original scientific paper

UDC 595.3:591.16(262-11)

OCCURRENCE OF LARVAE OF *SCYLLARUS ARCTUS* (CRUSTACEA, DECAPODA, SCYLLARIDAE) IN THE EASTERN MEDITERRANEAN - PRELIMINARY RESULTS

Ulrich FIEDLER

Abt. Meereszoologie, Institut für Meereskunde, Düsternbrooker Weg 20, D-24105 Kiel, Germany

Ehud SPANIER

The Leon Recanati Center for Maritime Studies and Department for Maritime civilizations, University of Haifa, Mount Carmel, Haifa 31905, Israel

ABSTRACT

Phyllosoma larvae of the broad lobster Scyllarus arctus *(Crustacea: Decapoda: Scyllaridae) were sampled by plankton nets in the Eastern Mediterranean. A scheme for distinguishing between larval stages is suggested. It describes the characteristic features of phyllosoma stages 3 to 12. Phyllosomes of the studied species were found almost all year round and nearly all stages were represented in the samples. Findings of early stage larvae may indicate a spawning season mainly from February to April and from July to September. Most larvae were caught at considerable distances offshore. Larvae were sampled mostly in four long-term persistent or recurrent eddies. Data from physical studies imply an increased probability that phyllosomes can be trapped in eddies for a relatively long period of time while drifting away from the coast. The possible ecological significance of this finding is discussed.*

Key words: Zooplankton, Phyllosoma larvae, Crustacea, Decapoda, Scyllaridae, *Scyllarus*

INTRODUCTION

In comparison with the wealth of information available on the biology and ecology of larval stages of clawed lobsters, Nephropidae *(e.g.,* Cobb and Wahle, 1994; Factor, 1995) and of spiny lobsters, Palinuridae *(e.g.,* Kittaka, 1994), the knowledge of the larval stages of slipper lobsters, Scyllaridae, is scanty, especially on the Mediterranean species. In the Eastern Mediterranean this family is represented by two genera, *Scyllarides* and *Scyllarus* (Holthuis, 1991). Only one species of the first genus, *S. latus,* (Latreille, 1803), and two of the latter, *S. arctus* (Linnè, 1758) and *S. pygmaeus* (Bate, 1888), are reported from this area (Seridji, 1989). The complete larval development of none of these species is known. Within the genus *Scyllarus,* phyllosoma larvae spend up to four months drifting in the ocean (Phillips & Mc William, 1989). How is larval dispersal controlled in the open sea in view of various physical "obstacles" such as eddies, or do they use these circling currents as a "development-loop" until metamorphosis?

In the Eastern Mediterranean, mesoscale eddies are recognized as potentially important oceanographic features (Robinson *et al.,* 1987, 1991). In this area, four long-term persistent or recurrent eddies have been investigated: a cyclonic, cold-core eddy south of Crete, two anti-cyclonic eddies at the Herodotus basin (Mersa Matruh and one eddy just north of it) and the anti-cyclonic Shikmona eddy south of Cyprus (Brenner, 1993). The diameter of the last eddy is approximately 150 km. Krom *et al.* (1991) found the waters in the core of the Shikmona eddy near Cyprus to be sealed off the surrounding waters. This is apparently true also for the Mersa Matruh and the eddy off Crete (Hecht, *personal communications).*

Stephensen (1923) found numerous phyllosoma larvae of the broad lobster *S. arctus* in plankton samples of the Thor expedition (1908-1910) in the Mediterranean.

He was able to distinguish the different larval stages starting with phyllosoma stage I that had been previously described by Dohrn (1870) based on larvae hatched from eggs of *S. arctus* in the laboratory.

The identification of larvae for the present study was based on Stephensen (1923). Our findings suggest several additions and corrections of his staging system, which are briefly stated in the identification scheme below.

Larvae of only two species of *Scyllarus* have been successfully reared in the laboratory (Robertson, 1968: *Scyllarus americanus*; Ito & Lucas, 1990: *Scyllarus demani*). Their descriptions of larval stages were used to confirm our staging system. As long as there are not enough results from laboratory rearing experiments, a key based on defining stages from field material may be a useful tool, despite its limitations. Thus, identification of larvae enables the attempt done in the present study relating their spatial and temporal distribution to their physical environment.

MATERIALS AND METHODS

The larvae used in this study were collected during cruises conducted by the Israel Oceanographic and Limnological Research (IOLR), Haifa, as part of the international POEM (Physical Oceanography of the Eastern Mediterranean) Program and the IOLR-Eddy-Program. From the summer of 1988 until the spring of 1990 several cruises were made with the R/V Shikmona II in the Eastern Mediterranean. A total of (50) stations, located in two arrays, were sampled in the Eastern Mediterranean. The locations of the sampling stations are given in Figure 1.

During these cruises, oblique plankton hauls were taken using a General Oceanics plankton net (60 cm in diameter, 500 µm mesh size) and a mesopelagic net (1 m² squared mouth, 1000 µm mesh size), both equipped with a 25 kg depressor and a General Oceanics digital flow meter. A neuston net (50 x 20 cm half submerged mouth, 500 µm mesh size) was also used. During the POEM-cruises 1988 - summer 1989 only the General Oceanics net was employed and from fall 1989 - spring 1990 only the mesopelagic net was used. The General Oceanics net and the neuston net were used alternating during the IOLR-eddy-program cruises. Samples were taken randomly at all times. Approximately 400 m³ of seawater were filtered per haul (General Oceanics and mesopelagic net). The neuston net was towed for 15 minutes with a speed 2 kn, resulting 0.5 nm towing range.

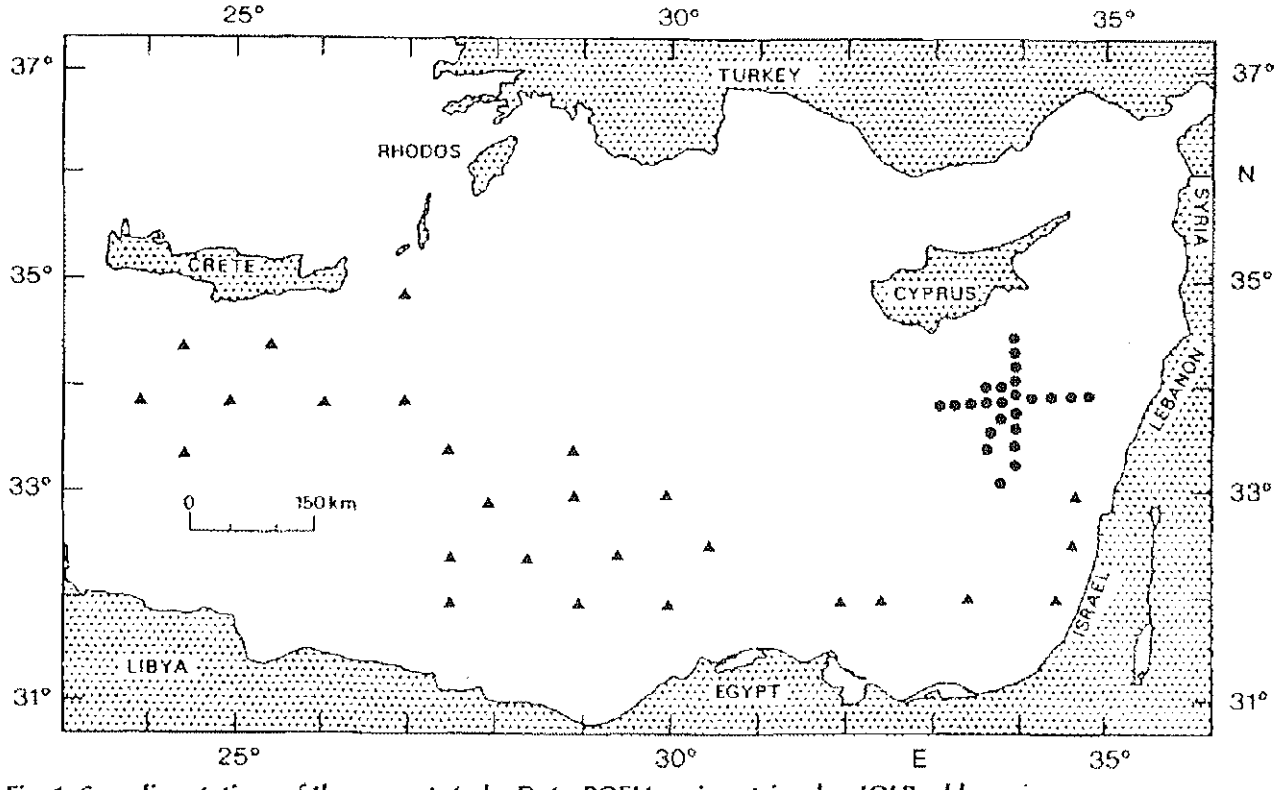

Fig. 1: Sampling stations of the present study. Dots: POEM cruises, triangles: IOLR eddy cruises.
Sl. 1: Vzorčevalne postaje. Pike: križarjenja v organizaciji POEM (Physical Oceanography of the Eastern Mediterranean). Trikotniki: križarjenja v organizaciji IOLR (Israel Oceanography and Limnological Research) za preučevanje morskih vrtincev.

***Tab. 1: Identification scheme for phyllosoma stages of** Scyllarus arctus.*
***Tab. 1: Identifikacijska shema stadijev filosom raka** Scyllarus arctus.*
List of abbreviations: Abd-Abdomen; biram biramous; Cs-Cephalic shield; L-length; Mx-Maxilla; Mxp-Maxilliped; Per-Pereiopod (Per 1-4: numbers of natatory setae on the exopodite); Pleop-Pleopod; pres.-present; T-total; Th-Thorax; Urop-Uropods; W-width.
Dimensions are given in mm.

Stage	3	4	5	6	7	8	9	10	11	12
Stephensens system	III	IV	V	V		VI	VI	VII	VIII	IX
No exam.	2	4	1	3		5	3	3	1	2
T-L	3.3-3.4	4.3-4.9	6.1	7.0-7.9		10.1-12.3	12.8-13.7	15.5-17	19	21.6-24.4
Cs-L	2.2-2.3	2.9-3.2	4.3	4.9-5.5		7.0-8.3	8.7-9.2	10.2-11.9	12.1	12.7-14.5
Cs-W	2.3-2.5	3.2-3.6	4.7	5.6-6.3		8.5-10.4	10.7-11.2	12.3-13.9	15.0	16.1-18.0
Th-W	1.2	1.5-1.8	2.2	2.5-2.7		3.3-4.1	4.5-4.8	5.2-5.8	6.2	6.8-7.6
Cs-W/Th-W	2.0-2.1	2.1-2.2	2.1	2.2-2.3		2.3-2.6	2.3-2.5	2.3-2.5	2.4	2.4
Abd-L	0.3	0.4	0.5	0.6-0.7		1.0-1.5	1.5-1.9	2.0-2.6	3.25	5.0-5.7
Abd-W	0.2-0.3	0.3-0.4	0.6	0.7-0.9		1.3-1.9	2.0-3.0	2.9-3.2	3.8	5.0-5.6
Mxp1	o	o	<Mx2	<Mx2		=Mx2	=Mx2	=Mx2	=Mx2	biram
Per1	10	12-13	14	15-16		19-22	21-22	23	24	25-27
Per2	10	12-13	14	15-16		20-22	22-23	23	24	25-27
Per3	6-7	8-11	11	13		17-19	19-22	21	22	24-25
Per4	2	4-7	?	9-11		15-16	17	19	20	21-23
Per5-L	0.03	0.03-0.2	0.3	0.2-0.3		0.4-0.7	0.6	1.2-1.4	1.8	3.5-4.1
Gills	o	o	o	o		o	o	o	o	pres.
Pleop	o		o			pres.	pres.	bilobed	bilobed	bilobed, elongated
Urop	o	o	o			bilobed	bilobed	bilobed	bilobed	bilobed
Abd.	concav	concav	concav			slightly *concav*	straight	straight	slightly *convex*	convex

Samples were preserved in 4% buffered formaldehyde/seawater. Specimens were examined and measured in natural seawater. The identification of specimens followed Stephensen (1923). In addition his staging system was modified. A brief identification table for the phyllosoma stages of *S. arctus* was developed (Table 1). This scheme uses morphological and morphometrical features; yet, mainly morphological characters were used for the final definition of stages. The most characteristic features are emphasized in the text of Table 1 by bold letters. Due to the relatively small number of specimens, no means or medians are given. This scheme is based only on material of the present study. Some phyllosoma stages are, therefore, not included.

RESULTS AND DISCUSSION

A total of 32 phyllosoma-larvae were found in these samples, 24 of which were identified as *S. arctus* larvae. Two of the remaining phyllosoma are most probably *Scyllarides latus* larvae (stage II), since they resemble closely the known first stage larvae of this species. Six phyllosoma could not be identified until now. A brief scheme for the identification of phyllosoma stages of *S. arctus* is presented in Table 1.

Sizes and morphological features of sampled phyllosoma agree well with Stephensen's (1923) description. We added to his larval description some morphological and morphometrical data. A detailed identification key to the phyllosoma stages of *S. arctus* is in preparation. The main difference between our scheme and Stephensen's is the splitting of his stages V and VI into at least two additional stages respectively. The absence or presence of uropods and the dimensions of cephalic shield and thorax shield are the key features for separating our stages 5 and 6. The gap between our stage 6 and 8 let us hypothesize a 7th phyllosoma stage, despite no specimens being sampled. The drastic increase in the number of setae per pereiopod between our stages 6 and 8 and the morphometrical data suggest a presence of an intermediate stage. The 8th and 9th stages are mainly distinguished by morphometrical differences.

Two *Scyllarus* species have been reared in the laboratory (Robertson, 1968; Ito & Lucas, 1990). Both developed within a few weeks and passed through 7 to 8 phyllosoma stages. There are only slight differences in the total length and development of maxilliped 1 and natatory setae on pereiopods between *S. arctus* and *S. americanus* stages 3-8 (Robertson, 1968). Uropods, pleopods and gills appear earlier in *S. americanus* lar-

vae. *S. demani* (Ito & Lucas, 1990) differs in size from *S. arctus*, but the development of morphological features is similar. *S. americanus* and *S. arctus* develop natatory setae on pereiopod 4 in stage 4, while *S. demani* develops such setae in stage 5. Last larval stages of *S. americanus* and *S. demani* are smaller than *S. arctus* stage 12. *S. kitanoviriosus* stage 8 (Wada *et al.*, 1989) and *S. timidus* stage 9 (Ritz, 1977) fall into approximately the same size range we found in *S. arctus*, in agreement to Stephensen's findings. Stephensen's system already consisted of 9 stages, more than described by Robertson and Wada *et al.* (1989). The duration of larval development of *S. americanus* described by Robertson is by far shorter than the duration of larval life suggested by larval findings for other species. Therefore the number of instars may vary, whereas the general developmental features remain constant.

Phyllosoma larvae of *S. arctus* were found in all seasons except winter (Tab. 2). Nearly all phyllosoma stages are represented in the samples. Larval stages in March ranged from stage 4 up to the last larval stage. Younger stages were found in spring, and fall; latest stages in spring and summer. Most larvae were found in March (54.2%) and May (20.8%). Rothlisberg *et al.* (1994) found significant differences in larval catches of stage I larvae between 142 µm and 500 µm mesh size. Since we did not use any net with less than 500 µm mesh size, the lack of stage I and II larval catches may be explained.

Basing on plankton material from the Mediterranean Sea, Stephensen (1923) suggested that the main spawning season was in summer. Zariquiey Alvarez (1968) found ovigerous females in the Western Mediterranean from February to April and from July to September. Our sampling of phyllosomes within the early stages confirms the results of Zariquiey Alvarez, with the exception of one stage 3 phyllosoma found in November. It may

Tab. 2: Times and stages of sampled phyllosoma larvae.
Tab. 2: Meseci in stadiji vzorčenih filosom.

Month / Stages	3	4	5	6	7	8	9	10	11	12
March		3	1	1		2	2	2	1	1
May				1		3	1			
August										1
September	1	1						1		
November	1			1						

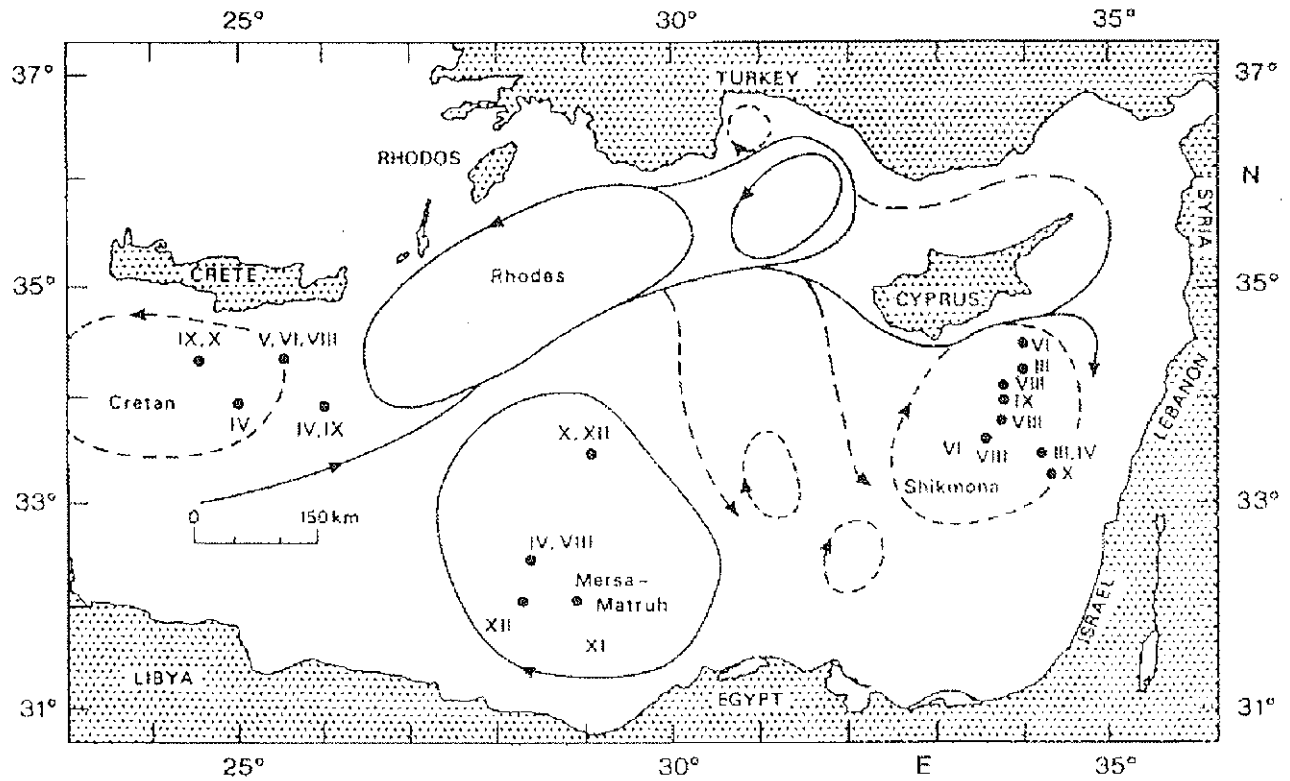

Fig. 2: Sampling locations of phyllosoma larvae of** Scyllarus arctus **of the present study and schematic general circulation of the Eastern Mediterranean (from Robinson** et al., **1991). Roman numbers: phyllosomes's stage; names of gyres according to Robinson** et al. **(1991).
Sl. 2: Vzorčevalne lokacije filosom raka** Scyllarus arctus **in shematsko splošno kroženje vzhodnega Sredozemskega morja (po Robinsonu** et al., **1991). Rimske številke: stadiji filosom; imena spiral po Robinsonu** et al. **(1991).

indicate a different spawning pattern in the Eastern Mediterranean. Similarly, Spanier *et al.* (1988) found that the spawning season of *Scyllarides latus* in the southeastern Mediterranean is different, to a certain extent, from the spawning season observed for the same species by Martins (1985) in the Azores, because of faster increase of water temperature in the spring in the southeastern Mediterranean.

Adults of *S. arctus* are known from all parts of the Mediterranean Sea (Holthuis, 1991; Holthuis & Gottlieb, 1958; Stephensen, 1923). They live in relatively shallow waters preferring muddy bottom (Pippitone, *personal communications).* While adults are reported from Israeli and Egyptian coasts (Holthuis & Gottlieb, 1958), no phyllosoma were found close to these coasts (Fig. 2). Most larvae were caught far away with two found as far as about 260 km off the coast.

Larvae (Fig. 2) were sampled mostly in the eddy south of Crete (cold-core eddy), Mersa Matruh and its northern neighbor gyre (south-east of Crete) and Shikmona eddy (south of Cyprus). Only two phyllosoma were found away from any eddy structure south of Crete. However, since most cruises were aimed for measurements of physical and chemical characteristics of eddies, the sampling pattern of larvae may be imbalanced. It is therefore suggested to extend the sampling range of the present preliminary study also to areas away from eddies.

Drifter experiments south of Crete showed that buoys that had been trapped for days or weeks in eddies moved for unknown reasons to the eddy boundaries, left the eddies, but became trapped once more, by neighboring eddies (A. Hecht, *personal communications).* The planktonic life of phyllosomes lasts several months. This implies an increased probability that they will be trapped in eddies while they drift away from the coast. Obviously there is a "trade off" between the advantage of reaching uninhabited coasts and the risk of being lost at sea. The amount of time larvae actually spend in a certain eddy has not been calculated and it is not known where they emerge. Yet, this explains the high dispersal of larvae. Long planktonic larval-life and high dispersal often correlate with a broad niche breadth in the adults. High larval dispersal reduces intraspecific competition that is of particular importance in environments with highly limited resources. The data of the present preliminary study is based on a relatively small number of phyllosomes. There is a clear need to expand the sample size, spatial and temporal scope of the coverage in future studies to verify the trends suggested here.

ACKNOWLEDGMENTS

The authors wish to thank M.D. Krom and A. Hecht for supporting lab facilities and ship time during POEM and IOLR-Eddy cruises and Cpt. A. Ben Nun, the crew of R/V Shikmona II and S. Kourilov and J. Bishop for assistance and cooperation.

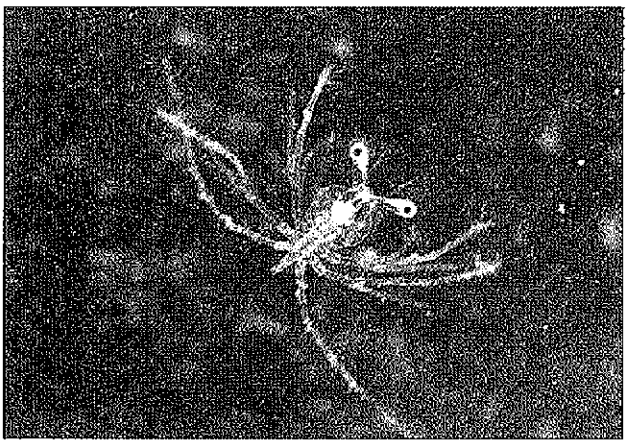

Fig. 3: Phyllosoma larva of the broad lobster *Scyllarus arctus* ***(Photo: E. Spanier).***
Sl. 3: Larva filosoma raka vrste *Scyllarus arctus* ***(Foto: E. Spanier).***

POJAVLJANJE LARV RAKA *SCYLLARUS ARCTUS* (CRUSTACEA, DECAPODA, SCYLLARIDAE) V VZHODNEM SREDOZEMLJU - PREDHODNI REZULTATI

Ulrich FIEDLER
Abt. Meereszoologie, Institut für Meereskunde Düsternbrooker Weg 20, D-24105 Kiel, Germany

Ehud SPANIER
The Leon Recanati Center for Maritime Studies in Department for Maritime Civilizations, University of Haifa, Mount Carmel, Haifa 31905, Israel

POVZETEK

Avtorja sta s planktonsko mrežo lovila in vzorčevala filosome raka nagajivca Scyllarus arctus *(Crustacea: Decapoda: Scyllaridae) v vzhodnem Sredozemlju. Na osnovi vzorčenja sta pripravila shemo za ločevanje med*

razvojnimi stadiji larv, z opisi značilnosti stadijev filosom od 3-12. Filosome preučevane vrste so bile najdene med skoraj vsakim vzorčenjem v teku leta in v vzorcih so bili zastopani skoraj vsi stadiji. Dobljeni zgodnji razvojni stadiji larv kažejo na to, da drstitveno obdobje poteka predvsem med februarjem in aprilom ter med julijem in septembrom. Večina larv je bila ujeta daleč od obrežja. Larve so bile vzorčene v štirih območjih s stalnimi ali ponavljajočimi se cirkulirajočimi vrtinci. Podatki teh raziskav kažejo na verjetnost, da se filosome lahko ujamejo v vrtince za razmeroma dolgo obdobje, ko jih nosi proč od obrežja. Avtorja razglabljata o možnem ekološkem pomenu teh odkritij.

Ključne besede: zooplankton, filosome, raki, deseteronožci, medvedji raki, *Scyllarus arctus*, razširjenost, vzhodno Sredozemlje

REFERENCES

Brenner, S., 1993. Long-term evolution and dynamics of a persistent warm core eddy in the Eastern Mediterranean Sea. Deep-Sea Research II, 40: 1193-1206.

Cobb, J. S. & Wahle, R. A., 1994. Early life history and recruitment processes of clawed lobsters. Crustaceana, 67: 1-25.

Dohrn, A., 1870. Untersuchungen über Bau und Entwicklung der Arthropoden. 6. Zur Entwicklungsgeschichte der Panzerkrebse (Decapoda loricata). Zeitschrift für Wissenschaftliche Zoologie, 20, p 248 ff.

Factor, J. R. 1995. Biology of the lobster *Homarus americanus*. Academic Press, London. 528 pp.

Holthuis, L., 1991. Marine lobsters of the world, an annotated and illustrated catalogue of species of interest to fisheries known to date. FAO Fisheries Synopsis No 125, Vol. 13, FAO Rome, 292 pp.

Holthuis, L. B. & Gottlieb, E., 1958. An annotated list of the Decapod Crustacea of the Mediterranean coast of Israel, with an appendix listing the Decapods of the Eastern Mediterranean. Bulletin of the Research Council Israel, 7 B (1-2): 1-126.

Ito, M. & Lucas, J. S., 1990. The complete larval development of the scyllarid lobster, *Scyllarus demani*, Holthuis, 1946 (Decapoda, Scyllaridae), in the laboratory. Crustaceana, 58 (2): 144-167.

Kittaka, J., 1994. Larval ecology. In: Spiny lobster management (ed. Phillips, B. F., J. S. Cobb & J. Kittaka), pp. 402-423. Oxford: Fishing News Book (Blackwell).

Krom, M. D., Kress, N., Brenner, S. & Gordon, L. I., 1991. Phosphorus limitation of primary productivity in the eastern Mediterranean Sea. Limnology and Oceanography, 36 (3): 424-432.

Martins, H. R., 1985. Biological studies of the exploited stock of the Mediterranean locust slipper lobster *Scyllarides latus* (Latreille, 1803) in the Azores. Journal of Crustacean Biology, 5: 294-305.

Phillips, B. F. & McWilliam, P. S., 1989. Phyllosoma Larvae and the Ocean Currents off the Hawaiian Islands. Pacific Science, 43 (4): 352-361.

Ritz, D. A., 1977. The larval stages of *Scyllarus demani* Holthuis, with notes on the larvae of *S. sordidus* (Stimpson) and *S. timidus* Holthuis (Decapoda, Palinuridea). Crustaceana, 32 (3): 229-240.

Robertson, P. B., 1968. The complete larval development of the sand lobster, *Scyllarus americanus* (Smith) (Decapoda, Scyllaridae), in the laboratory, with notes on larvae from the plankton. Bulletin of Marine Sciences, 18: 294-342.

Robinson, A. R., Golnarighi, M., Leslie, W. G., Artegiani, A., Hecht, A., Lazzoni, E., Michelato, A., Sansone, E., Theocharis, A. & Ünlüata, Ü., 1991. The Eastern Mediterranean general circulation: features, structure and variability. Dynamics of Atmosphere & Oceans, 15: 215-240.

Robinson, A. R., Hecht, A., Pinardi, N., Bishop, J., Leslie, W. G., Rosentroub, Z., Martiano, A. J. & Brenner, S., 1987. Small synoptic/mesoscale eddies and the energetic variability of the eastern Levantine basin. Nature, 327: 131-134.

Rothlisberg, P. C., Jackson, C. J., Phillips, B. S. & McWilliam, P. S, 1994. Distribution and abundance of scyllarid and palinurid lobster larvae in the Gulf of Carpentaria, Australia. Australian Journal of Marine and Freshwater Research 45: 337-349

Seridji, R., 1989. Étude des Larves de Crustacés Décapodes: Aspects taxonomique, écologique et biogéographique. Ph.D. Thesis Université des sciences et de la Technologie Houari Boumediene, Alger, 618 pp.

Spanier, E., Tom, M., Pisanty, S. & Almog, G., 1988. Seasonality and shelter selection by the slipper lobster *Scyllarides latus* in the southeastern Mediterranean. Marine Ecology Progress Series, 42: 247-25.

Stephensen, K., 1923. Decapoda Macrura excl. Sergestidae. Report Danish. oceanogr. Exp. 1908-1910 to the Mediterranean and adjacent seas, Vol. 2, D. 3.

Wada, Y., Kuwahara, A., Munekiyo, M. & Sobajima, N., 1989. Distribution and Larval Stages of the Phyllosoma Larvae of a Scyllarid Lobster, *Scyllarus kitanoviriosus*, in the Western Wakasa Bay. Bulletin of Kyoto Ocean Fishery Science, 9: 51-57.

Zariquiey Alvarez, R., 1968. Crustaceos décapodos Ibericos. Investigacion Pesquera, T 32, 500 pp.