Journal of Plankton Research Vol.15 no.7 pp.855–865, 1993

On the occurrence of Calycophorae (Siphonophora) in the southern Adriatic and Tyrrhenian Sea: a comparison of the annual cycles off Dubrovnik and Naples

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Abstract. The 1965/66 samples taken monthly at three stations in the Bay of Naples and in the south of Dubrovnik were used to compare the calycophore fauna of the Tyrrhenian Sea and the Adriatic. Nearly identical calycophore fauna were found, except for three rare Atlantic forms registered only by the deep-sea station in the Tyrrhenian Sea. Of numerical importance were the neritic species *Muggiaea kochi*, *Lensia subtilis*, *Sphaeronectes gracilis* and *S.irregularis*, and the characteristic open-sea species *Eudoxoides spiralis* and the deep-sea species *Lensia meteori*. The annual numerical abundance maxima in both areas were noted in spring. However, in the Tyrrhenian Sea, the values were two times higher, which agrees with the productivity patterns.

Introduction

The available data on the Mediterranean calycophores derive mainly from the Spanish, French and west Italian coasts (Tregouboff and Rose, 1957; Cervigon, 1958; Furnestin, 1960; Patriti, 1964; Kinzer, 1965; Vives, 1966; Gamulin, 1971; Ianora and Scotto di Carlo, 1981).

The most complete set of data for the eastern Mediterranean derive from the Adriatic Sea, where horizontal, vertical and annual distribution patterns have been investigated for 23 known species. The quantitative data on calycophores, especially for polygastric and eudoxid generations, are indispensable for estimating their importance in marine food webs (Moser, 1917; Bigelow and Sears, 1937; Gamulin, 1948, 1979, 1982; Hure, 1955; Rottini, 1966; Rottini and Gamulin, 1969). On the other hand, data from the Ionian waters and the Levantine coast are scarce (Patriti, 1969; Lakkis, 1971; Rottini, 1971). Furthermore, investigations carried out up to now in the shallow Mediterranean waters do not give us comparable data, because of large differences in the methods used.

The aim of this paper is to present the occurrence and the distribution patterns of the calycophores, based on the investigations in the Bay of Naples (western Mediterranean) and the southern Adriatic, near Dubrovnik (eastern Mediterranean).

Method

The calycophores were investigated monthly at three stations near Dubrovnik (southern Adriatic) and Naples (Tyrrhenian Sea), between October 1965 and September 1966, within the framework of a joint research programme run by the Biological Institute of Dubrovnik and the Statione Zoologica di Napoli:

'Comparazione tra lo zooplankton del Golfo di Napoli e dell'Adriatico meridionale presso Dubrovnik' (Figure 1). The samples were taken by vertical tows with a 100 cm diameter Nansen net of 250 μm mesh. In both study areas, the depth intervals sampled were as follows: Station A, 100–0 m; Station B, 300–0 m; Station C, near Dubrovnik, 900–0 m and near Naples 1000–0 m.

The samples were preserved in 2.5% formaldehyde neutralized with calcium carbonate buffer.

In the entire catch, the total number of the nectophores (polygastric) and gonophores (eudoxid) generation were counted, whereas in the present paper the numbers of gonophores are not considered.

All these results are presented as specimen numbers per 1 m^2. The data were subjected to statistical analyses by means of the Pearson coefficient of correlation (r).

Study areas

The Naples stations and the stations in the southern Adriatic are located at approximately the same geographic latitude, but have different bathymetric characteristics because of their specific physicochemical and biological properties.

The sea bottom at the Dubrovnik profile gradually declines from the coast towards the open sea. The stations investigated are under the direct influence of the incoming South Adriatic current (Zore-Armanda, 1968). On the other hand, only Station A is located in the vast Naples Bay, whereas Station B is at the entrance to the Bay and is therefore influenced by waters outflowing from the Bay. The offshore Station C is located outside the Bay, 4 miles south of the island of Capri. The inner stations are neritic, whereas only the outside station is under the influence of the open waters. At the coastal Dubrovnik station, the annual variability of surface salinity was 37.0–38.3‰ and at deep-sea stations 38.0–38.8‰. In Naples, the surface salinity at Station A was 37.1–37.9‰ and at Stations B and C 37.4–38.1‰.

The variability of temperature was similar for both areas as at open water of the Mediterranean, with minimum values of 13–14°C in February or March and a maximum of 25–26°C in August. More detailed hydrographical data about the present stations are given by Gamulin *et al.* (1968), as is the hydrography and productivity of the Bay of Naples in Carada *et al.* (1980, 1981).

Results and discussion

During the period under investigation, 21 species were found near Dubrovnik and 24 species of calycophores at Naples stations. According to their numerical abundance, six calycophores are common species in both regions: *Muggiaea kochi*, *Lensia subtilis*, *S.irregularis*, *Sphaeronectes gracilis*, *Eudoxoides spiralis* and *Lensia meteori* (Figures 2 and 3). Other calycophores were rare species and were seen in only some of the areas under investigation (Tables I and II).

Of the rare calycophores, three were registered only at the deepest Station C at Naples: *Lensia subtiloides*, *Muggiaea atlantica* and *Rosacea cymbiformis*.

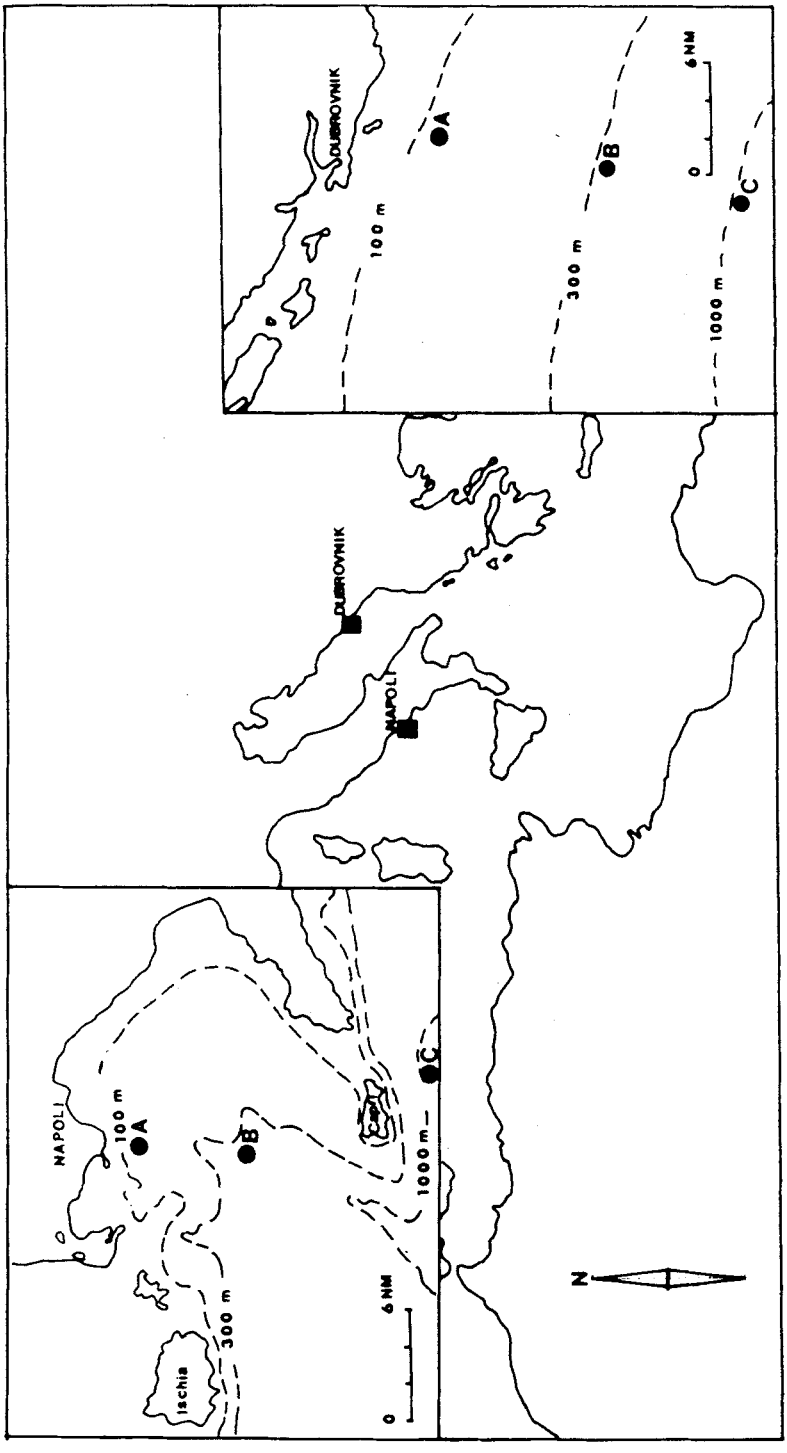

Fig. 1. Locations of sampling stations.

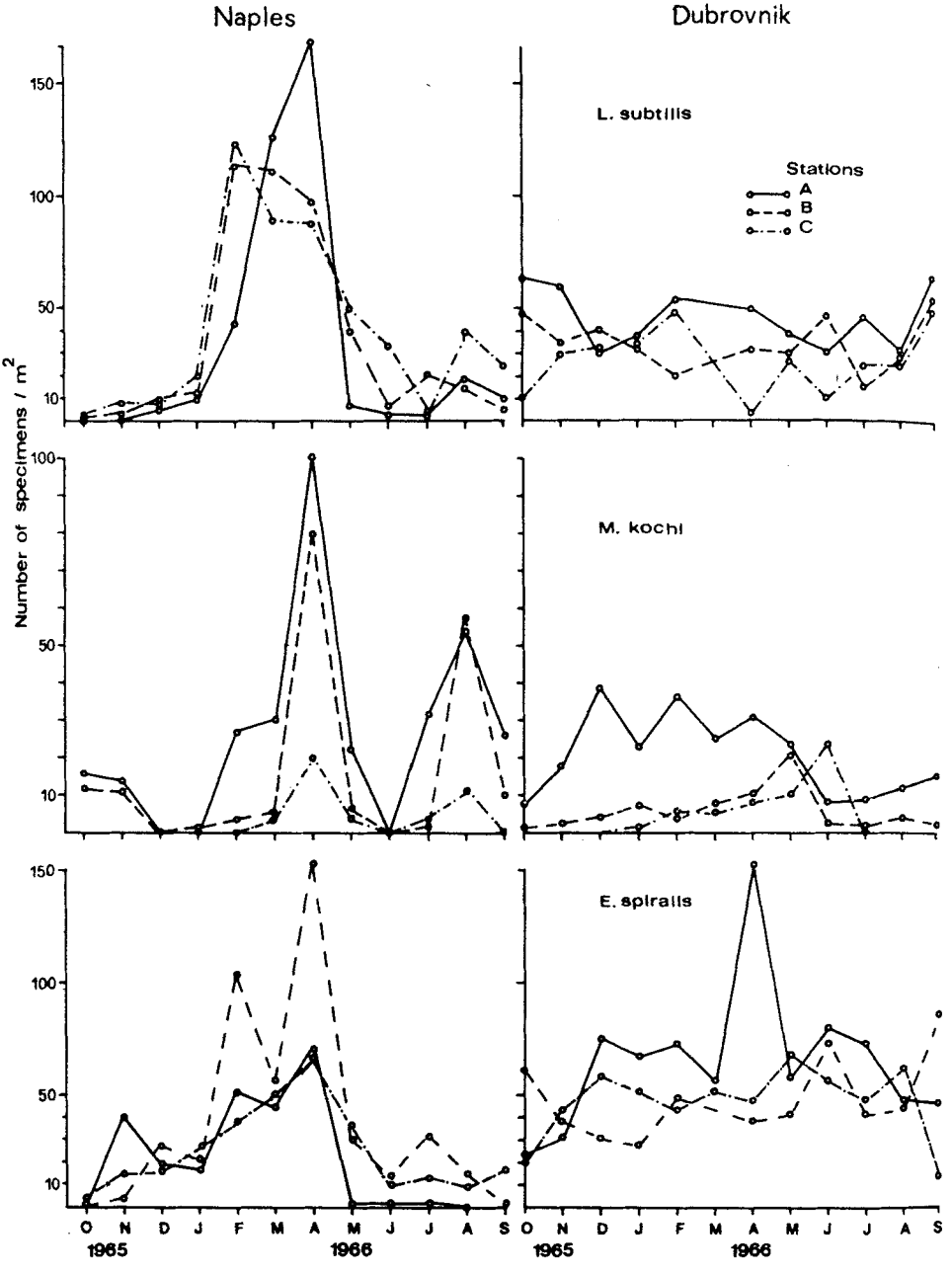

Fig. 2. Seasonal variation in the number of nectophores for the calycophore species *L.subtilis*, *M.kochi* and *E.spiralis* in the Naples and Dubrovnik areas.

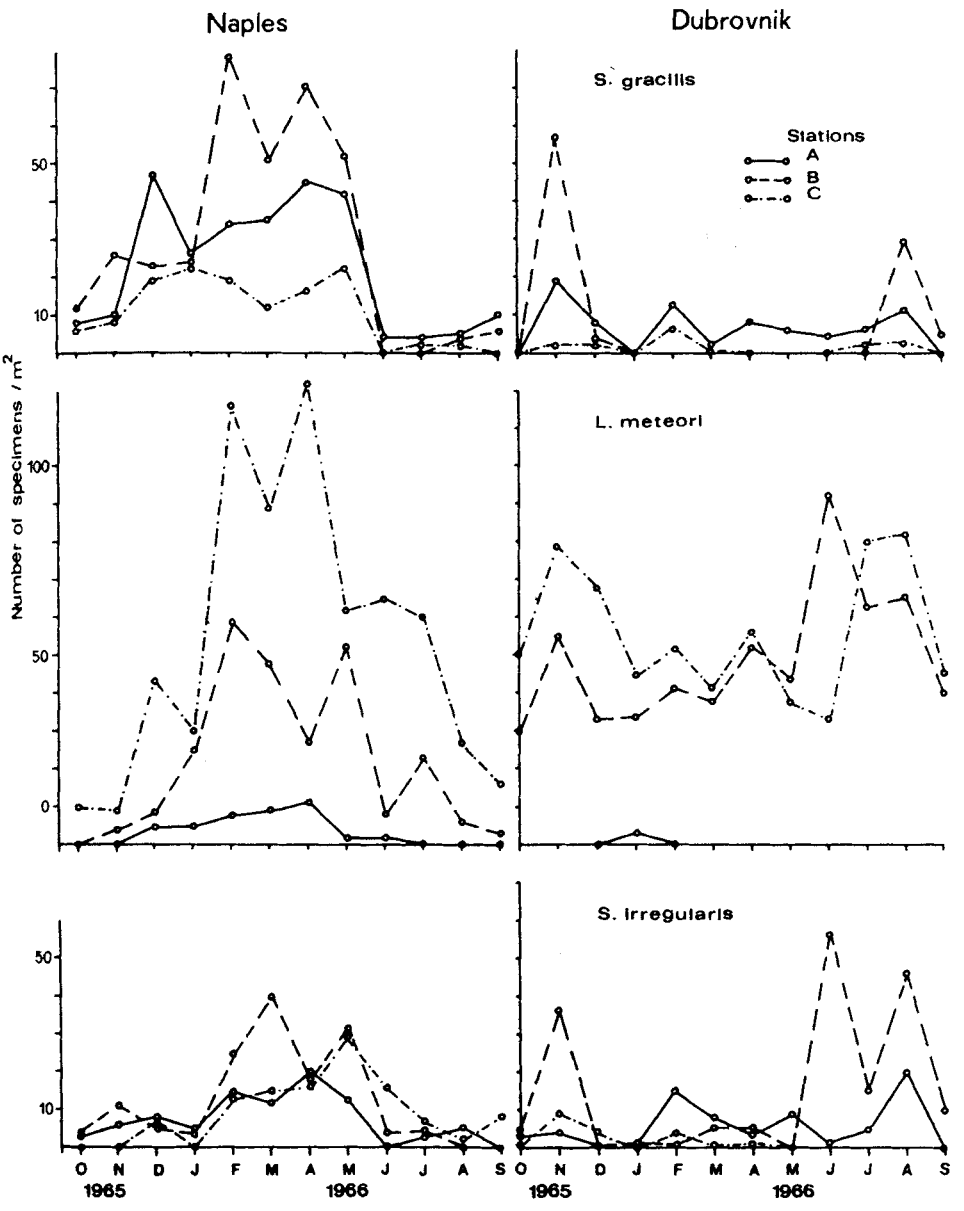

Fig. 3. Seasonal variation in the number of nectophores for the calycophore species *S.gracilis*, *L.meteori* and *S.irregularis* in the Naples and Dubrovnik areas.

Other rare species, based on their occurrences in both areas, have been divided into several groups; *Lensia campanela*, *Hippopodius hippopus* and *Lensia conoidea* were found regularly, but were never common in both profiles. The species *Bassia bassensis*, *Lensia fowleri* and *Sulculeolaria chuni* are characteristic calycophores for the Dubrovnik area, whereas *Abylopsis tetragona* and

Table I. The occurrence of rare calycophores on the profile Naples in 1965/66 (no. m^{-2}). Stations: A, 100–0; B, 300–0; C, 1000–0 m

	Month											
	O	N	D	J	F	M	A	M	J	J	A	S
Lensia campanella												
A		3	5	3	8		6		1		1	
B	5	5	10	5	8	11	11	13		4	1	
C		2	10		14		6	4	11		18	15
Hippopodius hippopus												
A			7	3	1		4	5			1	
B				1	5	7	6	5	5		3	
C	3	3	7		7		1	4		5		4
Lensia conoidea				1								
A			3	4								
B			1		1		2	1		1		
C			2		6		5	3	9	2	2	2
Bassia bassensis												
A												
B					1							
C			1		1							
Lensia fowleri												
A						1						
B												
C	1	2	1		1	1			2	1		
Sulculeolaria chuni												
A									1		9	
B										2	3	
C							2	5		3	23	
Abylopsis tetragona				3								
A			3		9	1	1	5		1		
B		3	5		11	7	6	5		4	1	
C		4	3		19		9	5	3	3	1	3
Chelophyes appendiculata												
A		1					2				6	
B		3	3				1			4	34	
C			1				1	2			23	26
Sphaeronectes gamulini												
A												
B							1					
C											1	
Sphaeronectes fragilis												
A								1		1		
B								3			3	
C									1		1	
Chelophyes ovata												
A												
B					3							
C								2		1	1	1
Sulculeolaria quadrivalis												
A					1							
B					1					2		
C					1						1	

Table I. Continued

	Month											
	O	N	D	J	F	M	A	M	J	J	A	S
Sulculeolaria turgida												
A							1					
B						1	3		1	1		
C								3	1	1		
Vogtia pentacantha												
A												
B												
C	2						4			2		
Lensia multicristata												
A				4			2					
B	4			6		5				2	2	
C	4						2		2	2	2	2
Muggiaea atlantica												
A												
B												
C					2							
Lensia subtiloides												
A												
B												
C								2				
Rosacea cymbiformis												
A												
B						1						
C												

Table II. The occurrence of rare calycophores on the profile Dubrovnik in 1965/66 (no. m^{-2}). Stations: A, 100–0; B, 300–0; C, 900–0 m

	Month											
	O	N	D	J	F	M	A	M	J	J	A	S
Lensia campanella												
A			2	5	6	15	4	9	9	2		18
B		1	5		1	8		14		4		8
C		1			5		1	6	15			1
Hippopodius hippopus												
A			10	1	6	3			4	1		4
B	3						8	3		5		
C		4	4		4	5		4	1	1		
Lensia conoidea												
A					1							
B	6	1	1		1	1	3	6	5			
C	2	5	1		6		1	7	15	1		2
Bassia bassensis												
A	1	1	32	3		4	4	1		5	1	
B	1	1	3		1			1		5		1
C	1	1	1		1					1		
Lensia fowleri												
A	1			1		3						
B	6	13	4		4	6	6	1	6	1		
C	13	1	6	2	10	10	4	8	26	23		7

Table II. Continued

	Month											
	O	N	D	J	F	M	A	M	J	J	A	S
Sulculeolaria chuni												
A	10	3					19	38	7	6	14	3
B	20	10						2		5		1
C	3							1		16		3
Abylopsis tetragona												
A			1		1	3						
B	1	1	3									
C			1		1		1			1		
Chelophyes appendiculata												
A					1							
B						1						
C	3					1						
Sphaeronectes gamulini												
A		3		1								
B	1					1				2		
C						1		1				
Sphaeronectes fragilis												
A												3
B		1				1			1			
C	1											
Chelophyes ovata												
A												
B												
C		3				1						
Sulculeolaria quadrivalis												
A							3					1
B									3			1
C		3						2				
Sulculeolaria turgida												
A					2			1				
B							1			2		1
C								1				
Vogtia pentacantha												
A												
B			8									
C	3					5				2		
Lensia multicristata												
A												
B												
C									1			

Chelophyes appendiculata are characteristic for the Naples profile, which confirms the observations by Bigelow and Sears (1937). Other species were found sporadically in small numbers, with higher diversity during the spring–summer periods. In both study areas, the higher numbers of specimens of all rare species were found at the deep-sea station, which agrees with the ecology of these open-sea forms.

The proportion of the common species in the overall number of nectophores is uniform and amounts to as much as 87%. In the Bay of Naples, there was a well-

Table III. Pearson correlation coefficients (r) between stations in the Naples and Dubrovnik areas for common calycophores

		Naples		Dubrovnik	
		A	B	A	B
L.subtilis	B	0.808*		0.601**	
	C	0.709*	0.948*	0.505$^{n.s.}$	0.294$^{n.s.}$
M.kochi	B	0.904*		0.371$^{n.s.}$	
	C	0.944*	0.929*	−0.018$^{n.s.}$	0.321$^{n.s.}$
E.spiralis	B	0.925*		0.263$^{n.s.}$	
	C	0.524$^{n.s.}$	0.656**	−0.117$^{n.s.}$	0.298$^{n.s.}$
S.gracilis	B	0.798*		0.732*	
	C	0.865*	0.725*	0.661**	0.255$^{n.s.}$
L.meteori	B	0.617**		−0.306$^{n.s.}$	
	C	0.845*	0.742*	−0.193$^{n.s.}$	0.191$^{n.s.}$
S.irregularis	B	0.737*		0.188$^{n.s.}$	
	C	0.526$^{n.s.}$	0.684*	−0.006$^{n.s.}$	0.093$^{n.s.}$

$n = 12$.
n.s., not significant.
* $P < 0.01$; ** $P < 0.05$.

defined spring maximum and summer minimum for all common species. From February to May, 70% of the specimens from the total amount of the annual population were found. Significant correlations of annual variation in numerical abundance between stations were noted (Table III). In the area of Dubrovnik, two peaks were registered in November 1965 and summer 1966 for *S.gracilis*, *S.irregularis* and *L.meteori*. The population variability of other common species through the year were not numerically expressed except for *E.spiralis* in April at Station A, a maximum were noted. However, significant correlations between stations were rarely registered (Table III).

In the Bay of Naples, the neritic forms *M.kochi* comprised only 30% at Station A and *L.subtilis* 18–23% at all stations of the average annual total number of common calycophores. However, the deep-sea species *L.meteori* comprised 15% at Station B and 34% at Station C. Near Dubrovnik, the dominant species *E.spiralis* contributed an average 36% and *L.subtilis* 25% at all stations, and *L.meteori* 38% at Station B, 42% at Station C, to the total annual number of nectophores. The species *E.spiralis* is present in higher number in the Dubrovnik area, in agreement with the results of the 'Thor' expedition (Bigelow and Sears, 1937), thus confirming its outstanding dominance in the eastern Mediterranean.

According to Gamulin (1982), *M.kochi* is an outstandingly dominant species of the Adriatic, contributing 57–87% of the total number of nectophores. It was especially abundant in the middle and northern Adriatic, and along the Italian coast. Presumably, due to the closed and neritic character of the Bay of Naples, its numbers in the Bay were nearly double those registered near Dubrovnik. A

maximum of 1 nectophore (n) m^{-3} was registered at Station A in the Bay of Naples. Values reported earlier were considerably lower. In the vicinity of Marseilles, the values did not exceed 0.02 n m^{-3}, whereas in Lybian coastal waters values were 0.1 n m^{-3} (Patriti, 1964, 1969). *Muggiaea kochi* was rarely registered in collections from the eastern Mediterranean (Patriti, 1969; Rottini, 1971; Alvarino, 1974).

Lensia subtilis was second in importance numerically among the Adriatic calycophores (Gamulin, 1982), although it was far less numerous than *M.kochi*. It may be found throughout the Adriatic Sea, above the 60 m isobath, and is more abundant in the eastern than the western Adriatic. The present investigation showed very similar distribution and numerical abundance patterns to *M.kochi*. The highest number of specimens was found at the coastal stations, whereas in the Bay of Naples a maximum of 1.7 n m^{-3} was observed in April. The mid-water species *L.meteori* was numerically highly significant in Stations B and C in both areas. However, its annual cycles were different. According to our data for vertical distribution, the bulk of the population was at between 300 and 100 m depth. Therefore, the maximum population density at Station B in the Bay of Naples was 0.3 n m^{-3}, which is higher than the data for Marseilles (2.19 n per 5000 m^3; Patriti, 1964).

In our data, *E.spiralis* appeared to be more abundant in the Dubrovnik area than at Station A and Station B in the Bay of Naples. It should be mentioned that *M.kochi*, *L.subtilis* and *L.meteori* were not registered in plankton hauls during the 'Thor' expedition in the open Mediterranean waters (Bigelow and Sears, 1937).

In the Bay of Naples, spring maximum values were nearly twice those of the Dubrovnik profile. Ianora and Scotto di Carlo (1981) have observed a similar annual distribution pattern of calycophores in the Bay of Naples. The spring population of calycophores near the Bay of Naples fits the maximum population density of neritic copepods (Hure and Scotto di Carlo, 1968). Since many species are present throughout the year at shallow stations in both study areas, their spring domination may be explained by favourable hydrographic and productivity conditions at that time. According to Purcell (1981), calycophores are carnivorous and prey on nauplii and copepods.

Owing to their complex life cycle, calycophores are a less well-known species of macrozooplankton and the role they play in marine food webs has been entirely neglected. Since some of the neritic forms are occasionally very numerous in the coastal ecosystem, the importance of these organisms in the pelagic waters should by no means be neglected.

References

Alvarino,A. (1974) Distribution of the Siphonophores in the regions adjacent to the Suez and Panama Canals. *Fish. Bull.*, **72**, 527–546.

Bigelow,H.B. and Sears,M. (1937) Siphonophorae. *Rep. Dan. Oceanogr. Exped., 1908–1910. Mediterr. Adjacent Seas*, **II (H 2)**, 1–144.

Carrada,G.C., Hopkins,T.S., Bonaduce,G., Ianora,A., Marino,D., Modigh,M., Ribera D'Alcala,M. and Scotto di Carlo,B. (1980) Variability in the hydrographic and biological features of the Gulf of Naples. *P.S.Z.N.I.: Mar. Ecol.*, **1**, 105–120.

Carrada,G.C., Fresi,E., Marino,D., Modigh,M. and Ribera D'Alcala,M. (1981) Structural analysis of winter phytoplankton in the Gulf of Naples. *J. Plankton Res.*, **3**, 291–314.

Cervigon,F. (1958) Contributión al estudio de los sifonóforos de las costas de Castellón (Mediterráneo Occidental). *Inv. Pesq.*, **12**, 21–48.

Furnestin,M.L. (1960) Zooplankton du Golfe du Lion et de la cote orientale de Corse. *Rev. Trav. Inst. Peches Marit.*, **24**, 153–252.

Gamulin,T. (1948) Prilog poznavanju zooplanktona srednjedalmatinskog otočnog područja. *Acta Adriat.*, **3**, 159–194.

Gamulin,T. (1971) Comparaisons entre le zooplancton de la baie de Naples et celui de l'Adriatique méridionale pres de Dubrovnik. *Rapp. Comm. Int. Mer Médit.*, **20**, 379–383.

Gamulin,T. (1979) Zooplankton istočne obale Jadranskog mora. *Prir. Istraz.*, **43**, 177–270.

Gamulin,T. (1982) Zooplankton. Siphonophora—Calycophorae. In *Reports and Results of the Oceanographic Investigations in the Adriatic Sea*, pp. 183–188.

Gamulin,T., Hure,J. and Scotto di Carlo,B. (1968) Comparazione tra lo zooplankton del Golfo di Napoli e dell'Adriatico meridionale presso Dubrovnik. *Pubbl. Staz. Zool. Napoli*, **36**, 8–20.

Hure,J. (1955) Distribution annuelle verticale du zooplankton sur une station de l'Adriatique meridionale. *Acta Adriat.*, 7, 3–72.

Hure,J. and Scotto di Carlo,B. (1968) Comparazione tra lo zooplankton del Golfo di Napoli e dell'Adriatico meridionale presso Dubrovnik. I. Copepoda. *Pubbl. Staz. Zool. Napoli*, **36**, 21–102.

Ianora,A. and Scotto di Carlo,B. (1981) The distribution and annual cycles of Siphonophora Calicophora in the Gulf of Naples and adjacent waters. *Arch. Oceanogr. Limnol.*, **20**, 51–65.

Kinzer,J. (1965) Untersuchungen uber das Makroplankton bei Ishia und Capri und im Golf von Neapel im Mai 1962. *Pubbl. Staz. Zool. Napoli*, **34**, 245–255.

Lakkis,S. (1971) Contribution a l'etude du zooplancton des eaux libanaises. *Mar. Biol.*, **11**, 138–148.

Moser,F. (1917) Die Siphonophoren der Adria und ihre Beziehungen zu denen des Weltmeeres. *Sitzungsber. K. Akad. Wiss. Wien Math. Naurwiss Kl.*, **126**, 703–762.

Purcell,J.E. (1981) Dietary composition and diel feeding patterns of epipelagic siphonophores. *Mar. Biol.*, **65**, 83–90.

Patriti,G. (1964) Les Siphonophores Calycophores du Golfe de Marseille. *Recl. Trav. St. Mar. Edn. Bull.*, **35**, 185–258.

Patriti,G. (1969) Apercu sommaire sur la distribution des siphonophores dans le Golfe de Gabes et dans les eaux cotieres de Tripolitane. Compagne de la 'Calypso', April–May 1965. *Tethys*, **1**, 249–254.

Rottini,L. (1966) I Sifonofori del Medio Adriatico. *Boll. Pesca Pisc. Idrobiol.*, **21**, 305–318.

Rottini,L. (1971) Sifonofori del Mediterraneo orientale: Mare di Creta e Jonio. *Boll. Pesca Piscic. Idriobiol.*, **26**, 199–208.

Rottini,L. and Gamulin,T. (1969) Distributione dei Sifonofori in Adriatico a nord della transversale Fano–Lussino. *Boll. Pesca Piscic. Idrobiol.*, **24**, 79–89.

Tregouboff,G. and Rose,M. (1957) *Manuel de Planctologie Mediterranéenee*. Cent. Natl. Rech. Sci., Paris, pp. 1–2.

Vives,F. (1966) Zooplancton neritico de las aquas de Castellón (Mediterráneo occidental). *Inv. Pesq.*, **30**, 49–166.

Zore-Armanda,M. (1968) The system of currents in the Adriatic sea. *Stud. Rev. Gen. Fish. Counc. Medit.*, **34**, 1–48.

Received on March 19, 1992; accepted on March 15, 1993