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THE DISTRIBUTION AND ANNUAL CYCLES OF SIPHONOPHORA CALICOPHORA IN THE GULF OF NAPLES AND ADJACENT WATERS [1]

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ABSTRACT

The annual variation, vertical distribution range and community structure of 23 species of Calicophorid Siphonophores in the Gulf of Naples and its adjacent waters are examined, based on year-round sampling at two fixed stations within the Gulf and the material collected during the course of three cruises in the open waters of the Mediterranean. The annual cycles at both stations in the Gulf showed a late winter and fall period of maxima which reflected the annual variation of the most dominant surface species. Calicophorids were almost completely absent from our samples in summer. Open-sea hauls indicate that Calicophorids show a wide vertical range (0-2000 m) with a maximum in subsurface waters. Based on the vertical range of the single species, three Calicophorid communities have been identified: a surface community (0-200 m) mainly characterized by *Chelophyes appendiculata, Eudoxoides spiralis, Muggiaea kochi, Sulculeolaria chuni, Lensia subtilis, Sphaeronectes gracilis* and *S. irregularis;* a mid-water community (200-500 m) characterized by *Lensia conoidea, L. multicristata, L. fowleri* and *L. meteori;* a deep-water community (500-2000 m) characterized by *Lensia subtiloides, Clausophyes ovata, Vogtia pentacantha* and *V. spinosa.* The horizontal spread of the species comprising these communities is discussed in relation to their vertical distribution pattern.

INTRODUCTION

Calicophorid Siphonophores are a constant and relatively important quantitative component of the zooplankton community of most tropical,

[1] We are indebted to Prof. Tomo Gamulin for having introduced one of us to the study of this group and to both Prof. Gamulin and Dr. Jure Hure of the Biološki Institut of Dubrovnik for critically reviewing the manuscript.

subtropical regions, especially if one considers the role they play as secondary consumers in trophic food webs. Quantitatively, they may be important in subsurface waters, and, together with other organisms, probably contribute to the deep scattering layers of the Mediterranean and other oceans (Pedenovi and Della Croce 1971). Moreover, due to their poor capacity for active movement, they have often been utilized as indicators of different water masses (Russel 1935; Furnestin 1957; Rottini 1969).

To date, rather little information is available on Siphonophores within the Gulf of Naples though its study dates back to the works of Keferstein and Ehlers (1861), Spagnolini (1870), Bedot (1881) and Neppi (1921), as well as to several citations encountered in the works of Lo Bianco (1902, 1903). More recently, Kinzer (1963) sampled 13 species of Calycophorids, giving their areal and vertical depth distribution in May. Gamulin (1971), in a preliminary note, gives the numerical and relative percentage values for six of the quantitatively more important Calycophorids, based on a one-year study at 3 stations within the Gulf.

During our observations on the zooplankton of the Gulf of Naples, especially on its distribution, abundance and seasonal fluctuations, we have gathered a notable amount of data as regards this planktonic group.

The present study is an attempt to single out the annual variation and vertical distribution patterns of Calicophorids in the Gulf of Naples. In addition, several considerations on the horizontal distribution and Calicophorid-community structure in subsurface and deep waters have been drawn from the data collected during the course of 3 cruises performed in the open waters of the Tyrrhenian Sea.

MATERIAL AND METHODS

The data reported are based on 2 annual cycles performed in the Gulf, from December 1973 to November 1974 at Station A (120 m depth), and from January 1976 to January 1977 at Station L 20 (300 m depth) (fig. 1).

At Station A, vertical hauls from 100-75, 75-50, 50-25 and 25-0 m were carried out at bi-weekly intervals from 9:00 - 10:00 a.m. using a 250 μm Indian Ocean Standard closing net 113 cm in diameter (1 m^2 surface area), 400 cm in length. At St. L 20, vertical hauls from 50 m and from the bottom (300 m) to the surface were carried out at bi-weekly intervals from 9:00 - 10:00 a.m. using a 250 μm open Nansen net of the above - mentioned dimensions.

Three series of day-night hauls were also performed in April and October

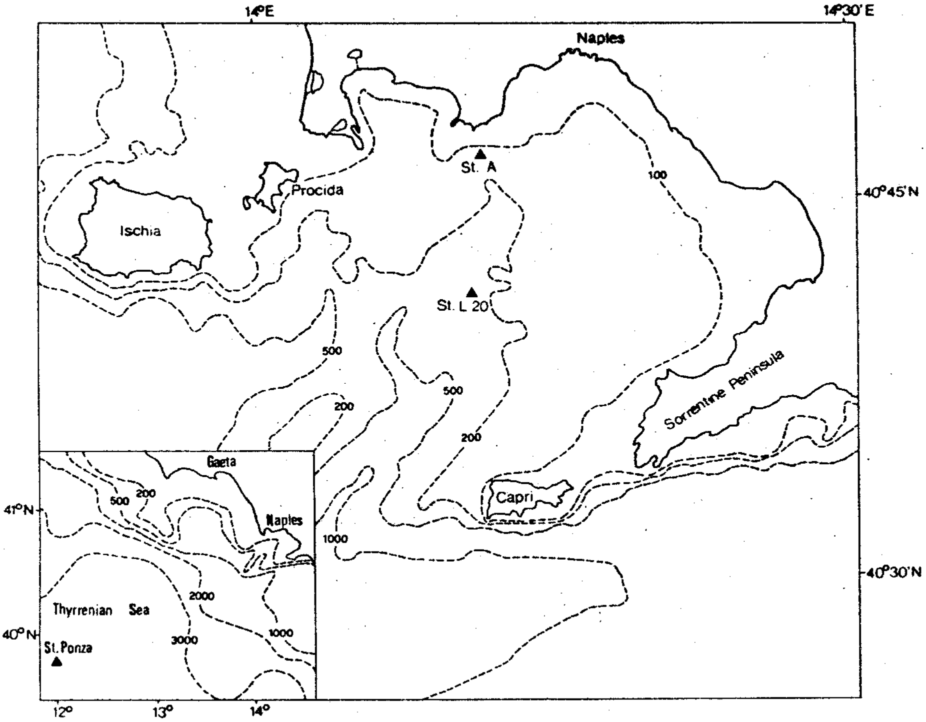

FIG. 1. Gulf of Naples. Sampling sites.

1977 at a fixed station located south-west of the Island of Ponza (lat. 40°36',00; long. 12°44',00), using a 250 μm Indian Ocean Standard closing net. The depth intervals sampled were the following: 3000-2000, 2000-1500, 1500-1000, 1000-800, 800-600, 600-500, 500-400, 400-300, 300-200, 200-100, 100-50 and 50-0 m.

Finally, a series of hauls were performed in the vicinity of Ponza in April, June 1976 and October 1977 using an open Isaacs-Kidd midwater trawl (15 ft) on which a depth recorder was mounted. The net was towed for one hour at 4 knots at the required depth and was then hauled aboard obliquely. The levels sampled were as follows: April 1976: 600 m; June 1976: 200, 750 m; October 1977: 0, 50, 250, 500, 800, 1000, 1500 m. This sampling technique did not permit us to correctly evaluate the depth at which the various species were caught. The material collected while the net was being hauled aboard contaminated the community we had set out to sample. The greater the depth, the greater the degree of contamination, to the point that when the net sampled in deep levels, very poor in Siphonophores, the specimens caught were almost entirely from the upper levels.

The total number of anterior nectophores of each of the Indian Ocean and Nansen net samples were counted and determined. On the other hand, due to the huge amount of material, an aliquot varying from 1/5 to 1/10 of the total was looked at for those samples collected with an IKMT.

One of the major drawbacks of this study resides in the fact that only anterior nectophores were determined to the species level. However, the difficulty in determining the posterior nectophores and eudoxoid stages restricted us to limit our objectives.

RESULTS

List of Species

A total of 23 species, listed in order of abundance in tables 1 and 2, were found throughout the period of investigation.

Within the Gulf, a total of 20 species were found during 2 years of sampling at Stations A and L 20.

In the open waters of the Tyrrhenian, a total of 21 species were found even though the data are based on sporadic sampling. Three of these species (*C. ovata, V. spinosa* and *S. quadrivalis*) were not found within the Gulf. On the other hand, *S. gamulini* and *M. atlantica,* both of which occurred rarely within the Gulf, were not found at our open-sea station.

Annual Cycles

In number, Calicophorids comprised an annual mean of 0.18% of the total zooplanktonic population in the 50-0 m and 0.16% in the 300-0 m levels at Station L 20, and 0.12% from 100-0 m at Station A. Figures 2 and 3 show the annual variation, at both stations, in total number of Calicophorids and of the quantitatively more important species.

Both annual cycles showed a late winter and fall period of maxima which more or less reflected the annual variation of the dominant species. In particular, Station A was characterized by the association of *L. subtilis* and *S. gracilis* which together comprised 83.1% of the mean annual total. These two species, together with *E. spiralis, H. hyppopus, A. tetragona* and *S. irregularis,* not only contributed to the late winter peak but furthermore characterized

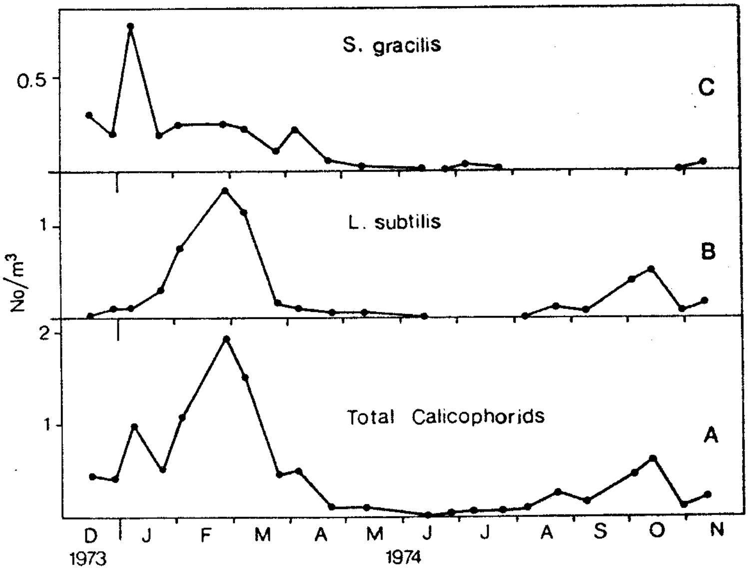

FIG. 2. Annual cycles in No. m^{-3} from 100-0 m of A: total Calicophorids and B, C: total *Lensia subtilis*, *Sphaeronectes gracilis* at Station A.

the Calicophorid population of the entire winter-spring period. On the other hand, the fall peak was almost entirely due to the simultaneous increment of *L. subtilis* and *M. kochi*. Other species were found to be extremely rare in this period.

The above-mentioned species were also dominant in the 50-0 m level sampled at Station L 20. The only significant difference between both stations was the increase in number of *M. kochi* (from 4.5% to 26.4%) and decrease of *S. gracilis* (from 27.0% to 6.8%) at Station L 20. This station was characterized by the association of 2 species, *L. subtilis* and *M. kochi*, which together comprised 82.5% of the mean annual total in this level. The late winter peak observed at this station was almost entirely due to the increment of *L. subtilis* and, to a lesser degree, that of *S. gracilis*, *H. hyppopus*, and *E. spiralis*. *Lensia subtilis* and *M. kochi* were almost entirely responsible for the fall peak.

The species found below the 50 m level were rare and their annual variation hardly influenced the general trend in total numbers in the entire water column. Six of these species, *L. conoidea*, *L. multicristata*, *L. fowleri*, *L. subtiloides*, *V. pentacantha* and *S. fragilis* were found only below the 50 m level.

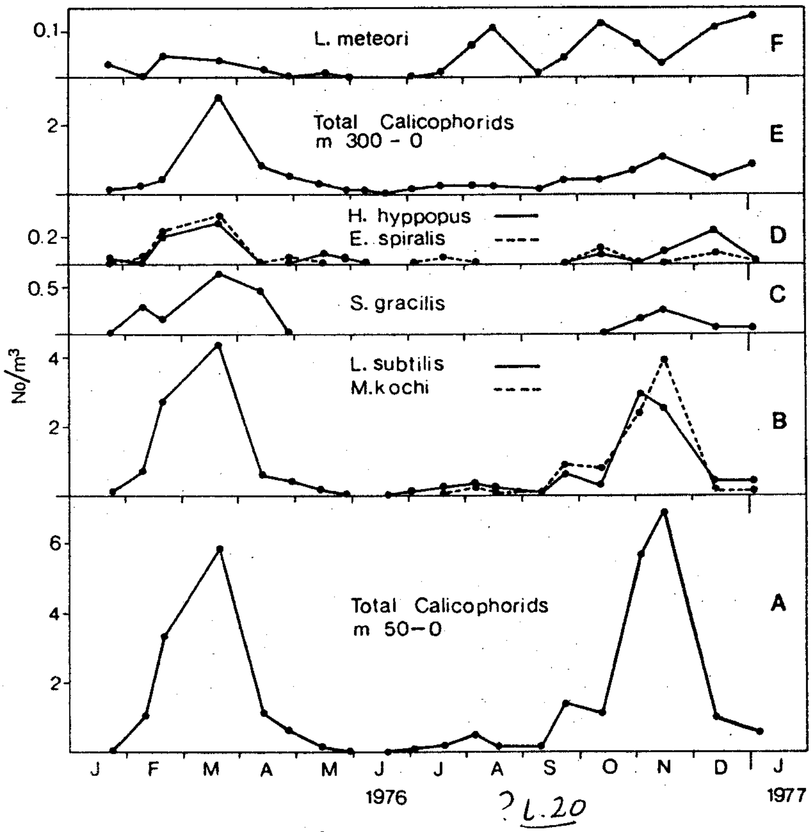

FIG. 3. Annual cycles in No. m^{-3} from 50-0 m of A: total Calicophorids and B, C, D: total *Lensia subtilis, Muggiaea kochi, Sphaeronectes gracilis, Hyppopodius hyppopus, Eudoxoides spiralis* and from 300-0 m of E: *Lensia meteori* at Station L 20.

Of particular interest was the fact that, except for a few isolated specimens, Calicophorids were almost entirely absent from our samples in summer.

Vertical Distribution

Figure 4 shows the mean annual vertical distribution of the quantitatively more important species sampled at Station A in the Gulf. The only typically surface species appear to be *L. subtilis, S. gracilis, M. kochi* and *S. irregularis.* On the other hand, *E. spiralis, A. tetragona* and *H. hyppopus* do not seem to be strictly tied to surface waters.

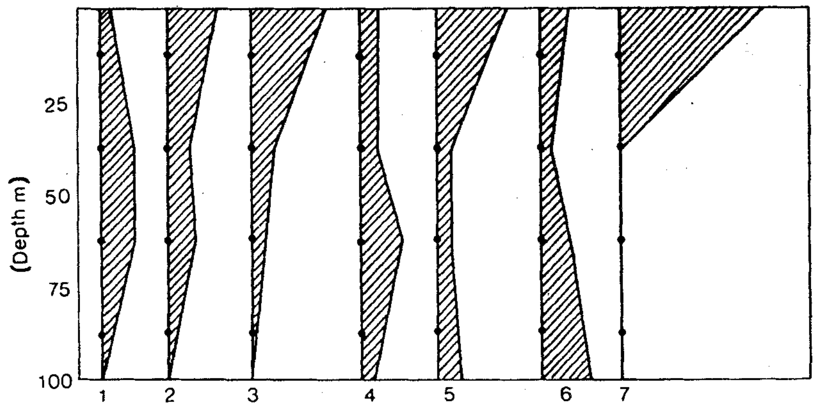

FIG. 4. Annual mean vertical distribution of 1. *Lensia subtilis*, 2. *Sphaeronectes gracilis*, 3. *Muggiaea kochi*, 4. *Eudoxoides spiralis*, 5. *Abylopsis tetragona*, 6. *Hyppopodius hyppopus* and 7. *Sphaeronectes irregularis* (based on 23 series of hauls from 100-0 m at Station A).

Three series of open-sea hauls from 3000 m to the surface indicate that the large mass of Calicophorids occur in the 0-400 m level, with a maximum in the 100-200 m level (fig. 5). No specimens occur below the 2000 m depth.

These data, together with those obtained in the same area with an Isaacs-Kidd midwater trawl, have permitted us to single out 3 Calicophorid communities:

— a surface community, mainly characterized by the presence of *C. appendiculata*, *A. tetragona*, *E. spiralis*, *M. kochi*, *S. chuni*, *S. gracilis*, *S. irregularis*, *L. subtilis* and *H. hyppopus*. The vertical range of these species is approximately in the upper 200-0 m level, though *A. tetragona* and *H. hyppopus* can also be found deeper.

— a mid-water community, mainly characterized by the presence of *L. conoidea*, *L. multicristata*, *L. fowleri* and *L. meteori*. The vertical range of these species is approximately from 200-500 m, though *L. conoidea* and *L. multicristata* can also be found deeper.

— a deep-water community, very poor in species and number of individuals, mainly characterized by the presence of *V. pentacantha*, *L. subtiloides* and *C. ovata*. All 3 species showed a wide vertical range and were found down to the 2000 m depth. *Vogtia spinosa*, extremely rare in our deep-water hauls, can also be considered a deep-sea species (Leloup 1933; Bigelow and Sears 1937).

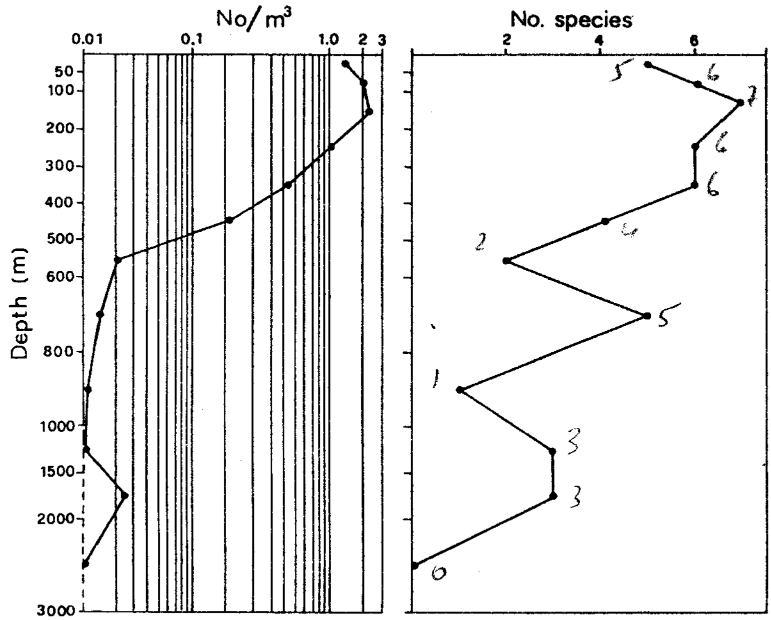

FIG. 5. Mean variation whith depth in number af Calicophorid (No. m^{-3} and number of species (based on 3 series of day-night hauls at Station Ponza).

Horizontal Spread

All surface species showed a wide horizontal distribution but assumed a different quantitative importance depending on the area sampled. Species of the surface community such as *L. subtilis, M. kochi* and *S. gracilis* were found to be of notable importance within the Gulf (tab. 1). The presence, in large numbers, of all three of the above species of Calicophorids in many coastal areas of the Mediterranean has also been demonstrated by a number of authors (Patriti 1964; Cervigon 1958; Vives 1966).

Lensia subtilis, M. kochi and, to a lesser degree, *S. gracilis,* quantitatively diminish in number from the coast to the open waters of the Tyrrhenian, but are nevertheless of considerable importance also in these latter areas. These observations are more or less in accordance with those of Hure (1961), Gamulin (1968) and Rottini (1971) for the eastern Mediterranean, in particular for the Aegean and Adriatic Seas, where *S. gracilis, L. subtilis* and *M. kochi* were found to have a wide horizontal distribution even though they

TABLE 1.
List of species sampled at Stations A and L 20, arranged in order of decreasing abundance.

Species	Stat. A		Stat. L 20			
	m 100-0		m 50-0		m 300-0	
	Total No.	%	Total No.	%	Total No.	%
Lensia subtilis (Chun 1886)	559	56.7	871	56.3	1560	57.8
Muggiaea kochi (Will 1844)	42	4.3	409	26.4	360	13.4
Sphaeronectes gracilis (Claus 1873)	266	27.0	105	6.8	60	2.2
Lensia meteori (Leloup 1934)	2	0.2	11	0.7	240	8.9
Eudoxoides spiralis (Bigelow 1911)	41	4.2	42	2.7	120	4.4
Hyppopodius hyppopus (Forskål 1776)	23	2.3	42	2.7	60	2.2
Chelophyes appendiculata (Eschscholtz 1829)	3	0.3	11	0.7	60	2.2
Lensia conoidea (Kefferstein and Ehlers 1860)	—	—	—	—	69	2.6
Rosacea cymbiformis (Chiaje 1822)	—	—	42	2.7	18	0.7
Sphaeronectes irregularis (Claus 1873)	17	1.7	11	0.7	30	1.1
Lensia multicristata (Moser 1925)	—	—	—	—	43	1.6
Abylopsis tetragona (Otto 1823)	26	2.6	2	0.1	12	0.4
Lensia fowleri (Bigelow 1911)	—	—	—	—	30	1.1
Sulculeolaria chuni (Lens and Riemsdijk 1908)	2	0.2	—	—	12	0.4
Sphaeronectes fragilis Carré 1968	—	—	—	—	12	0.4
Lensia campanella (Moser 1925)	3	0.3	2	0.1	3	0.1
Vogtia pentacantha Köllicker 1853	—	—	—	—	6	0.2
Lensia subtiloides (Lens and Riemsdijk 1908)	—	—	—	—	6	0.2
Muggiaea atlantica (Cunnigham 1892)	—	—	2	0.1	2	0.1
Sphaeronectes gamulini Carré 1966	2	0.2	—	—	—	—

were more abundant in coastal waters. Bigelow and Sears (1937) do not cite these species in the open waters of the Mediterranean. It is probable, though, that the nets used in the Thor expedition did not permit the capture of these smaller species.

Other species of the surface community, in particular *C. appendiculata, E. spiralis, S. chuni, H. hyppopus* and *A. tetragona*, also showed a marked horizontal distribution but, in this case, their quantitative importance decreased from the open waters towards the coast. Except for *S. chuni*, which has often been considered a neritic species, all of these species have generally been considered as being oceanic (Patriti 1964; Boucher and Thiriot 1972; Razouls and Thiriot 1968). Furthermore, Gamulin (1948), Rottini and Gamulin (1969) and Rottini (1971) cite *E. spiralis, S. chuni* and *A. tetragona* throughout the Aegean and Adriatic Seas but do not cite *C. appendiculata* and *H. hyppopus* in the coastal waters of the North Adriatic.

The above observation imply that surface species have a wide horizontal spread and that there are no species which seem to be strictly tied to the neritic environment as is often the case for other planktonic organisms. Species showing a more surface-type distribution, such as *L. subtilis, M. kochi* and *S. gracilis,* were found to be somewhat more common in coastal waters. Other species, such as *C. appendiculata, E. spiralis, S. chuni, H. hyppopus* and *A. tetragona,* abundant in surface waters but which show a wider vertical range and perform quite extensive diel migrations (Franqueville 1971; Hure 1961), were found to be more dominant in surface waters of the open sea.

Species of the mid-water community, such as *L. multicristata, L. conoidea, L. meteori* and *L. fowleri,* were found to be quite common in the 300-0 m hauls performed at Station L 20 in the Gulf of Naples, but were found to be much more abundant in the open waters of the Tyrrhenian. The presence of these species within the Gulf is most probably due to the fact that the Gulf communicates with the deep waters of the Tyrrhenian via the large, deep canyons of Ammontatura and Procida through which Levantine Intermediate and Tyrrhenian Deep Waters penetrate into the Gulf (Hopkins and GONEG 1977; Carrada et al. 1980).

On the other hand, species of the deep-water community were almost entirely absent in the Gulf except for a few isolated specimens of *V. pentacantha* and *L. subtiloides,* both of which were found at Station L 20.

DISCUSSION

Our data seem to confirm the fact that Calicophorids are more common in open rather than coastal waters. In fact, a drastic reduction in number of species was noted at our coastal station. However, in analyzing the horizontal distribution of these species, it seems difficult to define Calicophorids as being either neritic or oceanic. Generally, these organisms do not seem to be strictly tied to either of the two environments but rather show a marked horizontal diffusion. The distance to which these organisms extend is very variable and seems to depend on their vertical distribution pattern as well as on the local water currents.

The Calicophorid fauna of the area investigated is very similar to that found in other Mediterranean areas in that species dominant within the Gulf of Naples are also very common in all coastal areas of the Mediterranean. On the other hand, the dominant species in the open waters of the Tyrrhenian was *C. appendiculata,* already cited by Bigelow and Sears (1937) as the most common Mediterranean species.

The above observations verify the uniformity of the Calicophorid fauna throughout the Mediterranean basin. In fact, the only significant differences between the western and eastern Mediterranean seem to be those regarding the distribution of *M. atlantica* and *B. bassensis.* The former is a common Atlantic species which can at times be found in notable numbers only along more coastal, western Mediterranean shores. It has been considered as a typical indicator species of waters of Atlantic origin (Wirz and Beyeler 1954). Although very common in the Atlantic (Pugh 1974), *B. bassensis* has a discontinuous distribution in the Mediterranean: common in the Strait of Gibraltar (Bigelow and Sears 1937); rare throughout the western Mediterranean; assumes a definite quantitative importance in the eastern Mediterranean (Rottini 1971).

Whereas *B. bassensis* was completely absent from our samples, 4 anterior nectophores of *M. atlantica* were found. The above seems to imply that, though the area examined is grazed by both a surface current of Atlantic origin and a Levantine intermediate current as indicated by Wüst (1961), it lies too distant from the source region of these waters for there to be any hydrological influence at the faunistic level.

RIASSUNTO

DISTRIBUZIONE E CICLI ANNUALI DI SIFONOFORI CALICOFORI NEL GOLFO DI NAPOLI E NELLE ACQUE ADIACENTI

Sono stati analizzati i cicli annuali, la distribuzione verticale e la struttura delle comunità dei Sifonofori Calicofori del Golfo di Napoli e delle sue acque adiacenti, sulla base di campionamenti effettuati durante un anno su due stazioni fisse all'interno del Golfo e di materiale raccolto nel corso di tre crociere effettuate nelle acque aperte del Mediterraneo. Un totale di 23 specie sono state identificate. Alle stazioni interne si sono riscontrati due massimi annuali, alla fine dell'inverno ed in autunno, mentre in estate i Calicofori erano quasi del tutto assenti. Le pescate effettuate in mare aperto hanno indicato che i Calicofori hanno un'ampia distribuzione verticale (da 0-2000 m), con un massimo nelle acque subsuperficiali. Basandosi sulla distribuzione verticale delle singole specie si sono identificate tre comunità di Calicofori: una comunità di superficie (da 0-200 m), caratterizzata soprattutto da *Chelophyes appendiculata, Eudoxoides spiralis, Muggiaea kochi, Sulculeolaria chuni, Lensia subtilis, Sphaeronectes gracilis* e *S. irregularis;* una comunità di acque intermedie (200-500 m), caratterizzata da *Lensia conoidea, L. multicristata, L. fowleri* e *L. meterori;* una comunità profonda (500-2000 m), caratterizzata da *Clausophyes ovata, Lensia subtiloides, Votgia pentacantha* e *V. spinosa.* Infine viene discussa la distribuzione orizzontale delle specie appartenenti a queste tre comunità, in relazione al loro modello di distribuzione verticale.

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TABLE 2
List of species sampled at the open-sea station of Ponza, arranged in order of decreasing abundance.

Species	April '76	June '76		October '77							Total No.	%
Depht in meters	600	200	750	0	50	250	500	800	1000	1500		
1. *Chelophyes appendiculata* (Eschscholtz 1829)	70	170	40	2640	980	600	130	372	160	110	5272	41.6
2. *Lensia multicristata*(Moser 1925)	—	940	60	—	—	360	50	84	55	130	1624	12.9
3. *Eudoxoides spiralis* (Bigelow 1911)	80	320	310	50	560	40	10	42	10	40	1502	11.9
4. *Lensia subtilis* (Chun 1886)	30	30	30	70	290	60	30	96	50	90	776	6.1
5. *Muggiaea kochi* (Will 1844)	—	—	—	170	320	40	80	30	55	60	755	6.0
6. *Abylopsis tetragona* (Otto 1823)	10	40	30	10	60	110	60	90	20	90	520	4.1
7. *Sulculeolaria chuni* (Lens and Riemsdijk 1908)	—	10	10	210	150	20	30	48	15	20	513	4.1
8. *Vogtia pentacantha* (Köllicker 1852)	120	—	110	—	—	—	90	24	70	60	474	3.8
9. *Lensia meteori* (Leloup 1934)	20	70	70	—	—	60	10	36	15	40	321	2.5
10. *Lensia conoidea* (Kefferstein and Ehlers 1860)	10	40	50	—	—	120	30	18	10	10	288	2.4
11. *Hyppopodius hyppopus* (Forskål 1776)	50	—	10	10	110	40	30	18	15	—	283	2.2
12. *Sulculeolaria quadrivalvis* Blainville 1834	—	—	—	20	50	20	—	24	15	10	139	1.1
13. *Lensia fowleri* (Bigelow 1911)	—	—	10	—	—	20	—	—	—	10	40	0.3
14. *Clausophyes ovata* (Kefferstein and Ehlers 1860)	—	—	10	—	—	—	—	—	10	10	30	0.2
15. *Sphaeronectes gracilis* (Claus 1873)	—	—	—	10	—	—	—	—	—	10	20	0.2
16. *Sphaeronectes irregularis* (Claus 1873)	—	—	—	—	—	10	—	6	—	—	16	0.1
17. *Lensia subtiloides* (Lens and Riemsdijk 1908)	—	—	—	—	—	—	—	—	10	—	10	0.1
18. *Rosacea cymbiformis* (Chiaje 1822)	10	—	—	—	—	—	—	—	—	—	10	0.1
19. *Sphaeronectes fragilis* Carré 1968	—	—	—	—	—	10	—	—	—	—	10	0.1
20. *Lensia campanella* (Moser 1925)	—	10	—	—	—	—	—	—	—	—	10	0.1
21. *Vogtia spinosa* (Kefferstein and Ehlers 1861)	—	—	10	—	—	—	—	—	—	—	10	0.1