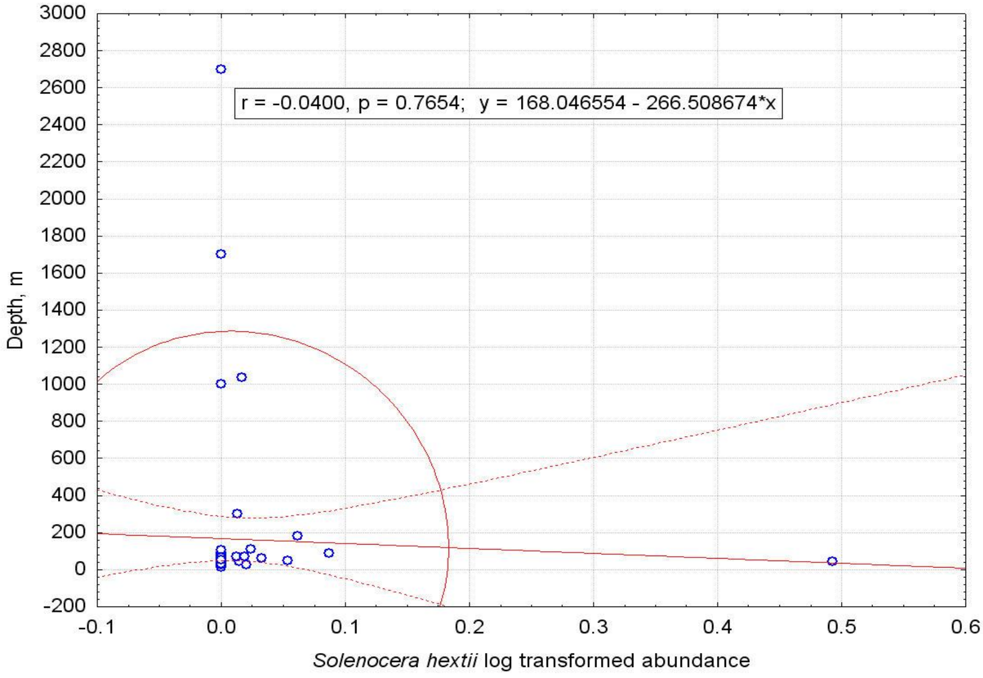


Figure 58. Correlation between *Solenocera* sp. abundance and location depth.

There are about 14 reported species of penaeid shrimps in the inner RSA (Al-Yamani *et al*., 1995 and Enamoto, 1971):

- Fiddler shrimp -*Metapenaeopsis stridulans;*
- Jinga shrimp - *Metapenaeus affinis;*
- Kadal shrimp - *Metapenaeus dobsoni;*
- Peregrine shrimp - *Metapenaeus stebbingi;*
- Kiddi shrimp - *Parapenaeopsis stylifera*
- Indian white prawn - *Penaeus indicus;*
- Kuruma prawn - *Penaeus japonicus;*
- Western king prawn - *Penaeus latisulcatus;*
- Green tiger prawn – *Penaeus semisulcatus;*
- Banana prawn – *Penaeus merguiensis*
- coastal mud shrimp – *Solenocera crassicornis;*

- Southern rough shrimp - *Trachypenaeus curvirostris;*
- Coarse shrimp - *Trachypenaeus granulosus;*
- *Trachypenaeus pescadoriensis;*

3.2.3.2 Pleocyemata

3.2.3.2.1 Brachyura

Brachyuran larvae, which were sampled in the ROPME Sea Area during the Winter Cruise of 2006 formed 8.3% of the total planktonic decapod composition (Figure 59), with a total abundance of 99.8 ind/m^3. Figure 59 displays the percentage composition of the different groups of brachyuran larvae in the RSA. Brachyuran larvae were widely distributed in the RSA with peak abundance in the northwestern part of the inner RSA (St. 1 in Kuwait waters) (Figures 60 and 61). They commonly occur in the inshore plankton community in lower latitudes (Al-Yamani and Khvorov, 2007).

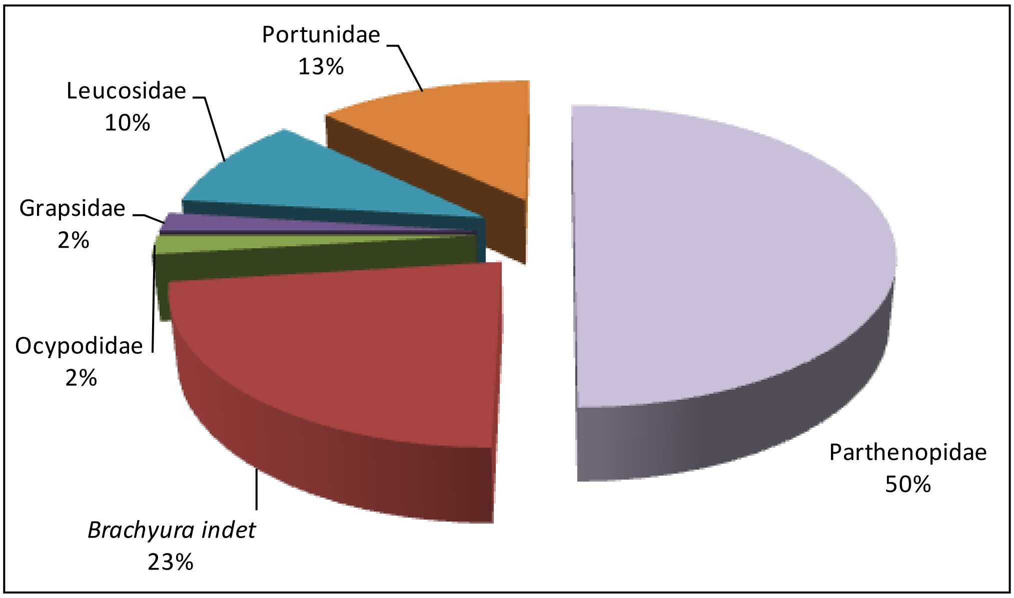


Figure 59. Composition of Brachyuran larvae in the RSA.

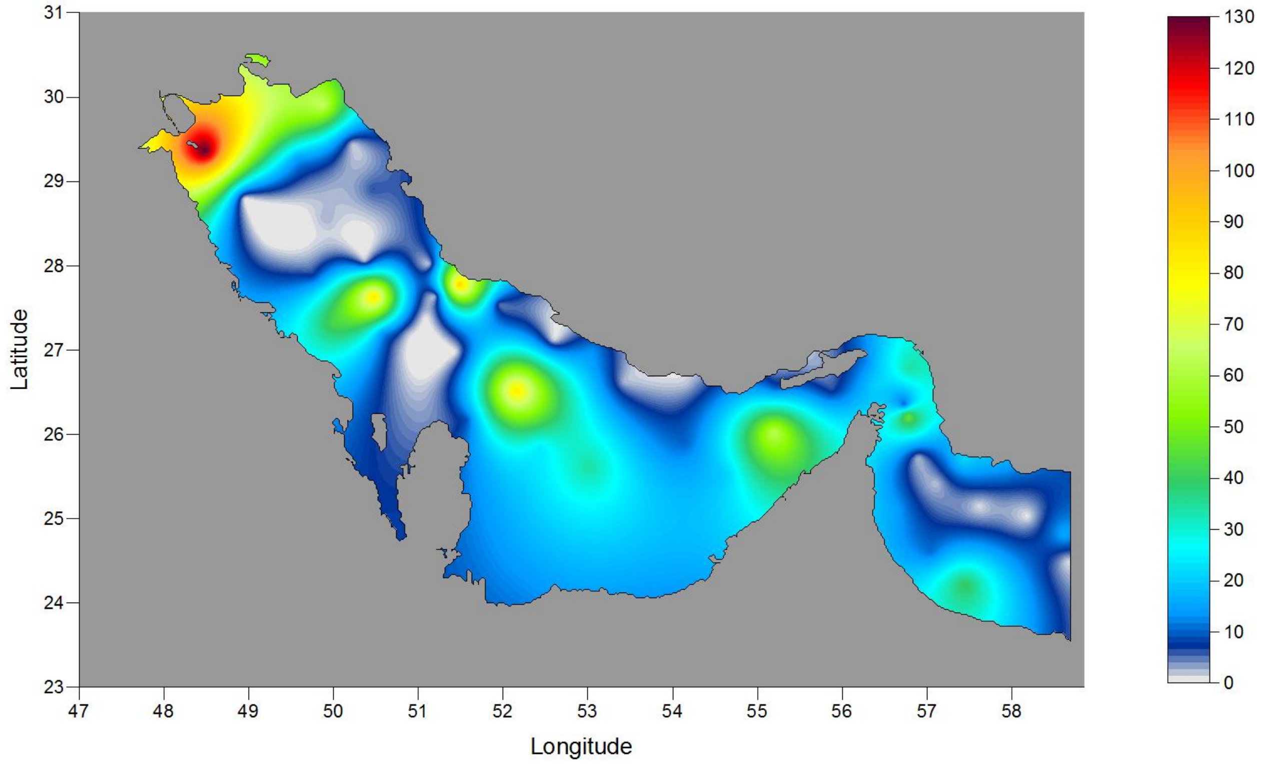
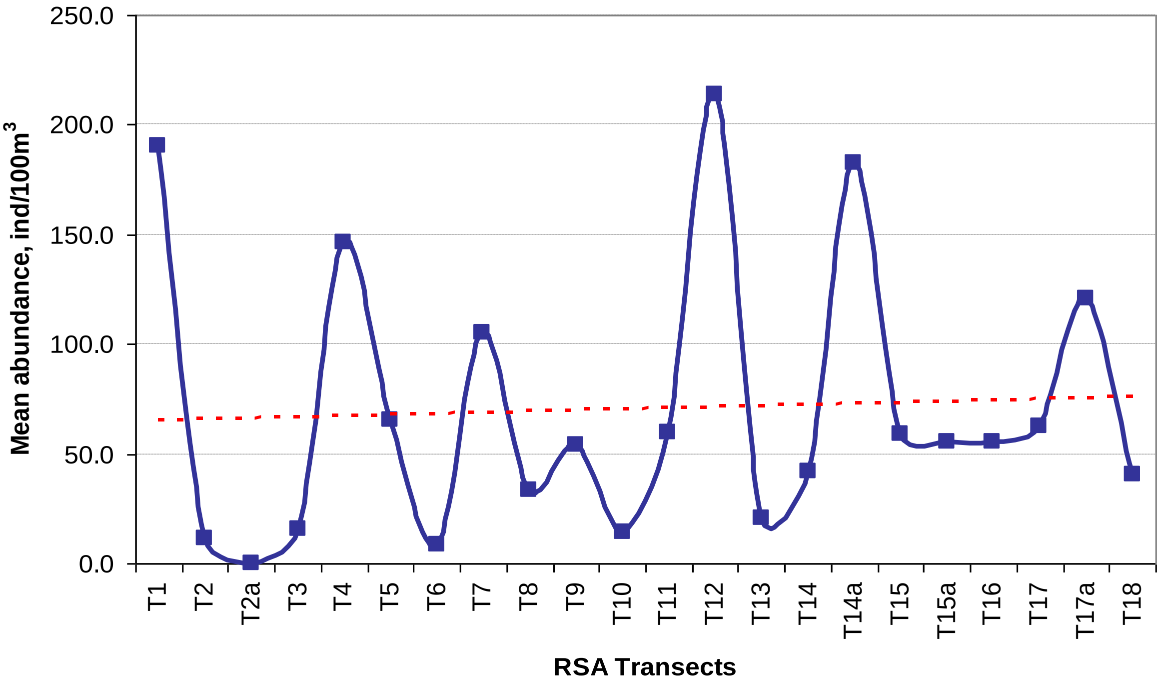


Figure 60. Spatial distribution of the brachyuran larvae in the RSA.



Red dotted line denotes linear increasing trend of mean abundance.

Figure 61. Spatial pattern of brachyuran larval mean abundance in the RSA (blue line).

Parthenopidae: *Parthenope* sp. larvae were the most abundant group in the brachyuran winter assemblage (50%) (Figure 59). Its abundance ranged from 0.01 to 7.40 ind/m^3. Among the sampled Parthenopidae larvae, only *Parthenope* sp. zoeae III-VIII were identified. The highest abundance of zoeae occurred at St. 22 (7.4 ind/m^3) (Figure 62). Zoea`e of *Parthenope* sp. were frequently distributed in the RSA: in the central (St. 36: abundance of 3.8 ind/m^3) and southern section of the inner RSA (St. 72, abundance of 5 ind/m^3), in the southern section of the Strait of Hormuz (St. 14a: 3.1 ind/m^3), and in the western (St. 85: 3.0 ind/m^3) and southern parts (St. 25a: 3.22 ind/m^3) of the Sea of Oman. Frequency of distribution, as well as correlation with station depth are displayed in Figures 63 and 64.

Portunidae: Portunidae larvae are less abundant brachyuran group in the RSA (13%). Among Portunidae sampled were identified zoeae (46%) and megalopa (54%). Highest value of Portunidae zoeae abundance occurred in the northwestern part of the inner RSA (St.11a, 5.86 ind/m^3), whereas megalopa were abundantly distributed in central part (St. 36, 3.17 ind/m^3) (Figure 65). Frequency of distribution, as well as correlation with station depth is displayed in Figures 66 and 67.

Leucosiidae: Leucosiidae larvae comprised 10% out of the total of Brachyuran larvae. It was represented by *Ebalia* sp. and *Leucosia* sp. zoeae. Highest abundance of Ebalia larvae were recorded in Kuwait waters (St. 1: 2.55 ind/m^3) (Figure 68a). Zoeae of *Leucosia* sp. were widely distributed within the RSA but in low abundance (Figure 68b).

Frequency of distribution, as well as correlation with station depth are displayed in Figures 69 and 70. Al-Aidaroos (1993) reported that zoeae of Brachyurans dominated the decapod larvae recorded in the area by 63.3% varying between 90% at Station A (Kuwait waters) and 10.3% at Station F (Dawhat Abu Ali) in spring time. These are Majidae (2%), Hymenostomatidae (6.3%), Leucosiidae (12.3%) and Ocypodidae (21.5%).

Al-Yamani and Khvorov (2007) found that Brachyuran larvae off Bubiyan Island in the NIG were the most abundant group among the decapods (St. 69: 3%) year around. Ocypodid larvae were the most abundant brachyuran zoeae, occurring all year (with rare exception), but peaking in spring (March, May). Highest composition of brachyuran larvae and lowest composition of carideans, thalassinids, anomurans, sergestids and penaeids larvae were recorded during the colder season.

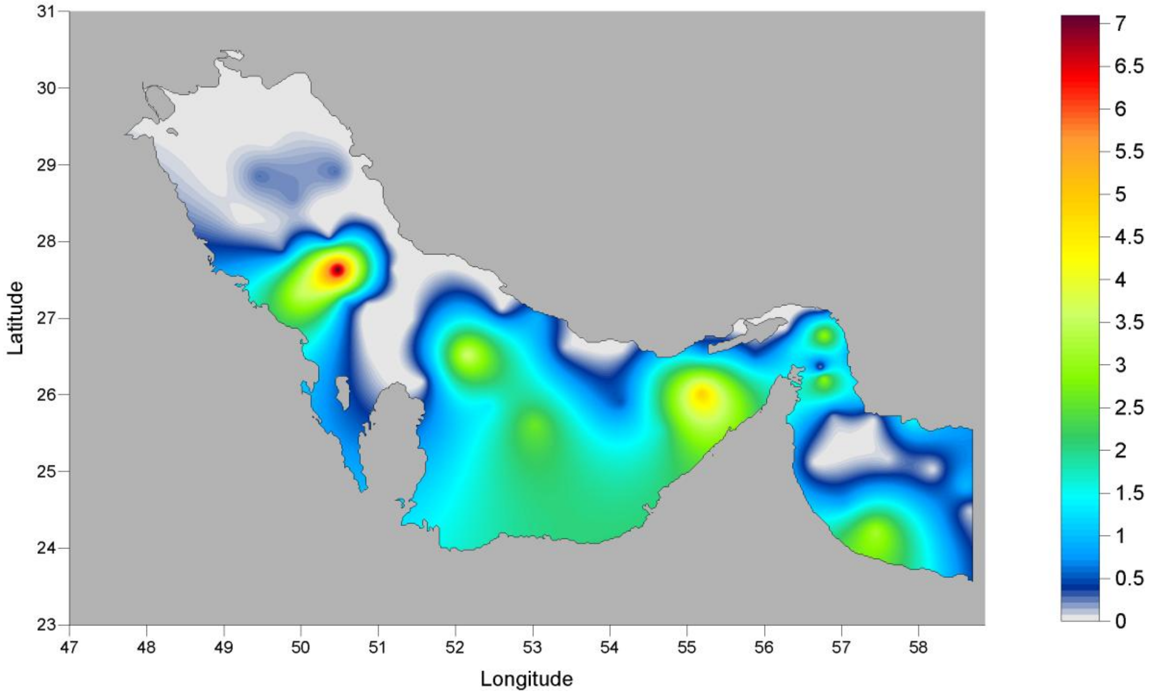


Figure 62. Spatial distribution of *Parthenope* sp. zoeae in the RSA.

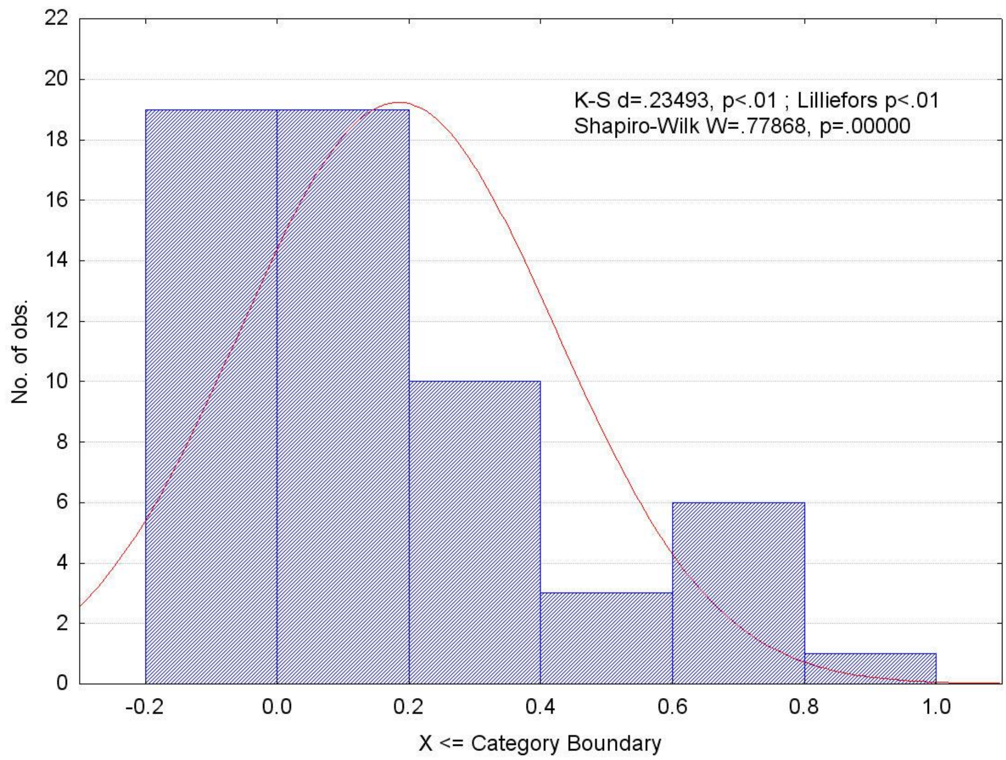


Figure 63. Frequency plot of log transformed abundance data of *Parthenope* sp.

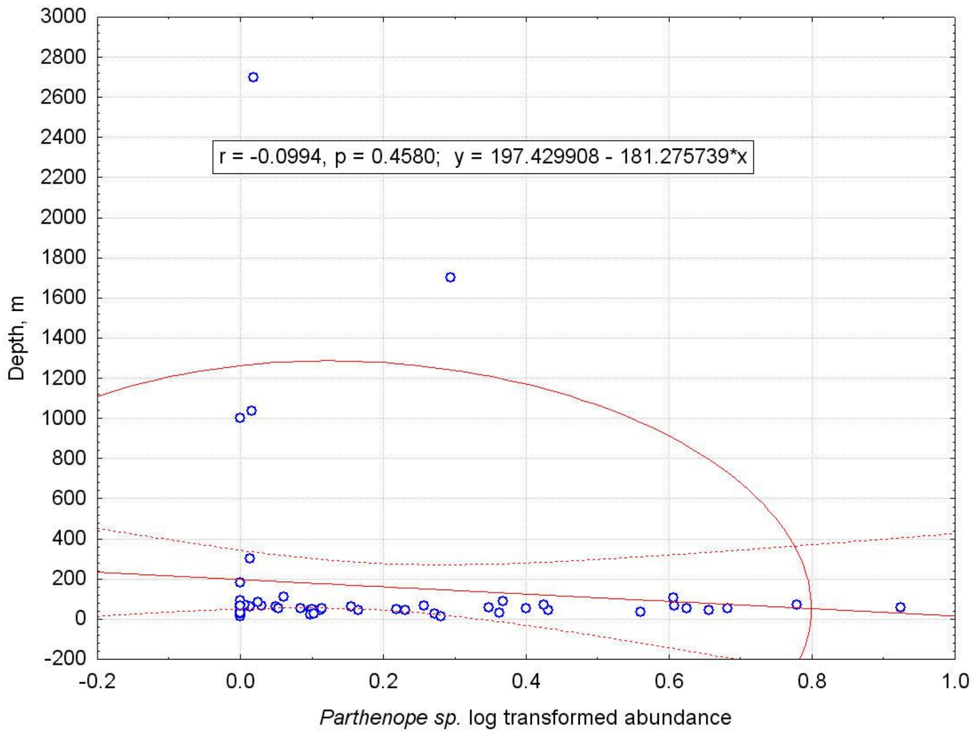


Figure 64. Correlation between *Parthenope* sp. abundance and location depth.

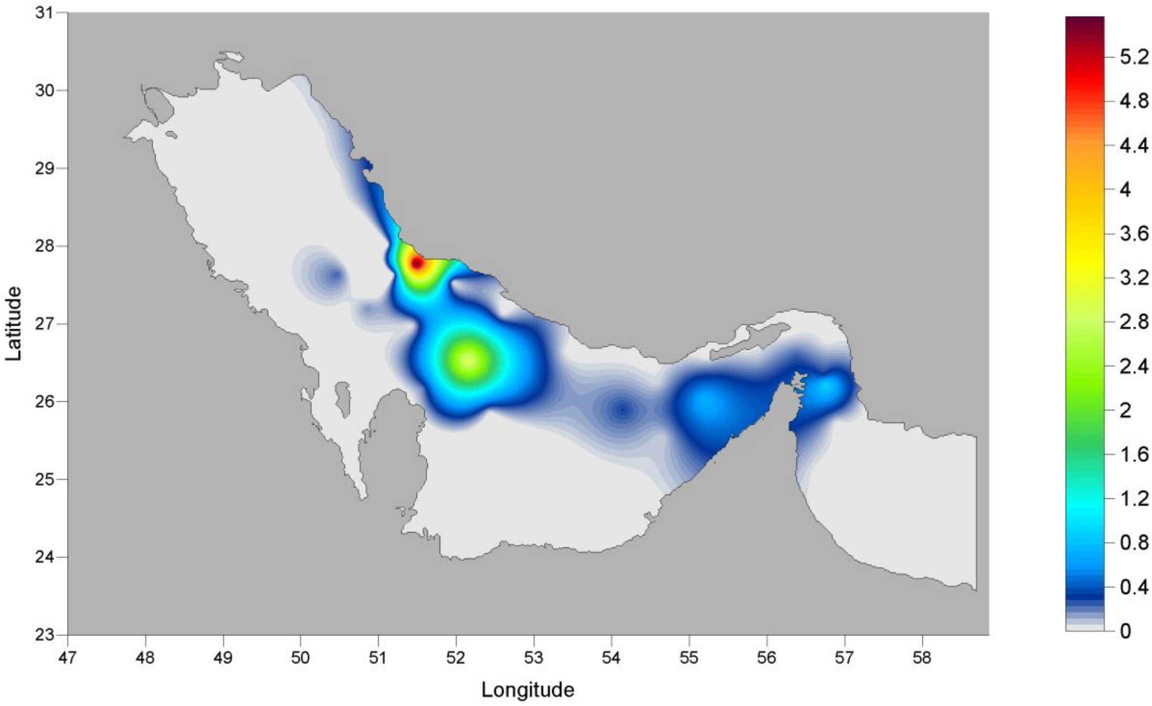


Figure 65. Spatial distribution of *Portunus* sp. larvae in the RSA.

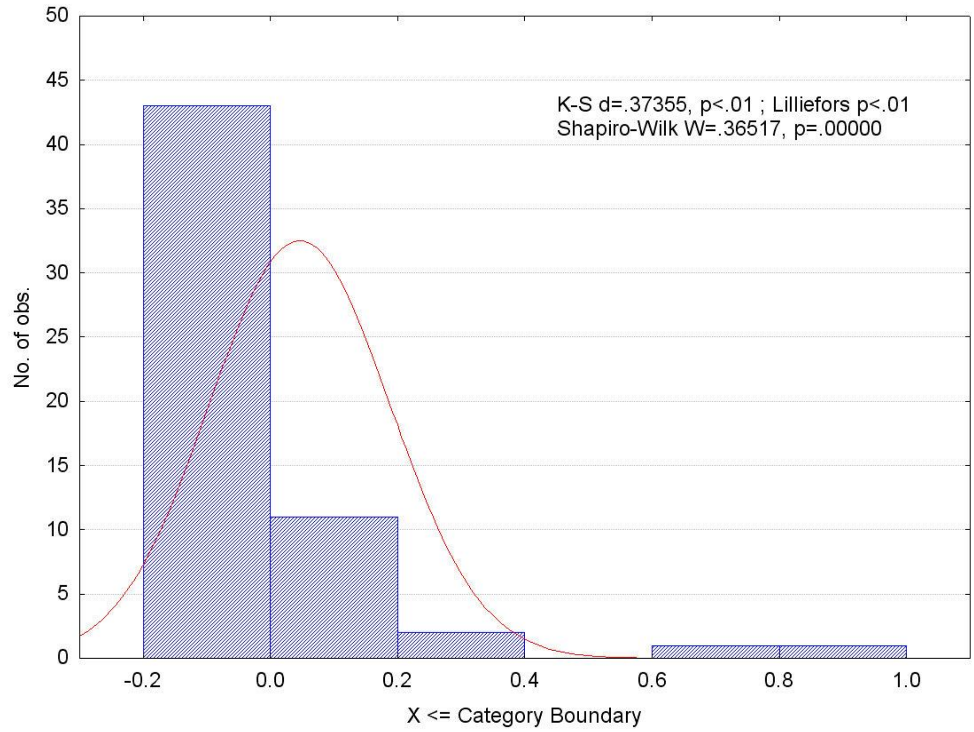


Figure 66. Frequency plot of log transformed abundance data of *Portunus* sp.

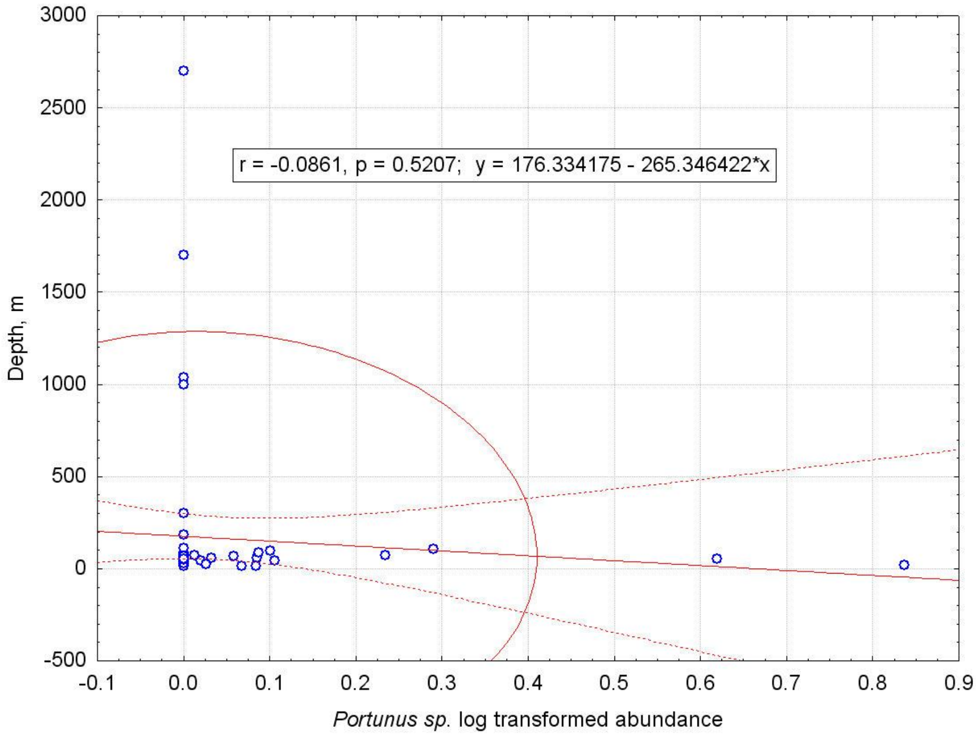
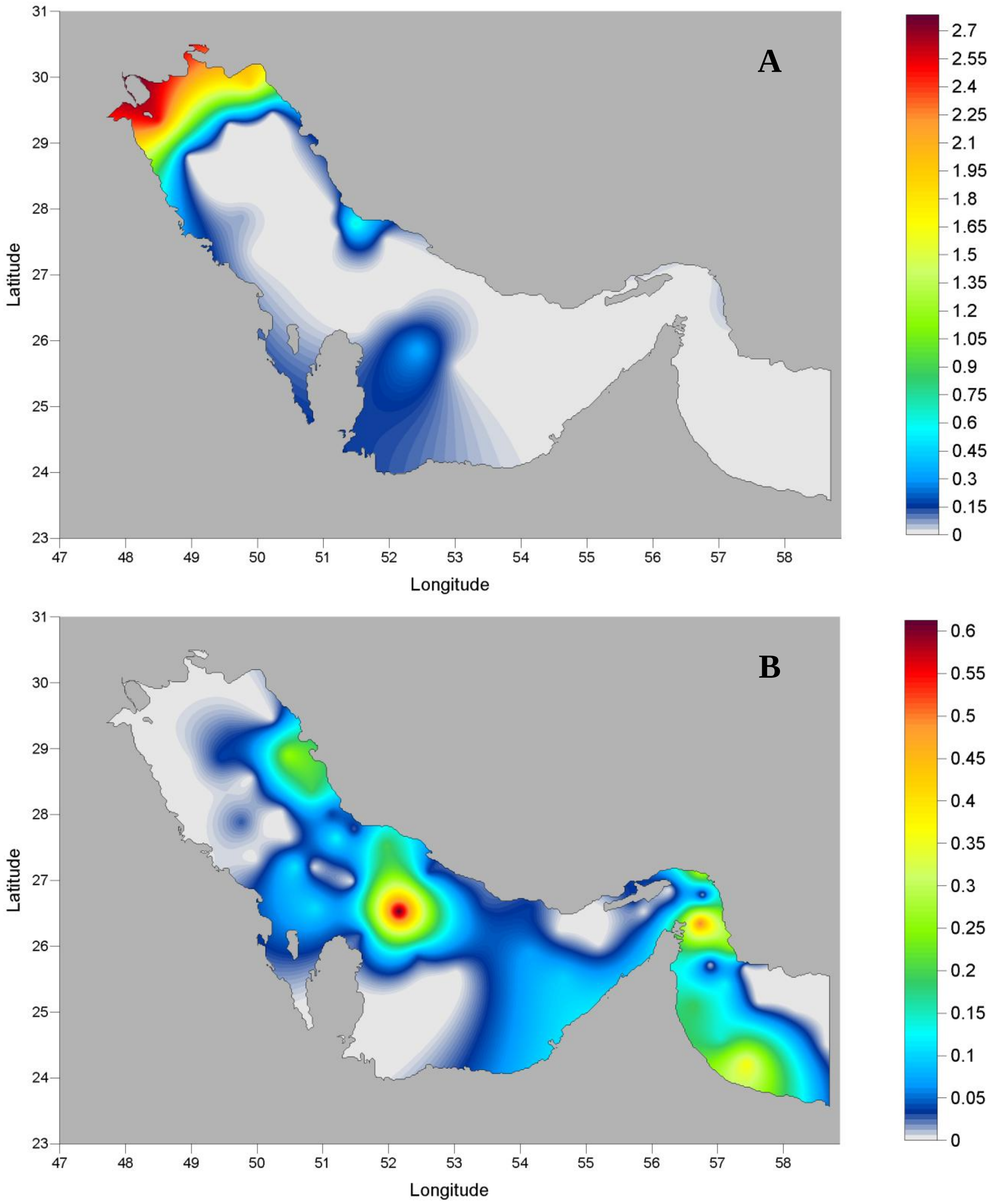


Figure 67. Correlation between *Portunus* sp. abundance and location depth.



A – *Ebalia* sp.; B- *Leucosia* sp.

Figure 68. Spatial distribution of *Leucosidae* larvae in the RSA.

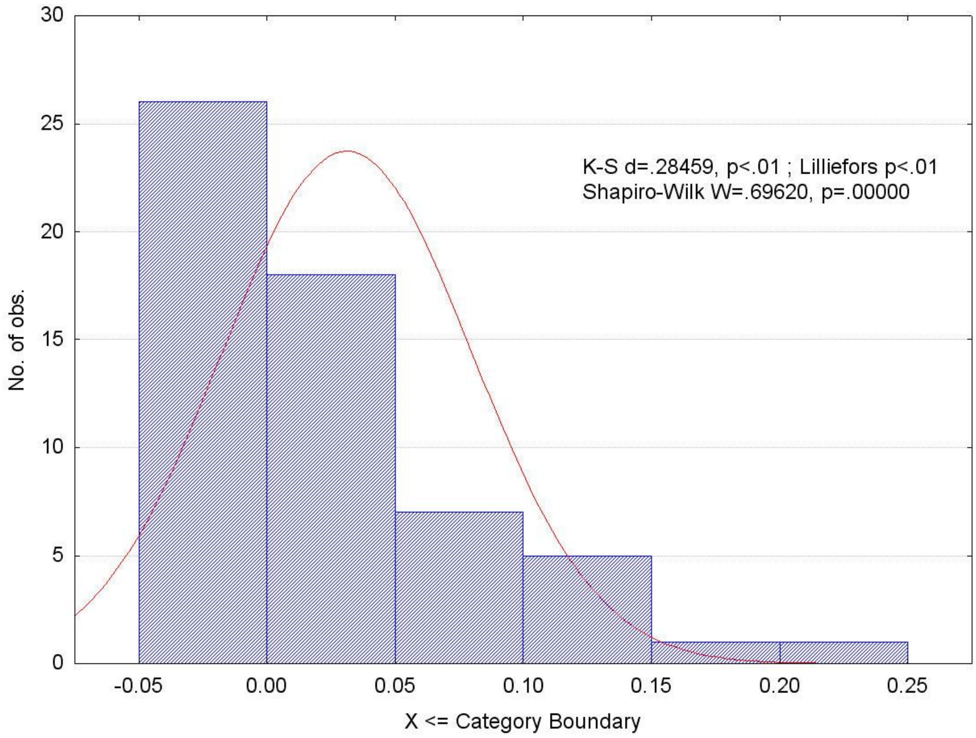


Figure 69. Frequency plot of log transformed abundance data of *Leucosidae* larvae.

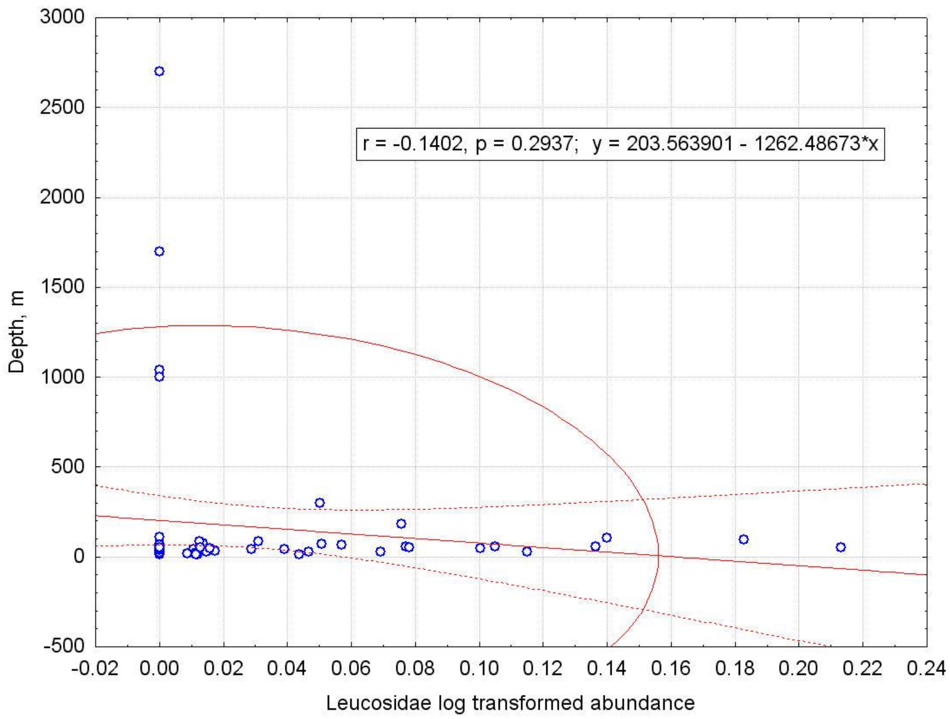


Figure 70. Correlation between *Leucosidae* larvae abundance and location depth.

3.2.3.2.2 Caridea

Caridean larvae (2.1% of decapods composition) in the RSA were observed in low abundance during the winter season. Larvae of six caridean families were identified: Alpheidae (71% caridean composition), Crangonidae (8.3%), Oplophoridae (6.2%), Pontoninae (2.1%), Hippolitidae (1.7%), and Palaemonidae (0.4%), while 11% of caridean larvae (hippolitids) remained unidentified (Figure 71). Figure 72 displays the spatial abundance of the caridean larvae in the RSA during Winter 2006.

Alpheus sp. zoeae were the most abundant species. Highest abundance value of *Alpheus* sp. zoeae was recorded in the Strait of Hormuz (St. 82: 414 ind/100 m^3) (Figure 73). Frequency of distribution, as well as correlation with station depth are displayed in Figures 74 and 75.

A single specimen of *Thalassocaris obscura* zoea X from the family Thalassocarididae was encountered at St. 55. This finding fills in the gaps of geographic distribution of *T. obscura* in the Indian Ocean basin (Menon and Williamson, 1971).

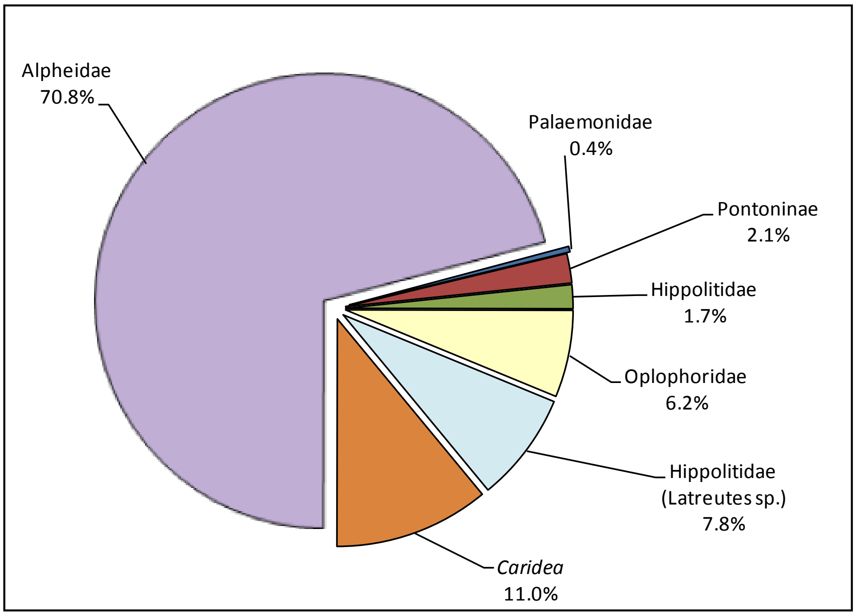


Figure 71. Composition of Caridean larvae in the RSA.

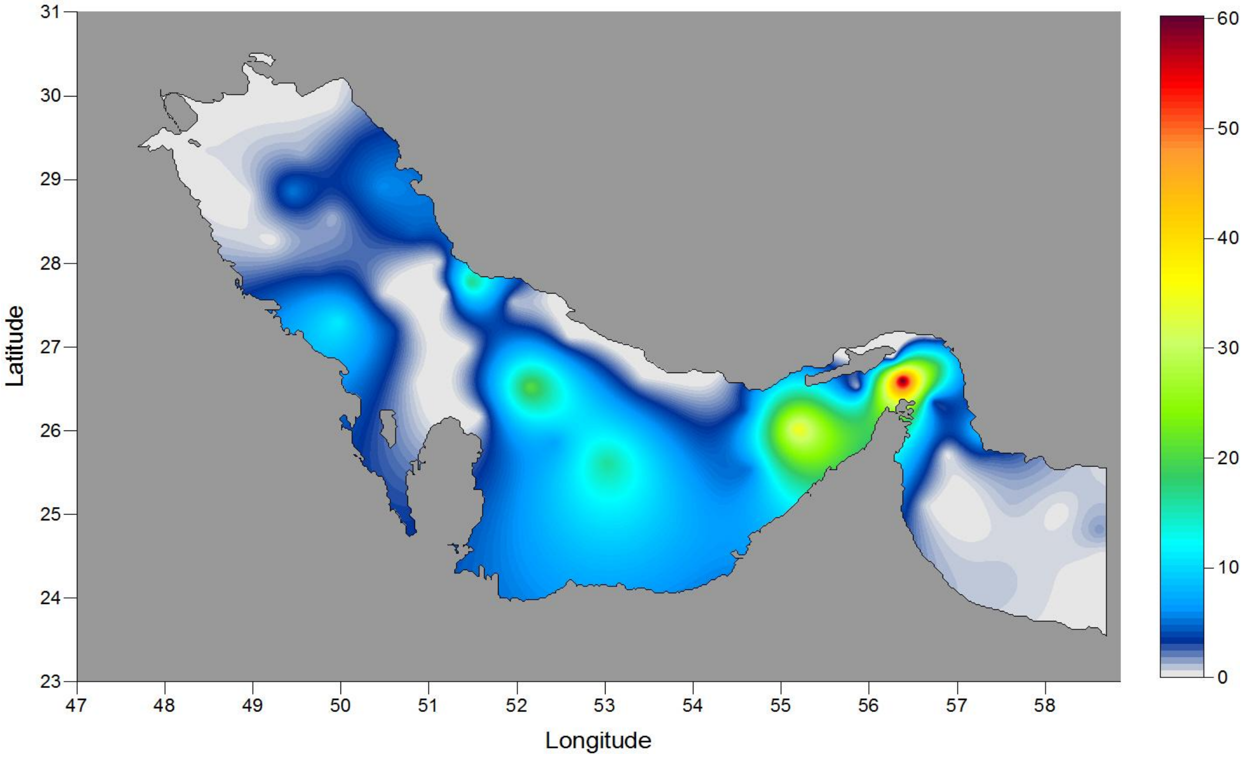


Figure 72. Spatial distribution of Caridean larval abundance in the RSA.

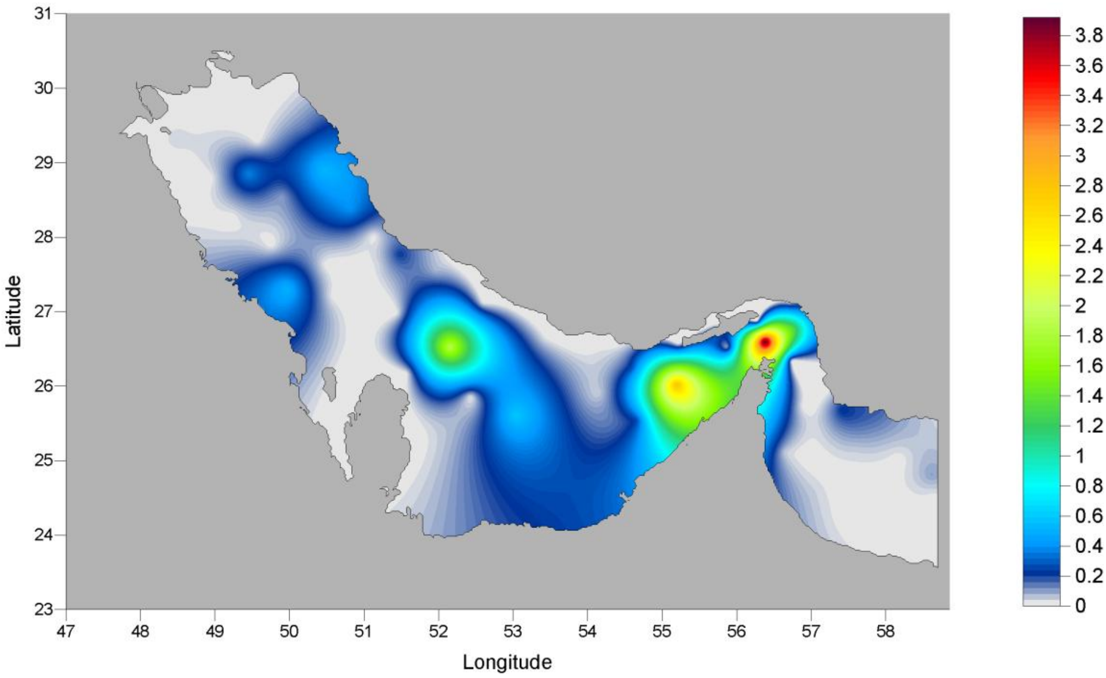


Figure 73. Spatial distribution of *Alpheus* zoeae abundance.

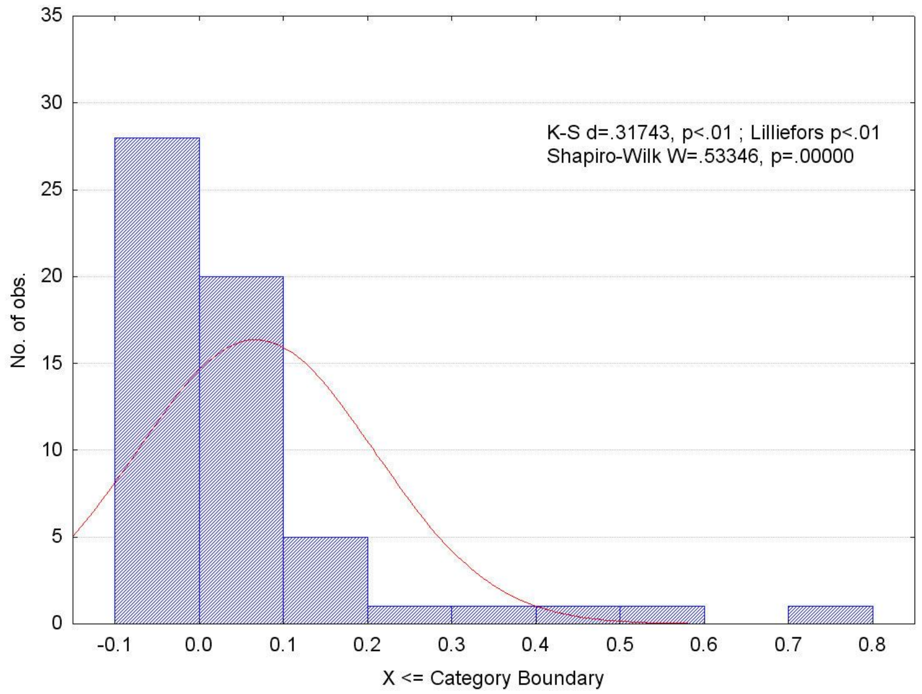


Figure 74. Frequency plot of log transformed abundance data of *Alpheus* zoeae.

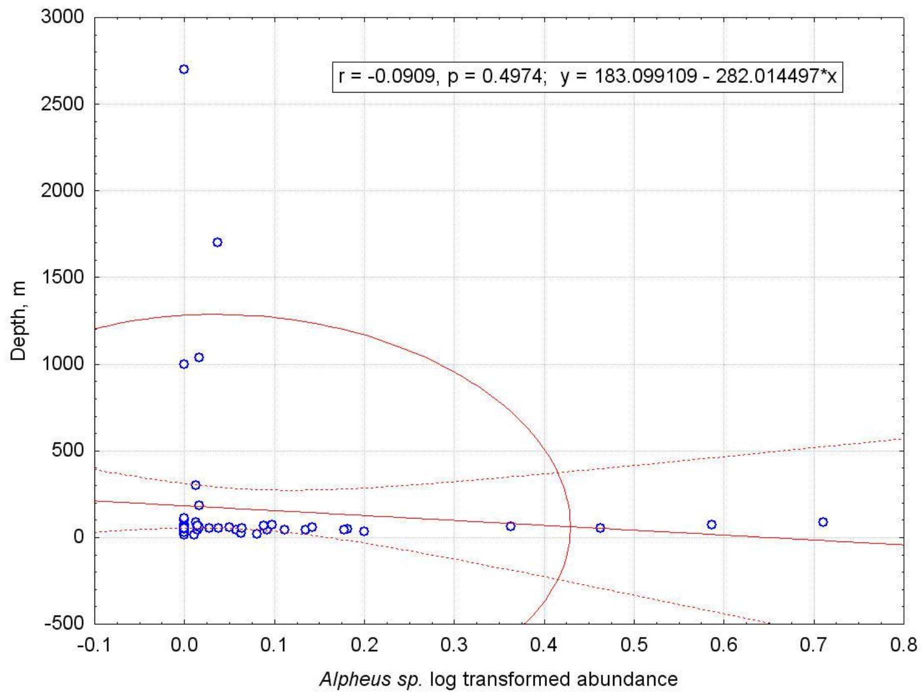


Figure 75. Correlation between *Alpheus* zoeae abundance and station depth.

Thalassocaris obscura is reported to be the most common species of *Thalassocaris* over most of the Indian Ocean. The largest numbers were encountered in the Arabian Sea, from which many samples contained more than five adults and juveniles and more than 20 larvae (Menon and Williamson, 1971) *T. obscura* is a deep water species, although it frequently occurs in the upper layers. *T. obscura* is most common in the northern part of the Indian Ocean, particularly the Arabian Sea; small numbers extend at least as far as 30°S in the western half of the Indian Ocean but it has not been recorded south of 10°S in the eastern half; it is probably confined to the Indian Ocean region. Karuppasamy *et al*. (2006) reported that *Thallassocaris crinita* occur in the eastern part of the Arabian Sea in swarms.

Grabe and Lees (1995) reported that alpheids (>80% of the Caridea) are the most abundant caridean larvae in Kuwait waters year around. Alpheids were represented by *Synalpheus* and a number of morphological types of *Alpheus*. Alpheids were most abundant during spring and summer months, and rare or absent during late fall through early spring. These larvae were found throughout Kuwait waters, but were most common at the southern stations, where the substrata included sponges, corals and other hard-bottom areas favored by alpheids.

Al-Aidaroos (1993) reported that caridean larvae constituted 23% of the total larvae recorded from the western coast of the inner RSA during spring time. *Alpheus* spp. constituted 13.5% of caridean larvae, *Periclimenes (Harpilus)* comprised 9.6% ,and *Leptochela* spp. comprised 12.4%.

Al-Yamani and Khvorov (2007) found that caridean larvae constituted 7.6% of the decapods composition off Bubiyan Island year around. The most abundant family Alpheidae was represented by *Athanas* sp. It occurs all year-long except in February, March and December and peaks in June and largely observed in the northern part of Bubiyan Island.

3.2.3.2.3 Anomura

Anomura larvae in the RSA during the winter season of 2006 were low in abundance (0.9%). Larvae of *Pachycheles* sp. were the most abundant anomuran taxon (Figure 76), reaching the highest abundance value (3.84 ind/m^3) off the Saudi waters (St.10a) of the inner

RSA (Figure 77). Larvae of the hermit crab sp. (24% of anomuran composition) were mostly recorded in the Strait of Hormuz (St. 82) with an abundance of 0.84 ind/m^3 (Figure 78). Frequency of distribution, as well as correlation with station depth are displayed in Figures 79-82.

Al-Aidaroos (1993) reported that larvae of Anomura constituted 9.2% of total larvae recorded from the western coast of the inner RSA in the spring time. The author erroneously attributed thalassinids *Upogebia* and *Callianassa* sp. to Anomura.

Grabe and Lees (1995) reported that *Diogenes* spp. in Kuwait waters were the predominant (>90%) anomuran larvae and porcellanids ranked second (9%). Both taxa had similar seasonal distributions: a late spring through fall maximum and a late fall through early spring minima.

Al-Yamani and Khvorov (2007) found that anomuran larvae collected off Bubiyan Island were comprised of three families: Porcellanidae, Paguridae and Hippidae. Larvae of *Porcellana* sp. were the most abundant anomuran taxon. *Porcellana* sp. zoeae occurred in the waters off Bubiyan Island during May –September with peak of abundance in July and were mainly observed in the southern part of Bubiyan Island (St. 12). Occurrence of *Diogenes* sp. zoeae (family Paguridae) were present for the longest duration from February 2004 to October 2004 with a peak of abundance in July. They were mainly concentrated (in contrast with porcellanids) in the northern part of Bubiyan Island (Khor Al-Milh - St.8).

3.2.3.2.4 Thalassinidea

Thalassinidea larvae had lowest abundance in the RSA (0.2% of total composition) in the winter season. *Upogebia* sp. larvae were the most abundant thalassinids taxon (Figure 83), reaching the highest abundance value (48 ind/100 m^3) in the waters off Qatar (St. 34) in the inner RSA (Figure 84). Larvae of *Callianassa* spp. were found at stations 11a, 16, and 66 with maximum of abundance (42 ind/100 m^3) at station 66. Zoea of *Laomedia* sp. were found for first time in the RSA (Figure 85). They were encountered at stations 59, 69, 83, 87, 92 and 25a with peak of abundance at St. 83 (24 ind/100m^3). Frequency of distribution, as well as correlation with station depth are displayed in Figures 86-89.

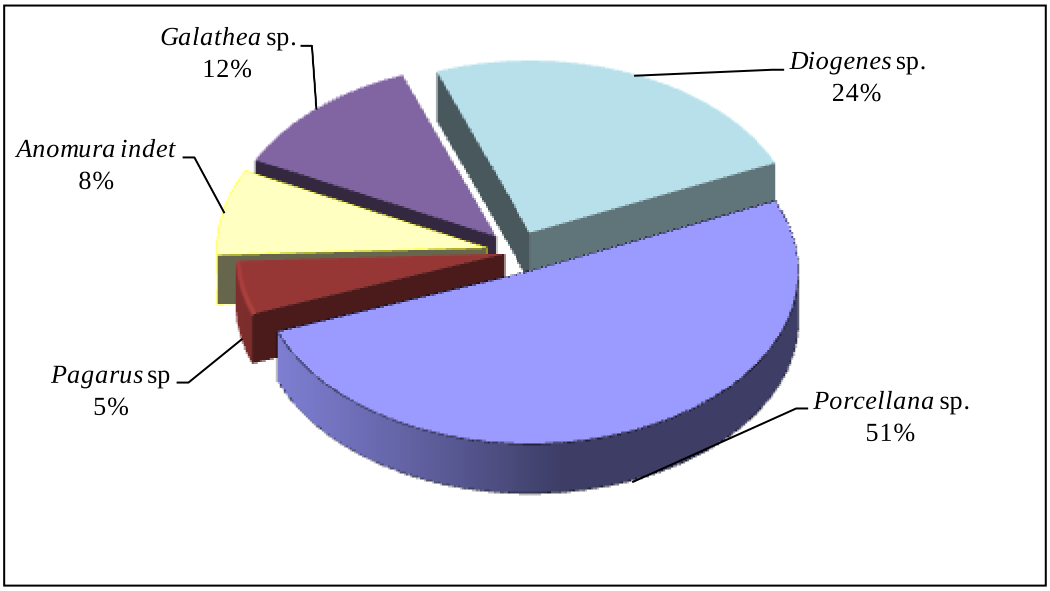


Figure 76. Composition of Anomura larvae in the RSA.

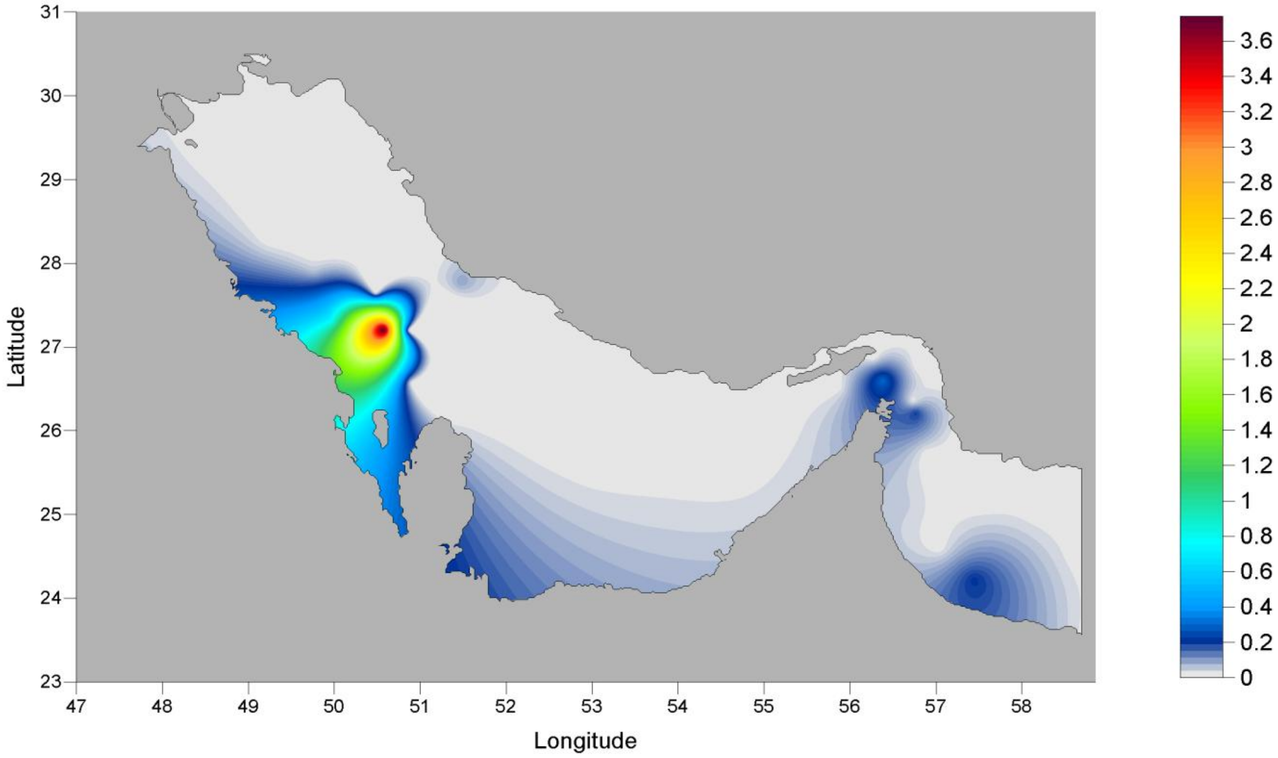


Figure 77. Spatial distribution of *Pachycheles* sp. zoeae in the RSA.

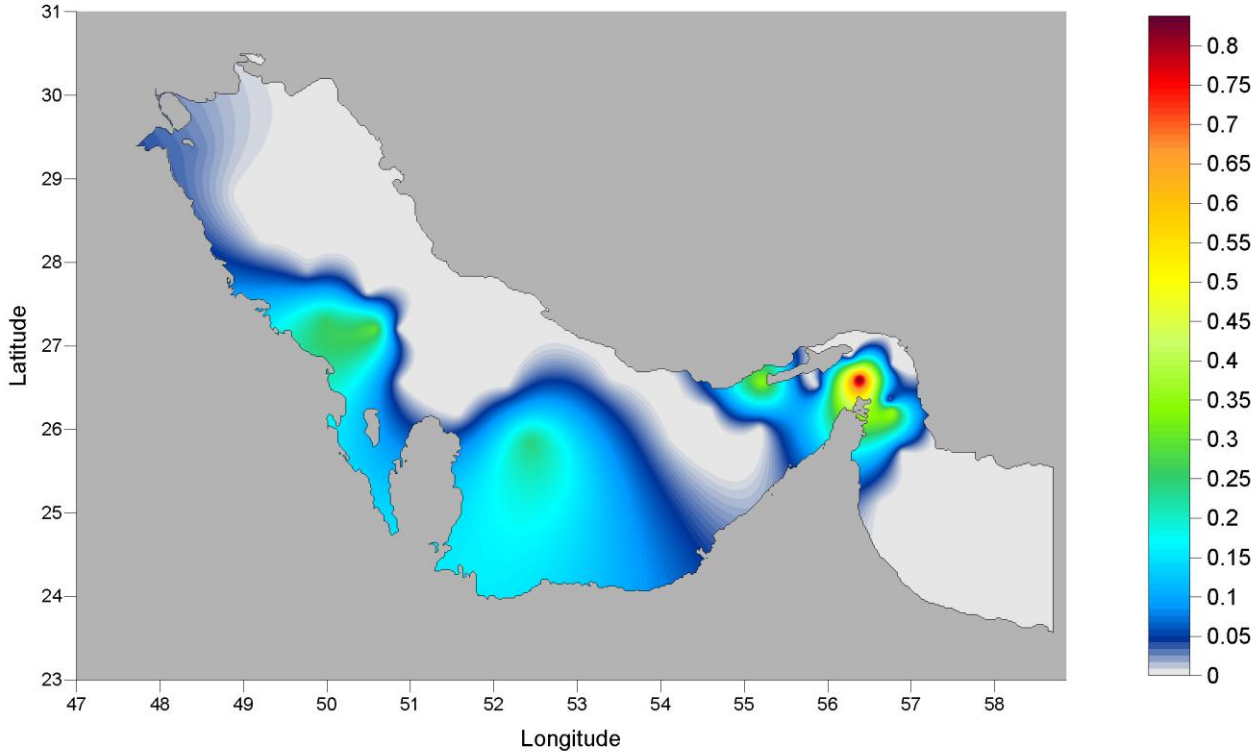


Figure 78. Spatial distribution of *Diogenes* sp. zoeae in the RSA.

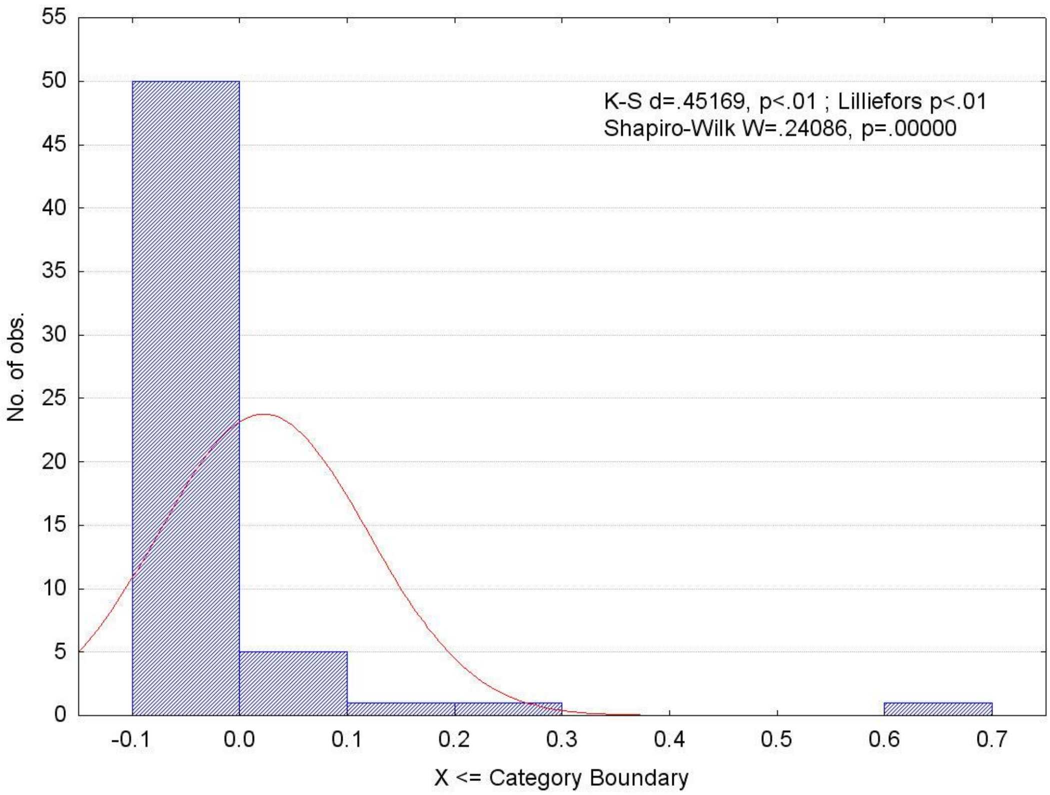


Figure 79. Frequency plot of log transformed abundance data of *Pachycheles* sp. zoeae.

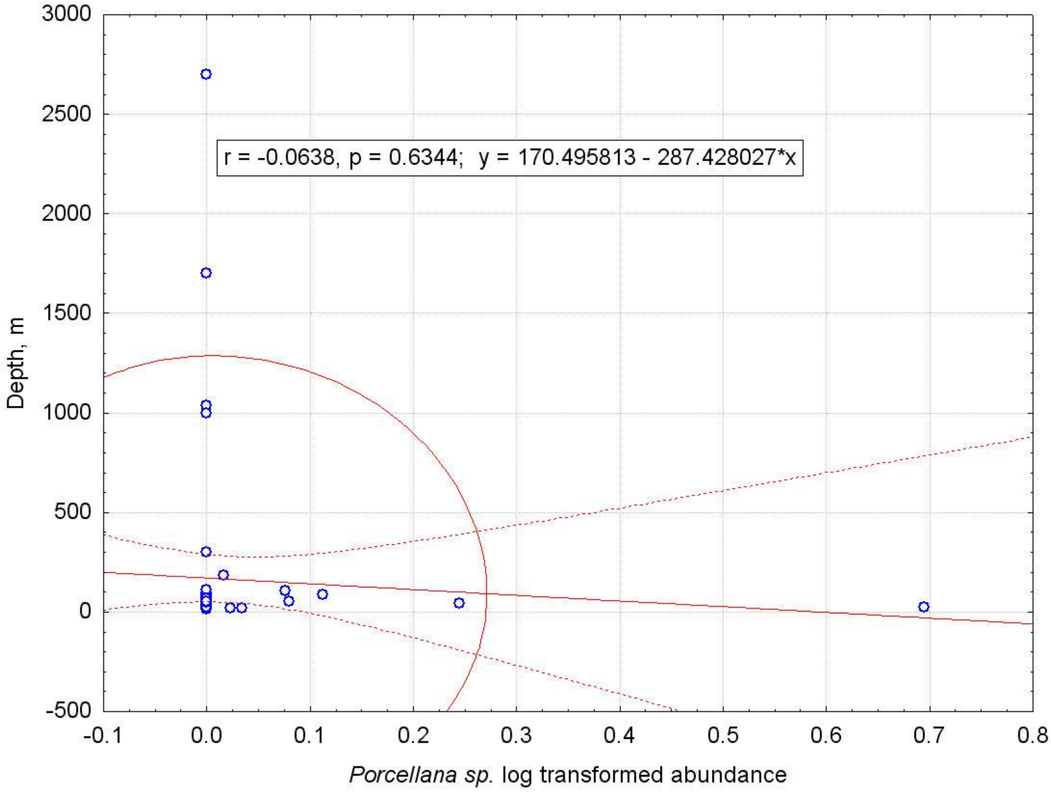


Figure 80. Correlation between *Porcellana* sp. zoeae abundance and location depth.

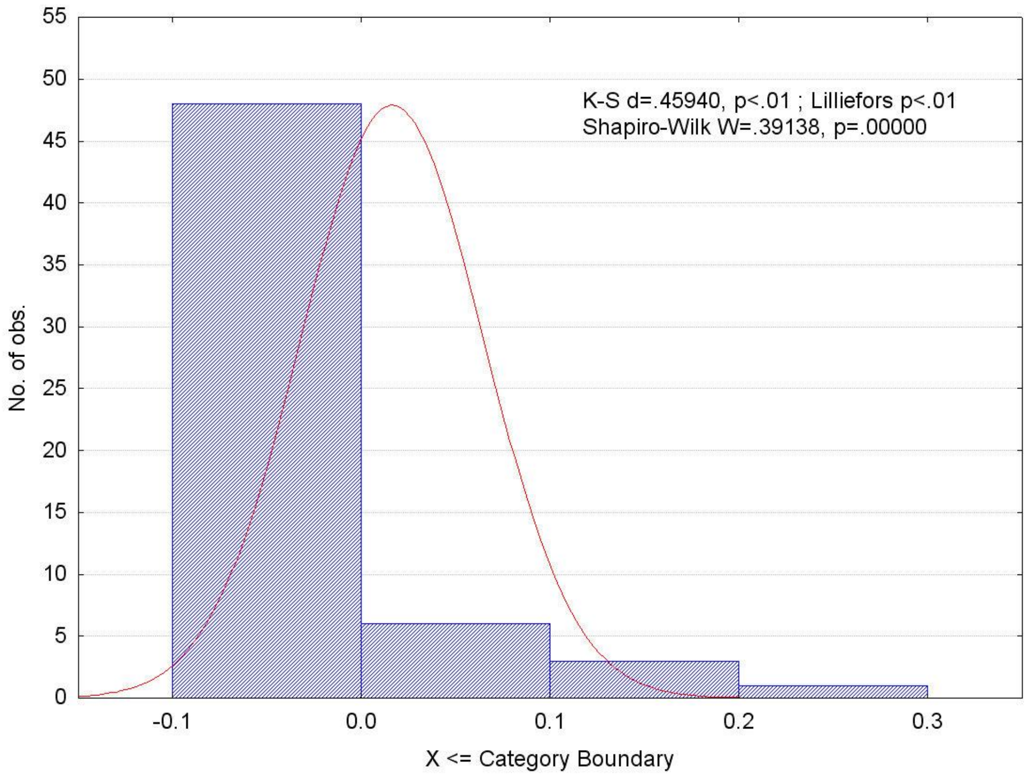


Figure 81. Frequency plot of log transformed abundance data of *Diogenes* sp. zoeae.

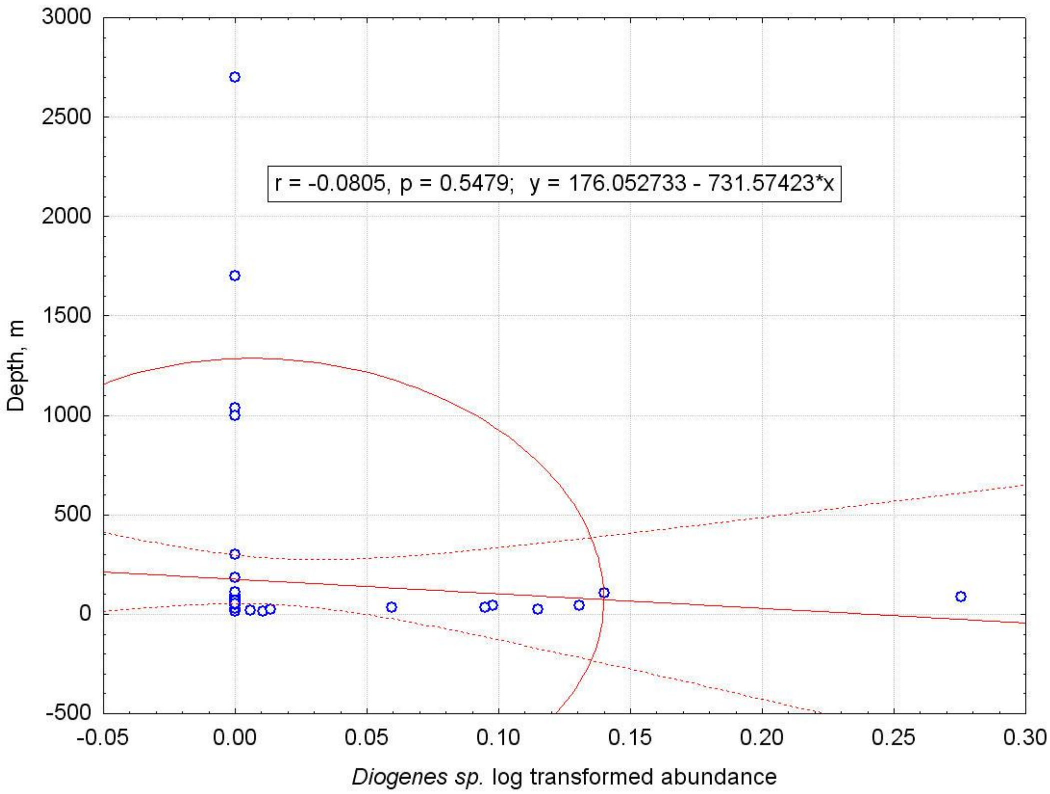


Figure 82. Correlation between *Diogenes* sp. zoeae abundance and location depth.

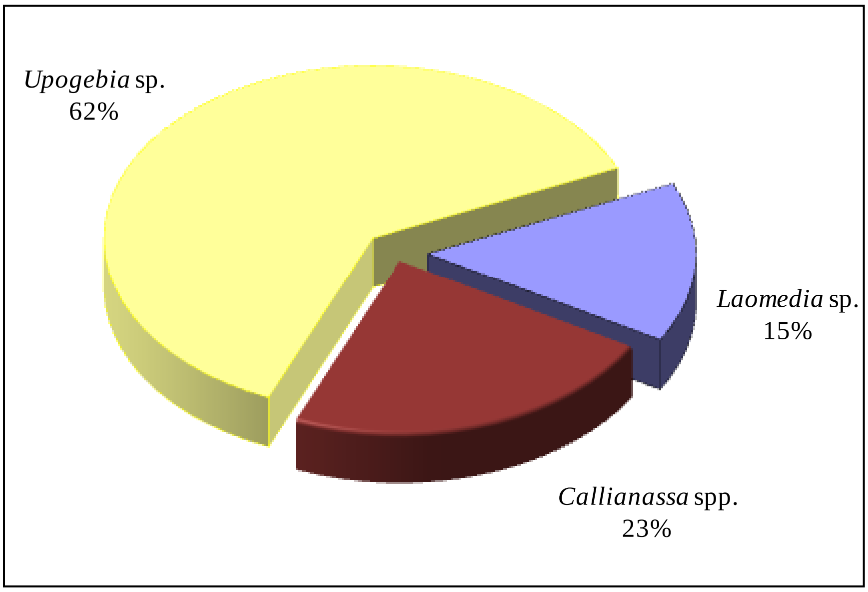


Figure 83. Composition of thalassanid larvae in the RSA.

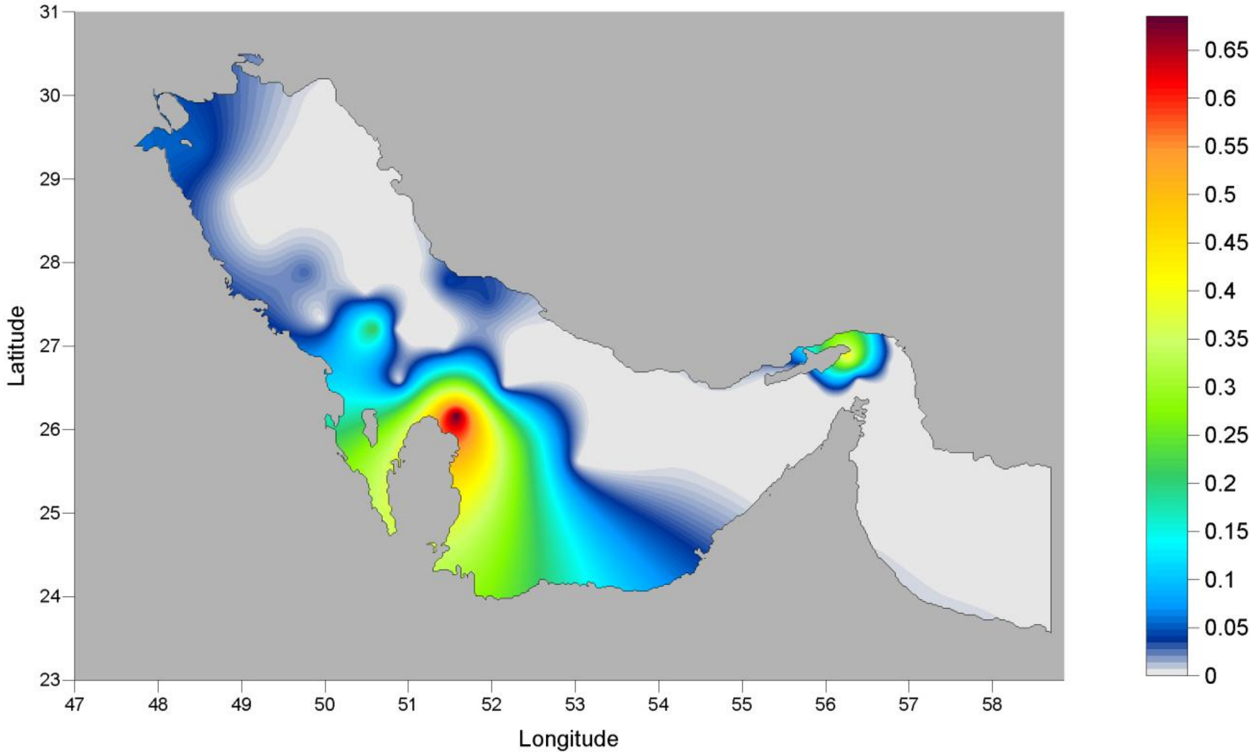


Figure 84. Spatial distribution of *Upogebia* sp. zoeae in the RSA.

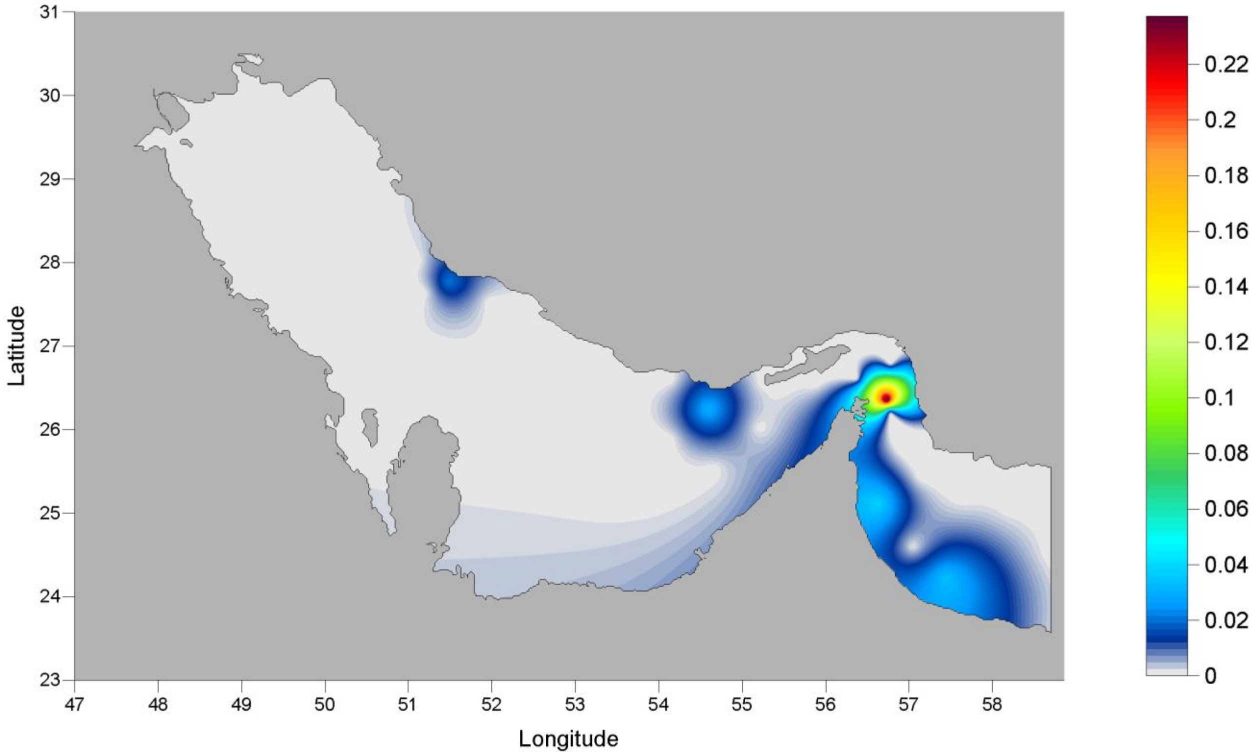


Figure 85. Spatial distribution of *Laomedia* sp. zoeae in the RSA.

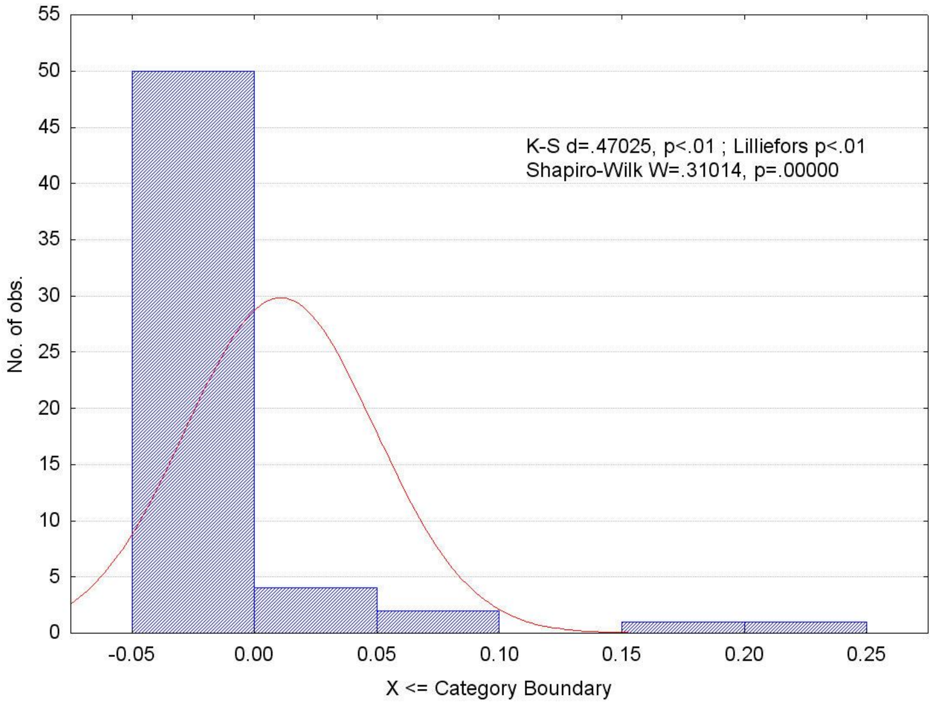


Figure 86. Frequency plot of log transformed abundance data of *Upogebia* sp. zoeae.

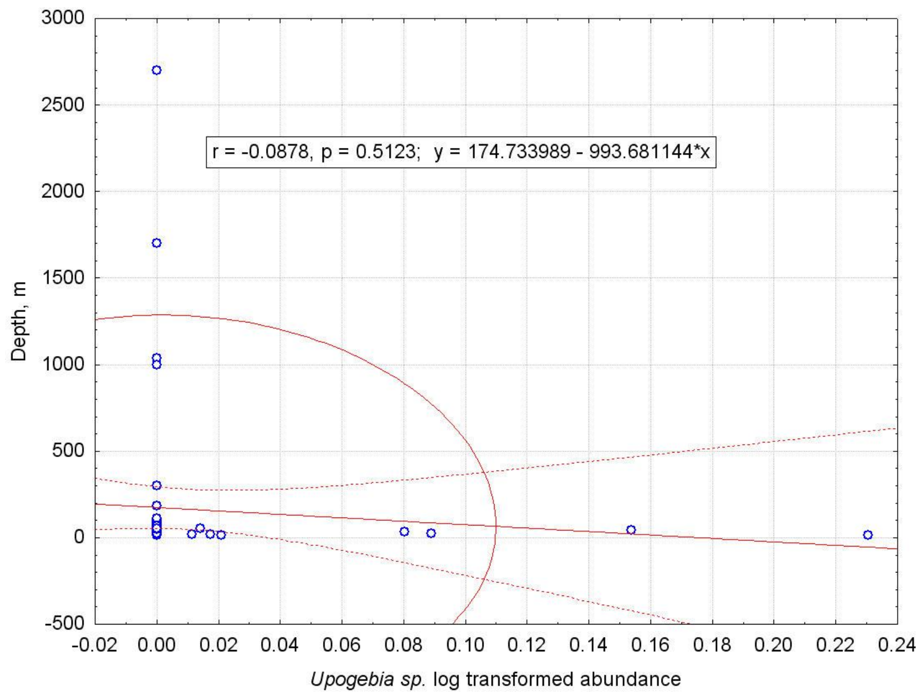


Figure 87. Correlation between *Upogebia* sp. zoeae abundance and location depth.

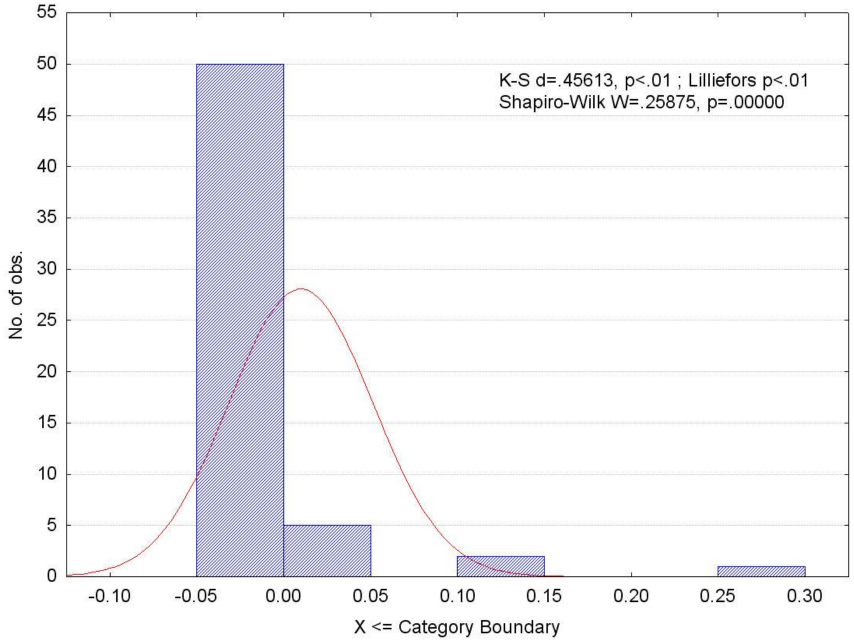


Figure 88. Frequency plot of log transformed abundance data of *Callianassa* spp. zoeae.

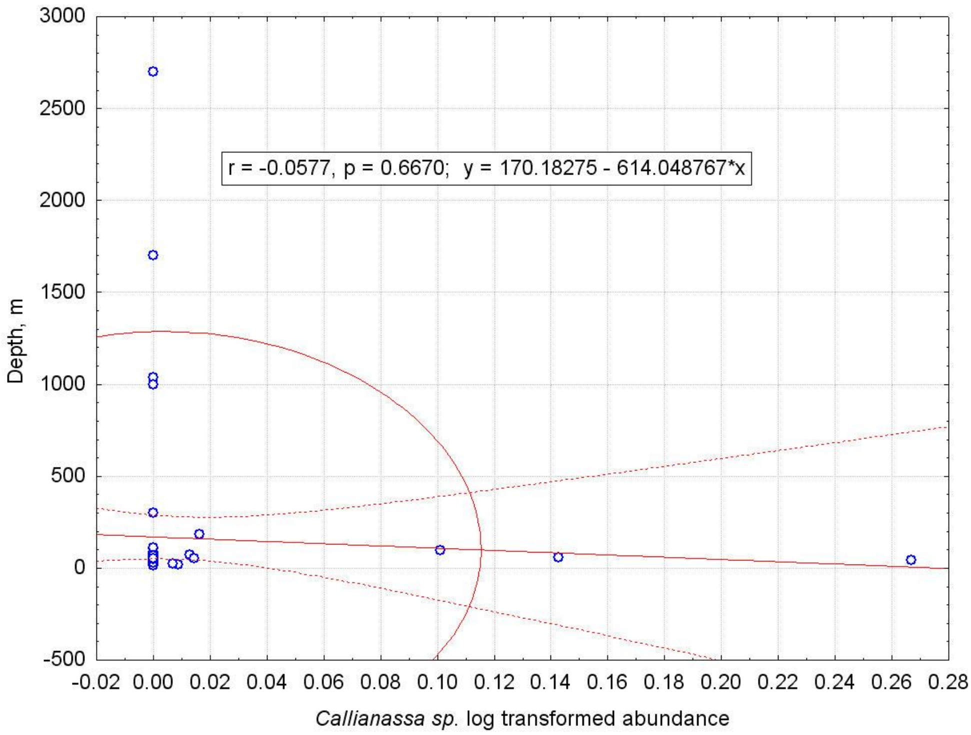


Figure 89. Correlation between *Callianassa* spp. zoeae abundance and location depth.

Grabe and Lees (1995) identified in the plankton collections from Kuwait waters 15 thalassinidean taxa, *Upogebia* spp. (>80%) and callianassid sp. B (9%) larvae, which were the most abundant. *Upogebia* spp. were the only thalassinidean larvae collected throughout the year. These larvae were present throughout Kuwait Bay, but were especially common at the south-central Bay stations and in the Khor Al-Sabiya (9%).

Al-Yamani and Khvorov (2007) identified in the plankton off Bubiyan Island thalasssinids *Upogebia* sp. and *Callianassa* sp. *Upogebia* sp. larvae were abundantly distributed. It occurred in the plankton during May – September with two peaks of abundance in May and August, while *Callianassa* sp. zoeae were abundant in July. Both taxa were largely found at Khor Al-Tha'alib (St. 6).

3.2.4 Diversity of Planktonic Decapods of the RSA

Shannon's diversity index of planktonic and larval decapoda in the ROPME Sea Area during the winter season of 2006 ranged from 0 to 1.89, reaching higher values in the Sea of Oman (Figure 90). In general, the diversity of planktonic decapods of the RSA in the winter season was low. This could be partly due to the decrease in the reproductive activity of Decapoda due to low temperature impact in winter.

There is a clear spatial pattern of decapods' diversity distribution, which increases toward the Sea of Oman (Figure 91).

3.2.5 Spatial Distribution

It was shown that 33% of the identified planktonic decapods in the RSA during the winter season showed aggregated distribution (Table 3).

3.2.6 RSA Zonation

An attempt to zone the RSA in terms of planktonic decapods composition is shown. The investigated region can be classified into 3 major subregions as follows:

- Northern inner RSA (61% of sergestids);
- Central and Southern inner RSA (92% of sergestids);
- Sea of Oman (54% of sergestids).

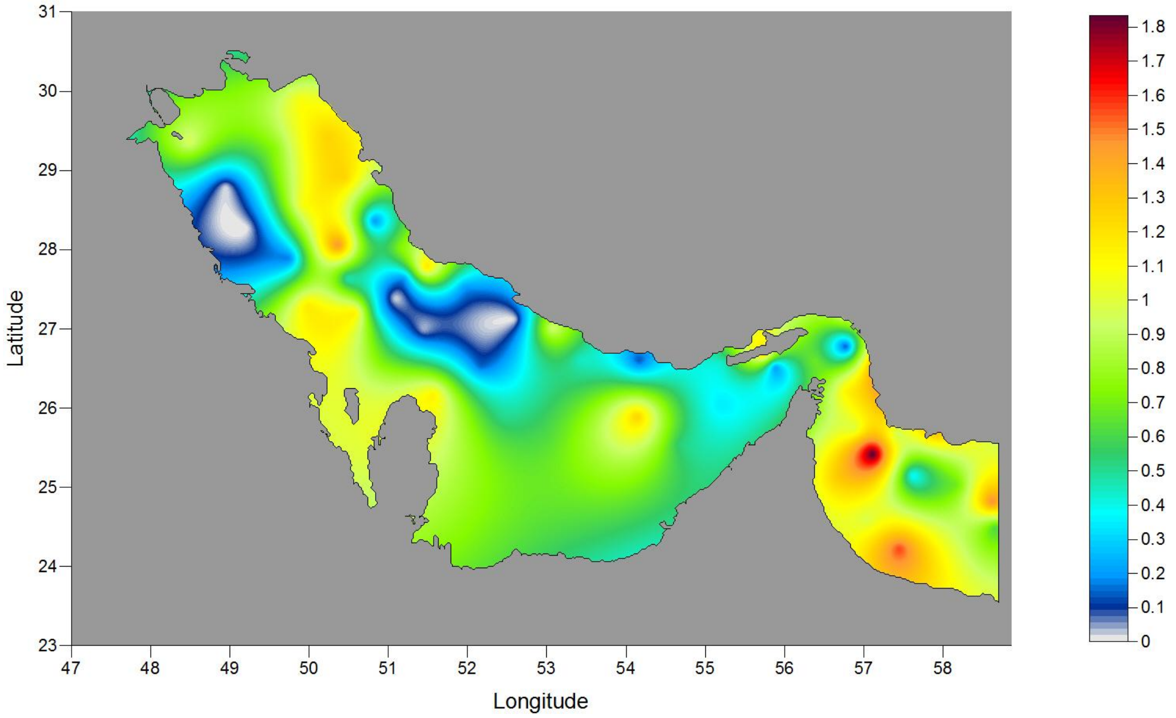
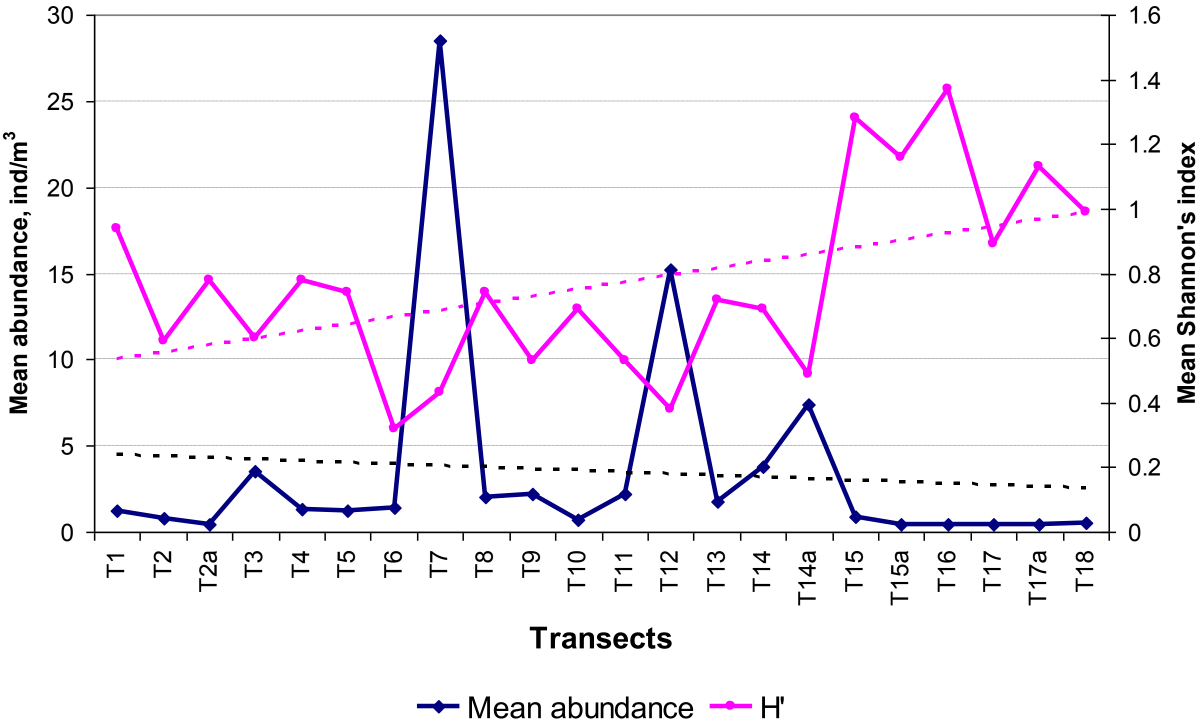


Figure 90. Spatial distribution of Shannon's index in the RSA.



The red dotted line is the linear trend of Shannon's index. The blue dotted line displays larval decapods mean abundance.

Figure 91. Distribution of mean abundance and mean diversity of larval decapods in the RSA.

Considering the dominance of *Lucifer hanseni* in the winter plankton assemblage and the high dependence on surface currents - as segregation/limiting factor on their distribution, this classification seems proper.

3.2.7 Relationship of Abundance with Depth

Calculation of correlations between log transformed abundance of planktonic decapods of the RSA and depth of sampled stations were performed.

In the majority of cases, significant relationships were absent. Only two species, which are indicators of oceanic surface currents *Sergestes* sp. and *Lucifer typus* showed significant positive correlations ($r = 0.7539$, $p = 0.0000$ and $r = 0.7435$, $p = 0.0000$, respectively).

4. Conclusions

The main findings of the present study were as follows:

i) One third of the identified planktonic decapods in the RSA had aggregated distribution, while the rest showed regular distribution;

ii) The ROPME Sea Area can be adequately classified into 3 major subregions in terms of sergestids dominance:
- Northwestern inshore (61% of sergestids);
- Central inshore (92% of sergestids);
- Offshore (54% of sergestids).

iii) Dominance in winter assemblage of the RSA luciferid shrimp *Lucifer hanseni* showed swarming conditions in the central part of the inner RSA. The Strait of Hormuz could be a nursery area for this species. Statistical significance of the observed swarming events was low, hence, a long-term (3 yr) sampling program is needed to determine if warming is a regular pattern for winter season, and to describe the distribution and abundance during the other seasons. For the inner RSA population of *L. hanseni*, two seasonal patterns were evident. The first was observed by Michel *et al*. (1986b), Grabe and Lees (1992), Al-Yamani and Khvorov (2007) for Kuwait waters (northwestern part of the inner RSA), where the abundance of *L. hanseni* is higher during the warm season. The second one was evident in the present study – swarming of *L. hanseni* in the central and southern waters adjacent to the Sea of Oman waters during the cold season. Distribution of *L. hanseni* is well described by the model of gamma distribution, which determines mosaic spatial variability of abundance. Areas with high abundance are adjacent to areas with zero abundance.

iv) Occurrence of penaied shrimps *Penaeus semisulcatus* and *Parapenaeopsis stylifera* protozoeae in the winter season in the RSA showed that reproduction of commercial penaeids is continuous and year around;

v) Presence in the RSA waters of larvae of deep sea mud shrimp *Solenocera* sp.*,* sergestid shrimp *Sergestes* sp., oceanic luciferid shrimp *Lucifer typus,* pelagic caridean shrimp *Thalassocaris obscura,* oplophorid shrimp *Acanthephyra* sp. indicated the influence of the Indian Ocean currents;

vi) Dominance of brachyuran larvae in the northern part of the inner RSA confirms the findings of this group of larvae in inshore plankton of lower latitudes (estuarine effect);

vii) Distribution of pleocyemata larvae (Brachyura, Caridea, Anomura, Thalassinidae) in the RSA was patchy and showed spatial dissociation (most abundant areas of pleocyemata groups were observed in separate and different locations). Brachyuran larvae were most abundant in northwestern waters (Kuwait waters), Caridea larvae – in the Strait of Hormuz, Anomura larvae – in the waters off the Saudi coast, and Thalassinidae – in the waters off Qatar.

viii) Diversity of planktonic decapoda was seen to increase toward the Sea of Oman.

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Appendix A

Table A1. Composition of Decapoda Larvae by Sampled Stations within the RSA

Species	Stations											
	1	**4**	**7**	**8**	**11**	**14**	**5_a**	**7_a**	**9_a**	**15**	**17**	**19**
Acanthephyra sanguinea												
Alpheidae indet		2.4										
Alpheus sp.	0.2			18.5	4.0			25.0	10.8		30.8	1.1
Anomura indet										0.1		
Athanas sp.										0.3		
Brachyura indet	64.6	31.4	52.5	14.8						0.6		0.6
Callianassa sp.												
Callianassa truncata												0.6
Caridea indet					1.2						15.4	
Crangonidae indet				18.5								
Decapoda indet					2.8				5.4			
Dendrobranchiata indet								8.3				
Diogenes sp.	0.2									0.0		
Ebalia sp.	21.0		32.5							0.1		
Galathea sp.												
Grapsidae indet												
Ilyoplaxs sp.			5.0									
Leucosidae indet		0.6			0.4				5.4	0.1		0.6
Lucifer hanseni	0.6	65.7		48.1	88.5	100.0	100.0		62.2	97.7	15.4	97.2
Lucifer typus												
Lysmata sp.												
Macrophthalmus sp.	12.1		10.0									
Metapenaeus ensis												
Oplophoridae indet												
Pagurus sp.										0.1		
Palaemon sp.												
Parapenaeopsis stylifera	0.4										7.7	
Parthenope sp.					2.8			58.3	5.4	0.6	30.8	
Penaeidae indet												
Penaeus semisulcatus	0.4							8.3				
Periclimenes sp.										0.2		
Porcellana sp.										0.1		
Portunidae indet					0.4							
Portunus sp.												
Sergestes seminudus												
Sesarmidae indet												
Sicyonia sp.									10.8			
Solenocera hextii												
Stenopus sp.												
Upogebia sp.	0.4									0.1		

Species	Stations												
	20	**22**	**23**	**10_a**	**24**	**26**	**11_a**	**27**	**30**	**33**	**34**	**36**	**39**
Acanthephyra sanguinea				0.2									
Alpheidae indet													
Alpheus sp.			2.9			0.8	0.8	0.5				0.5	
Anomura indet			1.5										
Athanas sp.					1.7								
Brachyura indet	4.8	2.3	1.5	0.7		0.8	6.1	0.3		6.3	13.0		
Callianassa sp.							0.1						
Callianassa truncata													
Caridea indet			1.5	0.7			0.4						
Crangonidae indet	4.8			1.2			4.3						
Decapoda indet											5.0		
Dendrobranchiata indet													
Diogenes sp.			1.5	2.0									
Ebalia sp.							2.5						
Galathea sp.			1.5				0.2						
Grapsidae indet													
Ilyoplaxs sp.				0.7									
Leucosidae indet	4.8			0.7		3.3	0.1	1.6		18.8	0.6	0.2	0.6
Lucifer hanseni	81.0	4.7	63.2	61.0	90.8	95.0	61.3	96.2	99.5	75.0	62.1	97.7	99.4
Lucifer typus													
Lysmata sp.		0.3					0.2						
Macrophthalmus sp.							0.2						
Metapenaeus ensis													
Oplophoridae indet													
Pagurus sp.													
Palaemon sp.													
Parapenaeopsis stylifera													
Parthenope sp.	4.8	90.0	20.6	5.6	2.5			1.1	0.5			0.9	
Penaeidae indet							1.0						
Penaeus semisulcatus													
Periclimenes sp.			1.5				0.3						
Porcellana sp.			4.4	25.5			0.3						
Portunidae indet													
Portunus sp.		2.7			5.0		22.2				3.7	0.8	
Sergestes seminudus													
Sesarmidae indet													
Sicyonia sp.													
Solenocera hextii													
Stenopus sp.													
Upogebia sp.				1.5			0.2	0.3			15.5		

Species	Stations									
	40	**43**	**50**	**55**	**56**	**59**	**66**	**69**	**70**	**72**
Acanthephyra sanguinea			0.9					0.2		
Alpheidae indet									2.4	
Alpheus sp.			1.8	1.4		1.1	1.0	1.8		2.3
Anomura indet					7.0					
Athanas sp.										
Brachyura indet		0.8	1.3	4.3	1.6	2.1	0.2			
Callianassa sp.								0.2		
Callianassa truncata							1.8			
Caridea indet			1.8			9.6	1.0	0.4		
Crangonidae indet		1.8								
Decapoda indet				2.9						
Dendrobranchiata indet										
Diogenes sp.		0.8	0.4						0.8	
Ebalia sp.		1.0								
Galathea sp.										
Grapsidae indet										
Ilyoplaxs sp.		0.8								
Leucosidae indet	1.5	0.1		1.4	0.5	2.1	0.4			
Lucifer hanseni	33.8	89.7	85.5	85.7	90.9	61.0	87.8	85.3	90.5	92.7
Lucifer typus										
Lysmata sp.										0.3
Macrophthalmus sp.										
Metapenaeus ensis										
Oplophoridae indet										
Pagurus sp.										
Palaemon sp.										
Parapenaeopsis stylifera				1.4						
Parthenope sp.	52.3	4.2	7.9	2.9		14.4	7.3	11.7	1.6	4.1
Penaeidae indet							0.2			
Penaeus semisulcatus										
Periclimenes sp.		0.1								
Porcellana sp.										
Portunidae indet										
Portunus sp.	12.3					8.6	0.2	0.2		0.6
Sergestes seminudus										
Sesarmidae indet										
Sicyonia sp.										
Solenocera hextii						1.1		0.2	4.8	0.0
Stenopus sp.			0.4							
Upogebia sp.		0.7								

Species	Stations										
	77	**78**	**79**	**82**	**14_a**	**16_a**	**83**	**85**	**87**	**88**	**90**
Acanthephyra sanguinea											
Alpheidae indet								1.9			
Alpheus sp.	0.2	24.2		5.4	1.6				2.6	4.8	9.1
Anomura indet											
Athanas sp.				0.4			4.3				
Brachyura indet			10.9	0.2					31.9	39.7	
Callianassa sp.							4.3		0.3		
Callianassa truncata											
Caridea indet					0.5						
Crangonidae indet											
Decapoda indet			4.3								
Dendrobranchiata indet						16.0		1.9			
Diogenes sp.				1.2				1.9	0.5		
Ebalia sp.									1.0		
Galathea sp.				0.2				0.9			
Grapsidae indet						10.8					
Ilyoplaxs sp.											
Leucosidae indet		3.0		0.1		1.5	8.7	1.9	2.8		36.4
Lucifer hanseni	96.6	45.5	80.4	85.8	94.3	70.4	73.9	69.4	36.0	53.2	9.1
Lucifer typus											
Lysmata sp.											
Macrophthalmus sp.											
Metapenaeus ensis		3.0									
Oplophoridae indet				1.5							
Pagurus sp.									0.3	2.4	9.1
Palaemon sp.				0.1					0.5		
Parapenaeopsis stylifera						0.8			13.9		
Parthenope sp.	2.3	24.2		1.7	3.6			14.8	4.4		9.1
Penaeidae indet				1.9			4.3	1.9	1.0		9.1
Penaeus semisulcatus						0.5			1.3		
Periclimenes sp.											
Porcellana sp.				0.4				0.9			
Portunidae indet									0.3		
Portunus sp.	0.4			0.3			4.3	4.6	1.0		
Sergestes seminudus											9.1
Sesarmidae indet				0.1							
Sicyonia sp.				0.4					1.5		
Solenocera hextii	0.4			0.3					0.8		9.1
Stenopus sp.											
Upogebia sp.			4.3								

Table A2. Descriptive Statistics of Planktonic Decapoda Abundance

Species	N	Abundance, ind/m^3					
		Min	Max	Mean	S.E.Mean	S.Dev	Variance
Lucifer hanseni	55	0.03	408.66	18.85	7.77	57.64	3321.82
Lucifer typus	5	0.03	0.81	0.39	0.15	0.33	0.11
Sergestes seminudus	6	0.03	3.28	1.11	0.64	1.57	2.47
Penaeus semisulcatus	6	0.03	0.16	0.07	0.02	0.05	0.00
Parapenaeopsis stylifera	8	0.03	0.85	0.24	0.11	0.32	0.10
Solenocera hextii	12	0.03	2.11	0.25	0.17	0.59	0.35
Parthenope sp.	39	0.01	7.4	1.25	0.26	1.62	2.62
Leucosiidae	32	0.02	0.63	0.15	0.03	0.15	0.02
Portunus sp.	16	0	5.86	0.78	0.39	1.56	2.44
Ebalia sp.	6	0.05	2.55	0.92	0.43	1.05	1.11
Macrophthalmus sp.	3	0.06	1.47	0.71	0.41	0.71	0.51
Ilyoplax sp.	3	0.11	0.29	0.22	0.05	0.09	0.01
Alpheus spp.	30	0.02	4.14	0.50	0.17	0.92	0.85
Athanas sp.	5	0.05	0.55	0.26	0.08	0.19	0.04
Crangon sp.	5	0.03	1.14	0.41	0.20	0.45	0.21
Periclimenes	5	0.04	0.25	0.11	0.04	0.09	0.01
Lysmata sp.	3	0.03	0.36	0.14	0.11	0.19	0.03
Acanthephyra sp.	3	0.03	0.29	0.12	0.09	0.15	0.02
Diogenes sp.	10	0.01	0.89	0.26	0.08	0.26	0.07
Porcellana sp.	8	0.04	3.95	0.70	0.47	1.33	1.78
Galathea sp.	6	0.04	0.64	0.22	0.09	0.22	0.05
Pagurus sp.	6	0.02	0.3	0.09	0.04	0.11	0.01
Upogebia sp.	8	0.03	0.7	0.21	0.09	0.24	0.06
Callianassa sp.	6	0.02	0.26	0.07	0.04	0.10	0.01

Table A3. Descriptive Statistics of Decapoda Larvae Abundance by Sampled Stations Within the RSA

St.	Species	Abundance, ind/m^3							
		Min.	Max.	Mean	Total	Variance	St.dev	St.er	Mean conf. interval.
1	9	0	7.856	0.304	12.152	1.711	1.308	0.207	0.53
4	4	0	2.756	0.105	4.197	0.228	0.478	0.076	0.071
7	4	0	3.069	0.146	5.846	0.323	0.568	0.09	0.1
8	4	0	0.37	0.019	0.769	0.005	0.067	0.011	0.002
11	7	0	8.147	0.23	9.202	1.655	1.286	0.203	0.513
14	1	0	0.054	0.001	0.054	0	0.009	0.001	0
15	12	0	42.526	1.089	43.542	45.161	6.72	1.063	13.996
17	5	0	0.122	0.01	0.397	0.001	0.03	0.005	0
19	5	0	33.432	0.86	34.404	27.907	5.283	0.835	8.648
20	5	0	0.548	0.017	0.677	0.008	0.087	0.014	0.002
22	5	0	7.398	0.205	8.217	1.366	1.169	0.185	0.423
23	10	0	10.843	0.429	17.147	3.177	1.782	0.282	0.985
24	4	0	2.597	0.072	2.862	0.168	0.41	0.065	0.052
26	4	0	3.537	0.093	3.723	0.312	0.559	0.088	0.097
27	6	0	11.525	0.3	11.985	3.315	1.821	0.288	1.027
30	2	0	2.717	0.068	2.732	0.185	0.43	0.068	0.057
33	3	0	0.423	0.014	0.564	0.005	0.069	0.011	0.002
34	6	0	2.801	0.113	4.51	0.212	0.46	0.073	0.066
36	5	0	408.663	10.454	418.166	4170.827	64.582	10.211	1292.553
39	2	0	5.339	0.134	5.371	0.712	0.844	0.133	0.221
40	4	0	0.908	0.043	1.736	0.029	0.171	0.027	0.009
43	10	0	27.994	0.78	31.209	19.53	4.419	0.699	6.052
50	8	0	28.398	0.831	33.229	20.174	4.492	0.71	6.252
55	7	0	1.747	0.051	2.038	0.076	0.276	0.044	0.024
56	4	0	5.816	0.16	6.398	0.846	0.92	0.145	0.262
59	8	0	1.959	0.08	3.213	0.102	0.319	0.05	0.032
66	9	0	20.432	0.582	23.263	10.439	3.231	0.511	3.235
69	8	0	12.117	0.355	14.211	3.708	1.926	0.305	1.149
70	5	0	40.075	1.107	44.293	40.08	6.331	1.001	12.421
72	6	0	114.405	3.085	123.387	326.71	18.075	2.858	101.248

St.	Species	Abundance, ind/m^3							
		Min.	Max.	Mean	Total	Variance	St.dev	St.er	Mean conf. interval.
77	5	0	17.915	0.463	18.539	8.015	2.831	0.448	2.484
78	5	0	0.551	0.03	1.211	0.011	0.106	0.017	0.003
79	4	0	7.863	0.244	9.775	1.562	1.25	0.198	0.484
82	16	0	65.603	1.912	76.463	107.211	10.354	1.637	33.225
83	6	0	4.447	0.15	6.016	0.498	0.706	0.112	0.154
85	10	0	14.27	0.514	20.549	5.232	2.287	0.362	1.621
87	17	0	2.198	0.153	6.106	0.22	0.469	0.074	0.068
88	4	0	2.514	0.118	4.728	0.24	0.49	0.077	0.074
90	8	0	0.123	0.008	0.338	0	0.022	0.003	0
92	9	0	2.893	0.123	4.911	0.235	0.485	0.077	0.073
93	6	0	0.806	0.027	1.086	0.017	0.128	0.02	0.005
95	6	0	2.975	0.079	3.17	0.221	0.47	0.074	0.068
97	6	0	1.511	0.095	3.797	0.103	0.321	0.051	0.032
98	3	0	1.176	0.049	1.959	0.044	0.211	0.033	0.014
99	7	0	0.972	0.055	2.209	0.031	0.177	0.028	0.01
100	4	0	3.281	0.104	4.18	0.282	0.531	0.084	0.087
10a	11	0	9.449	0.387	15.482	2.56	1.6	0.253	0.793
11a	16	0	16.208	0.661	26.451	7.284	2.699	0.427	2.257
14a	4	0	78.875	2.092	83.668	155.319	12.463	1.971	48.134
16a	6	0	13.813	0.49	19.618	5.015	2.24	0.354	1.554
19a	4	0	0.209	0.013	0.527	0.002	0.044	0.007	0.001
21a	5	0	1.913	0.106	4.236	0.133	0.364	0.058	0.041
23a	3	0	1.068	0.033	1.305	0.029	0.17	0.027	0.009
25a	11	0	3.219	0.152	6.069	0.278	0.527	0.083	0.086
26a	4	0	0.299	0.013	0.539	0.003	0.055	0.009	0.001
5a	1	0	0.054	0.001	0.054	0	0.009	0.001	0
7a	4	0	0.214	0.009	0.367	0.001	0.037	0.006	0
9a	6	0	2.988	0.12	4.806	0.233	0.483	0.076	0.072

Table A4. Descriptive Statistics of Decapoda Larvae Abundance by Transects Within the RSA

Tr.	Species	Min.	Max.	Mean	Var	St. Dev.	St. Err.	Total	Conf. Interval
T1	12	0	12.24	0.56	4.351	2.0862	0.33	22.18	1.348
T2	9	0	8.57	0.25	1.83	1.353	0.214	10.02	0.567
T2a	8	0	3.04	0.13	0.245	0.495	0.078	5.22	0.076
T3	16	0	76.02	1.96	144.267	12.011	1.899	78.33	44.709
T4	14	0	11.77	0.65	6.234	2.497	0.395	26.03	1.932
T5	21	0	31.79	1.21	25.916	5.091	0.805	48.5	8.031
T6	6	0	14.67	0.38	5.371	2.318	0.367	15.29	1.664
T7	8	0	416.8	10.70	4337.754	65.862	10.414	428.04	1344.284
T8	11	0	28.58	0.82	20.392	4.516	0.714	32.93	6.32
T9	11	0	30.14	0.88	22.71	4.766	0.754	35.27	7.038
T10	9	0	7.77	0.24	1.505	1.227	0.194	9.58	0.466
T11	12	0	32.55	0.94	26.569	5.155	0.815	37.48	8.234
T12	8	0	154.48	4.19	595.088	24.394	3.857	167.68	184.42
T13	7	0	18.47	0.494	8.513	2.918	0.461	19.76	2.638
T14	18	0	73.47	2.157	134.291	11.588	1.832	86.26	41.617
T14a	9	0	92.69	2.582	214.112	14.633	2.314	103.29	66.354
T15	22	0	20.91	0.817	11.026	3.321	0.525	32.68	3.417
T15a	7	0	2.12	0.119	0.161	0.402	0.064	4.76	0.05
T16	11	0	5.44	0.249	0.934	0.967	0.153	9.97	0.289
T17	11	0	3.01	0.202	0.393	0.627	0.099	8.07	0.122
T17a	12	0	3.22	0.185	0.332	0.576	0.091	7.38	0.103
T18	9	0	3.33	0.222	0.447	0.668	0.106	8.89	0.139