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Marine Biogeography of the Mediterranean Sea: patterns and dynamics of biodiversity

Floristic and biogeographic considerations about the benthic macroalgal flora in the Gulf of Taranto

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SUMMARY

A floristic research, based on both literature and collected data, was carried out on the seaweeds of the Gulf of Taranto. 462 taxa determined at both a specific and an intraspecific level were found, among which 313 are Rhodophyta, 79 Phaeophyta, 70 Chlorophyta. From a biogeographic point of view, 48.7% of species belong to the Atlantic element, 14.6% to the Mediterranean element, 24.8 % to the Cosmopolitan element, 5.3 % to the Indo-Pacific element, 5.3% to the Circumtropical element and 1.4 % to the Circumboreal one. Twelve alien species were recently collected, of which *Caulerpa racemosa* var. *cylindracea* and *Hypnea cornuta* proved to be invasive.

INTRODUCTION

For a long time, the knowledge of the marine benthic communities of the Gulf of Taranto, from both floristic and vegetational points of view, has been scarce and incomplete, being this sector of the upper Ionian Sea one of the least studied area of the Central Mediterranean Sea.

The first published papers date back to the end of the nineteenth century (Piccone, 1896) and the beginning of the twentieth one (Bentivoglio, 1903). Afterwards, some papers were published about the seaweeds of the coasts of both the provinces of Taranto (Pierpaoli, 1923; 1959; 1960; Mastrorilli, 1969) and Lecce (Solazzi, 1967; 1968; 1969; Pardi et al., 1988), respectively. However, most of these papers were short notes and reported just very few species. Only starting from the second half of the Eighties, a thorough study of the phytobenthic communities of the coasts near the town of Taranto was planned. Its aim was both to evaluate the effects of urban and industrial pollution and to

suggest measures useful to the environmental recovery of particularly polluted areas (i.e. Mar Piccolo, Mar Grande and the waters near the town and the industrial plants) (Cecere et al., 1991a; Cecere et al., 1991b; Cecere et al., 1992; Cecere et al., 1996; Cormaci et al., 2001). The results of this study provided a local baseline and increased the knowledge of the flora of the Mediterranean Sea. However, to date, the Ionian coasts of Calabria (Cecere and Perrone, 1987) and Basilicata still remain either scarcely or not at all studied.

The present paper aims at defining the marine phytobenthic biodiversity of the Gulf of Taranto, focusing on the presence of recently introduced species.

Fig. 1 - Map of the Gulf of Taranto. The picture in the frame indicates the location in Italy

DESCRIPTION OF THE AREA STUDIED

The Gulf of Taranto is located on the northern Ionian Sea and is bounded by Capo S. Maria di Leuca on the eastern side and by Capo delle Colonne on the western one (Fig. 1); therefore, it includes the Ionian coasts of Apulia, Basilicata and Calabria (Fig. 1).

Particularly interesting areas are the Ugento sandbanks, the Amendolara seamount, located offshore the homonymous cities, and the two basins of Mar Piccolo and Mar Grande, where the most important Italian both mussel culture plant and Navy Base are located.

FLORISTIC CONSIDERATIONS

A floristic list (available on request) was compiled, which numbers a total of 462 taxa determined at both a specific and an infraspecific level, among which 313 are Rhodophyta (3 *taxa inquirenda* included), 79 Phaeophyta (3 *taxa inquirenda* included), 70 Chlorophyta (4 *taxa inquirenda* included), 1 *incertae sedis*, 1 *nomen nudum* and 31 taxa identified only at a generic level. Therefore, the Rhodophyta are 67.7% of the flora, the Phaeophyta 17.1% and the Chlorophyta 15.2% (Fig. 2).

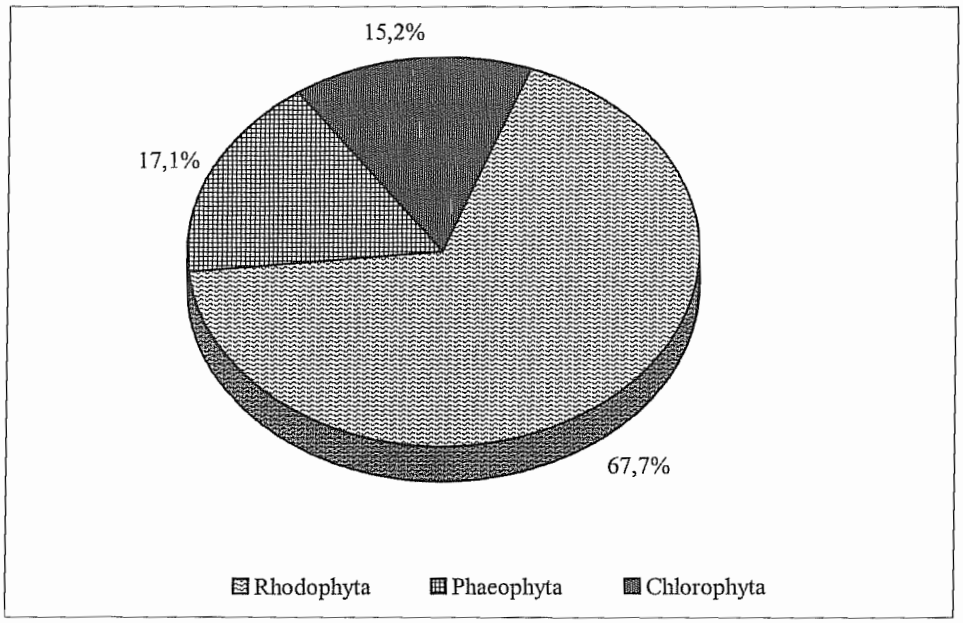

Fig. 2 - Per cent incidence of Rhodophyceae, Phaeophyceae, Chlorophyceae

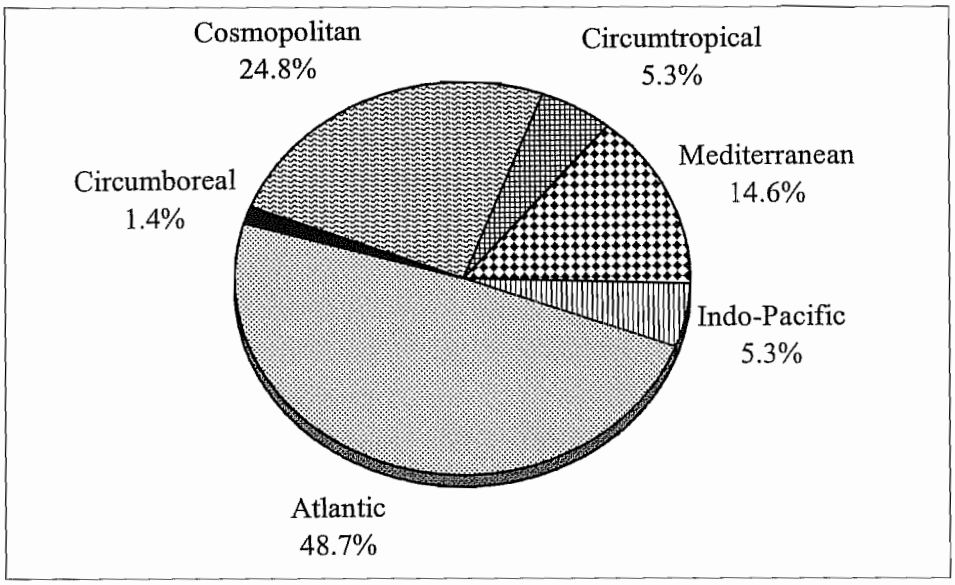

Fig. 3 - Per cent incidence of the biogeographic elements

BIOGEOGRAPHIC CONSIDERATIONS

From a biogeographic point of view, 48.7% of species belong to the Atlantic element, 14.6% to the Mediterranean element, 24.8 % to the Cosmopolitan element, 5.3 % to the Indo-Pacific element, 5.3% to the Circumtropical element and 1.4 % to the Circumboreal one (Fig. 3).

Compared to the chorological spectrum of the Italian flora (Furnari et al., 2002), the chorological spectrum of the Gulf of Taranto shows a higher percentage of Atlantic, Cosmopolitan, Indo-Pacific, and Circumtropical elements; an equal percentage of the Circumboreal element and a lower percentage of the Mediterranean one. The increased percentage of Atlantic, Indo-Pacific and Circumtropical species, these last two groups with a warm water affinity (Cormaci and Furnari, 1999), could be due to the presence, in the Gulf of Taranto, of several exotic species, mainly native of both Atlantic and Pacific Ocean (Tab. I). The higher percentage of Cosmopolitan species observed in the Gulf of Taranto can be probably explained by the highly polluted nature of the studied sites. In fact, Cosmopolitan species are mainly ubiquitous and eurieucious and are generally considered indicators of stress. Finally, the lower percentage of Mediterranean species likely depends on the low depth of the sites studied. In fact, Mediterranean species are more frequent in the rocky shady circalittoral zones (Boudouresque, 1973).

Tab. I- List of the exotic species recently introduced in the Gulf of Taranto. += species reported in literature as invasive; *= species with an invasive behaviour in the Gulf of Taranto.

Atlantic origin
Agardhiella subulata (C. Agardh) Kraft *et* M.J. Wynne
Apoglossum gregarium (E.Y. Dawson) M.J. Wynne
Botryocladia madagascariensis G. Feldmann
Chondria polyrhiza Collins *et* Hervey
Hypnea spinella (C. Agardh) Kützing
Solieria filiformis (Kützing) Gabrielson

Pacific origin
+*Asparagopsis armata* Harvey
+*Codium fragile* (Suringar) Hariot ssp. *tomentosoides* (van Goor) Silva
+*Undaria pinnatifida* (Harvey) Suringar
+*Womersleyella setacea* (Hollenberg) R.E. Norris

Lessepsian migrants
+**Caulerpa racemosa* Forsskål (J. Agardh) var. *cylindracea* (Sonder) Verlaque, Huisman *et* Boudouresque
**Hypnea cornuta* (Kützing) J. Agardh

The R/P (Rhodophyta/Phaeophyta) ratio resulted equal to 3.96, which is different from the value observed for the Italian flora (R/P equal to 2.63, Cormaci and Furnari, 1999). This could denote a flora with a tropical affinity (Feldmann, 1937); but, most likely, the ratio has to be considered more as an ecological index than as a biogeographic one (Cormaci et al., 1985). In fact, in highly polluted environments, like most of those studied in the examined papers, which suffer from industrial and urban pollution, the Phaeophyta, highly stenoecious, tend to disappear. On the contrary, Rhodophyta increase, as they are notoriously more ubiquitous and pollution-resistant (Cecere et al., 1991a).

PARTICULARLY INTERESTING SPECIES

Several species, among those recently collected, turned out to be interesting from a biogeographical point of view. Some of them are either first or among the first reports for the Mediterranean Sea; others are alien species of different origin (e.g. species of Atlantic origin, native Pacific species, lessepsian migrants), among which some are invasive and are quickly spreading over the Mediterranean Sea (Tab. I).

Agardhiella subulata and *Solieria filiformis* (Gigartinales, Rhodophyta)

Agardhiella subulata and *Solieria filiformis* were collected for the first time in the Mediterranean Sea in the Mar Piccolo of Taranto, in the second half of the eighties (Perrone and Cecere, 1994). Nevertheless, the latter was surely already

present in the basin in the Twenties, as shown by one sheet of the Pierpaoli's Herbarium, which preserves a dried sample of *S. filiformis* misidentified as *Gracilaria confervoides* Greville (Cecere and Petrocelli, 1999).

For about ten years, these two Solieriaceae were among the dominant species of the drifting algal beds of the Mar Piccolo (Cecere et al., 1992). Recently, another survey has shown that only some rare thalli of *S. filiformis* are still present (Cecere, unpublished data). At the moment, the reason of this impoverishment is not known. It could be due to either a natural species turnover or a massive collection of seaweeds for cultivation purposes (Cuomo et al., 1997).

Apoglossum gregarium (Ceramiales, Rhodophyta)

In summer 1995, few thalli of this diminutive Delesseriacea were collected outside the Mar Grande basin, not far from a sandbank, at a depth of 17m (Petrocelli et al., 1999). This finding represented the second report for the Mediterranean Sea, as the species had already been found in the Tyrrhenian Sea (Sartoni and Boddi, 1993). *Apoglossum gregarium* is reported as a species with a medium probability of introduction in the Mediterranean, as a fouling organism (Boudouresque and Verlaque, 2002). However, it is also possible that the presence of *A. gregarium* could have been neglected since then, as the Mediterranean deep water algal flora is not yet well known. Moreover, *A. gregarium* is easily mistaken with *A. ruscifolium* (Turner) J. Agardh, which is a common species of the Mediterranean flora, and shares the same habitat of *A. gregarium* (Sartoni and Boddi, 1993).

Asparagopsis armata (Bonnemaisoniales, Rhodophyta)

This Rhodophyta was probably introduced in the Mediterranean by the maritime traffic (Verlaque, 1994) through the Straits of Gibraltar. It was reported in the Twenties, for the first time in the basin, along the Algeria coasts (Sauvageau, 1925). But nowadays, it is widely distributed all over the Mediterranean Sea (Verlaque, 1994). *Asparagopsis armata* is characterised by a diphasic heteromorphic life cycle, with a macroscopic gametophytic generation and a filamentous tetrasporophytic generation, known as *Falkenbergia rufolanosa* (Harvey) Schmitz.

In the seas of Taranto, only very few thalli of the tetrasporophyte were collected up to now. Therefore, in this area, the species seems to have not shown its invasive behaviour.

Botryocladia madagascariensis (Rhodymeniales, Rhodophyta)

This species, native of Madagascar (Indian Ocean), was collected for the first time in the Mediterranean Sea, in 1991, at Lampedusa Island and Syracuse (Sicily, Ionian Sea) (Cormaci et al., 1992). Afterwards, it was found even in the

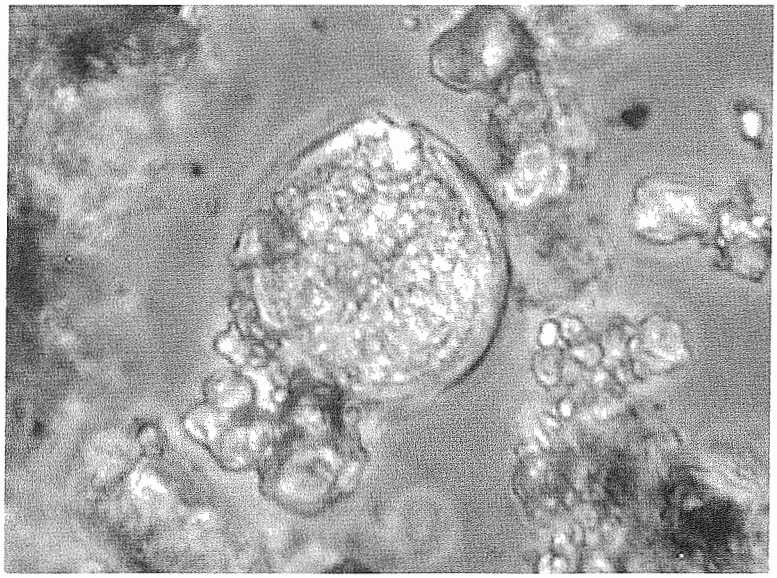

Fig. 4 - *Ostreopsis lenticularis* Fukuyo

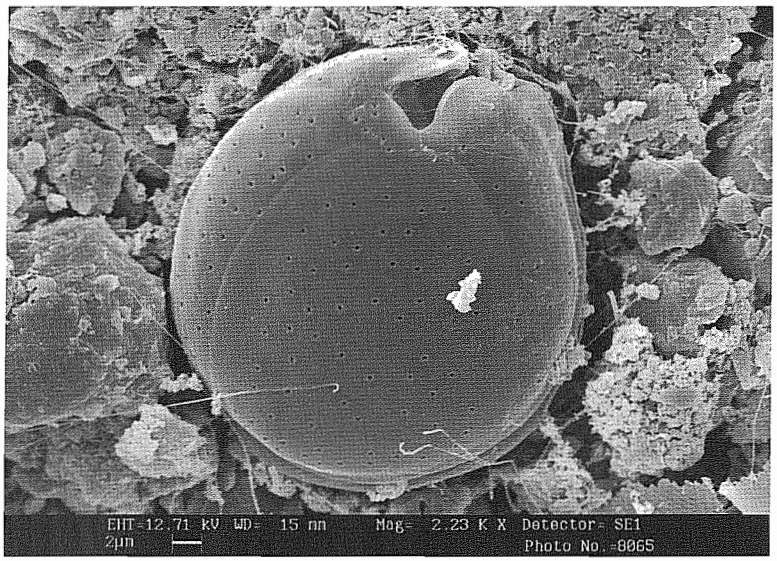

Fig. 5 - *Coolia monotis* Meunier

Through the quality-quantity analysis of samples taken in September 2002, it was establish the presence, once again, of *C. monotis*, with a concentration of 116 cell/1, and *O. lenticularis*, with a particularly high concentration of 5000 cell/1.

A description of the three dinoflagellate species follows.

Fig. 6 - Muscle tissue of *D. annularis* bright red cause congestion

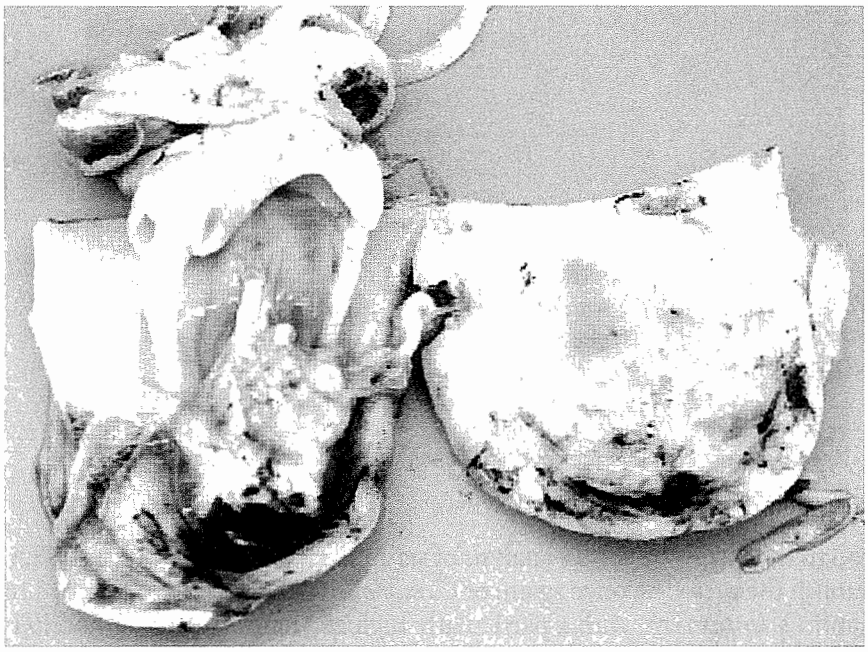

Fig. 7 - *S. officinalis* with signs of inflammation

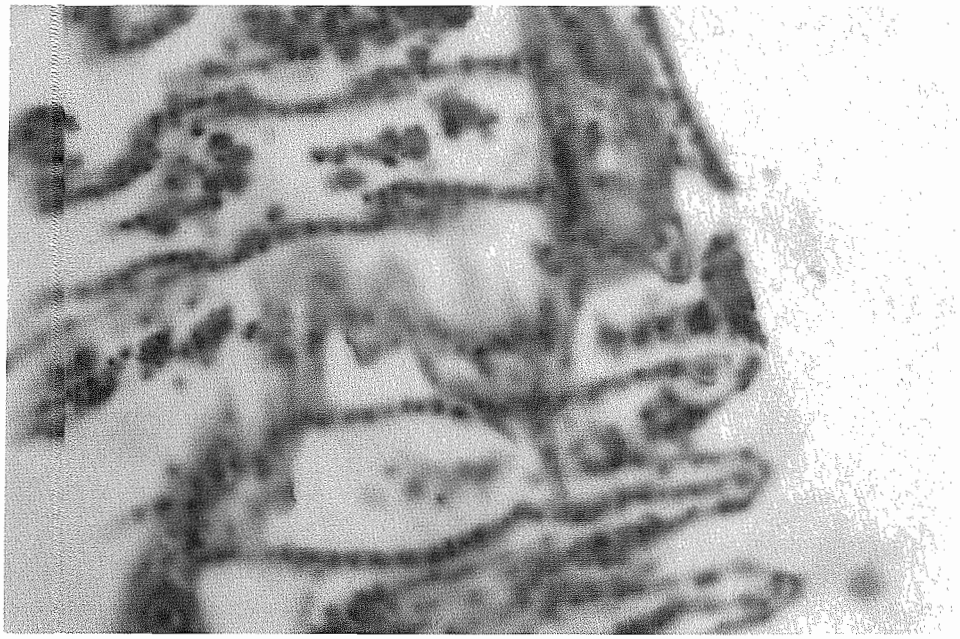

Fig. 8 -Alteration of gill epithelium of *S. officinalis* (dye haematoxylin eosin)

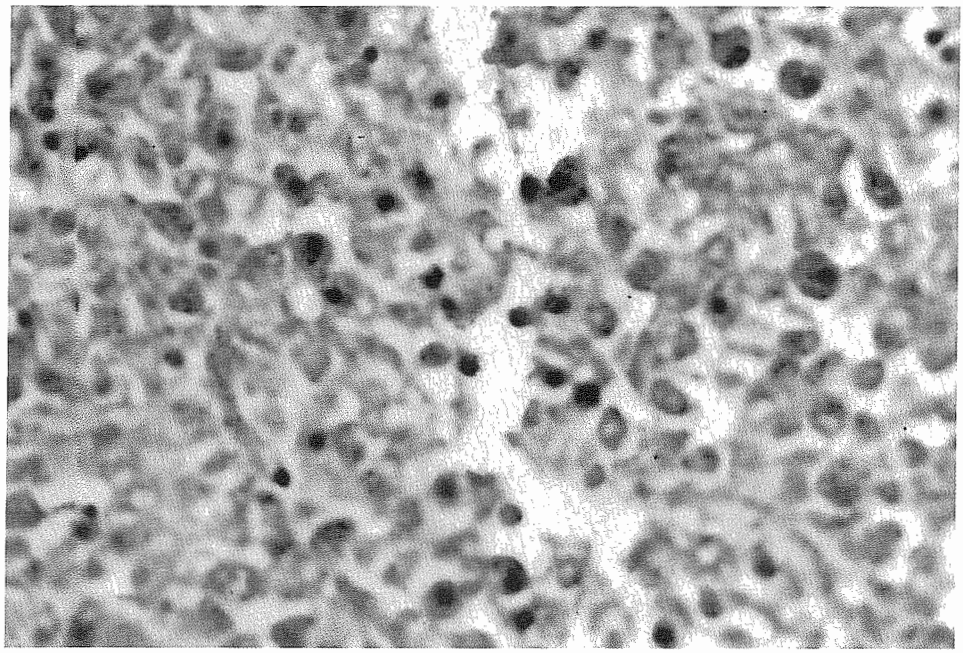

Fig. 9 – Liver oedematous of *D. annularis* (dye haematoxylin eosin)

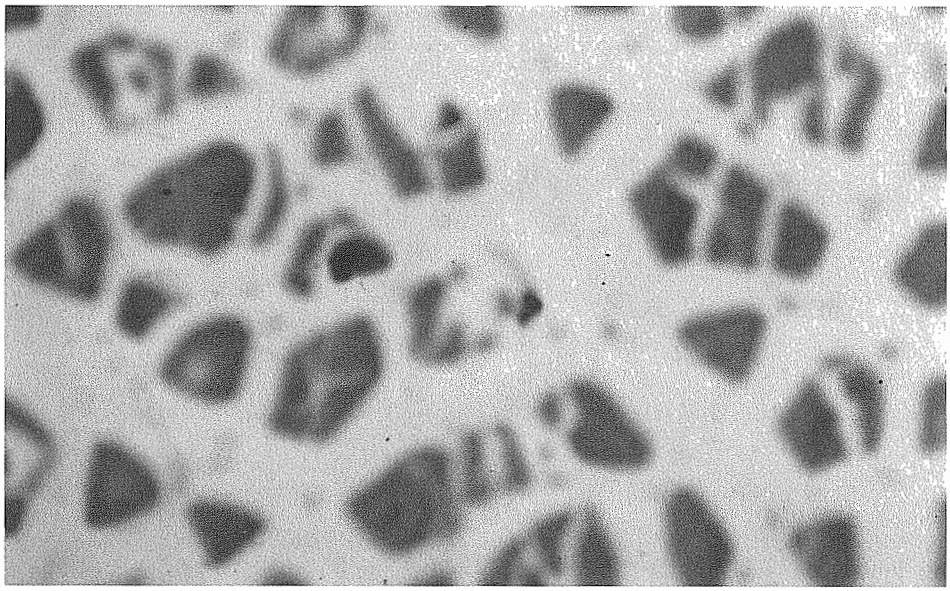

Fig. 10 - Muscle fibres of *D. annularis*: the lack of colour of the fibres has to be attributed to the phenomenon of imbibition (dye haematoxylin eosin)

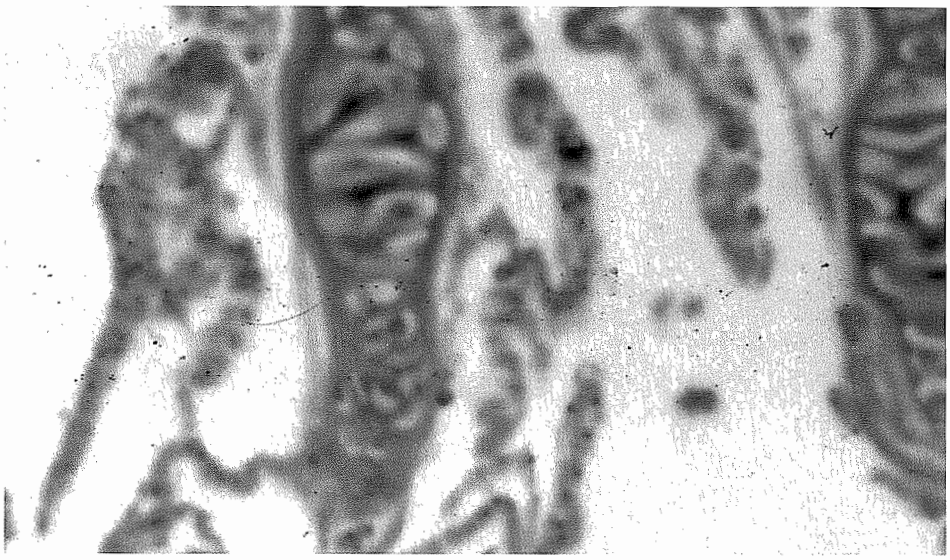

Fig. 11 - Changes in the gill epithelium of *D.annularis* (L.) (dye haematoxylin eosin).

Coolia monotis: the body is small and rounded, the epitheca is slightly smaller than the hypotheca. The thecal surface is covered by well defined plates, irregularly arranged. The thecal surface is smooth and covered by large pores. A distinct

oblong plate is located on the epitheca. This plate is positioned off center and contains an apical pore complex, about 12 µm long, that is slightly curved and endowed with a long slit, which have two supporting costal. Round pores are evenly spaced between the costae. Due to its large size, the apical pore complex is easily observed using a light microscope and is useful for identification. Cell size of *C. monotis* ranged from 20 to 50 µm in diameter and 23 to 45 µm in length. Cells have a short longitudinal flagellum, approximately 20 µm long. Finally, cells are photosynthetic and contain many golden-brown discoid chloroplasts.

Ostreopsis lenticularis: the body is lenticulate and antero-posterior compressed, without spines or horns. The epitheca and hypoteca are nearly equally sized and composed of asymmetrical plates. All the thecal plates have many trichocyst pores and additional minute ones scattered all over, which is species-specific and differentiates *O. lenticularis* from the other *Ostreopsis* species. Cells have a dorso-ventral diameter of 65-100 µm and a transdiameter of 57-63 µm. This species is photosynthetic. The body is filled with many golden-brown chloroplasts, except the ventral beak, which is transparent; a large nucleus and, sometime, a large red vacuole are located in the dorsal half of the body. *O. lenticularis* is similar to *O. siamensis* as far as size, but is distinguishable from the latter by the presence of fine pores densely scattered all over the thecal plates.

Prorocentrum mexicanum: the body is oval (length 38-40 µm; width 22-25 µm). It is covered by two large valves and seven or eighth small plates. The left valve is flat, whereas the right one has a slight indentation at the anterior end. Both valves have many trichocyst pores, most of which radially arranged in rows from the center and perpendicularly to the valve margin. Anteriorly a small spine (2-3 µm), with a wing, is present. The cell has a nucleus in the posterior half.

As far as the marine organisms involved in the sudden death phenomenon, an initial visual examination of the body detected disturbances which typically reveal the death as being occurred long before. Indeed, muscle tissue revealed a loss of consistency, was easily detached from the dorsal structure, and was bright red due to congestion (Fig. 6). In the cuttlefish examined, the edema and the imbibitions revealed clear signs of inflammation (Fig. 7).

Anatomic and -histopathological examinations carried out on the cuttlefish *Sepia officinalis* L., and on white bream *Diplodus annularis* (L.) revealed disturbances of the cardiac, respiratory and digestive apparatus, which appeared to have been caused by toxic substances. The epithelium of the gills of the cuttlefish was uneven due to exudation, which tends to dilate the gill structure (Fig. 8); the liver revealed widespread edema along with the presence of vacuoles with irregularly distributed coartic hepatocytes (Fig. 9). In the white bream the muscle fibre showed evident signs of severe suffering with imbibitions and fragmentation of the fibres themselves (Fig. 10); the epithelium of the gills was uneven due to exudation provoked by the dilation of the gill structure (Fig. 11).

CONCLUSIONS

The existence and spread of harmful microalgae in Italian waters might be, according to Hallegraeff and Boch (1991), the consequence of fish-farming and increase in sea transportation. Nevertheless, Tognetto et al. (1995) believe that it is difficult to assert that these species have been introduced into Italian waters by ships or through the importation of fish and seafood (molluscs) from tropical regions. They hypothesize, along with Margalef (1994), that such species are indeed indigenous Mediterranean species that have simply not been noted before. This hypothesis agrees with Penna's observations (2001) and with those of Giacobbe et al. (2001), who carried out studies on genetic variability of *Coolia monotis* and *Ostreopsis* spp. clones. They found similarities between these microalgae with those from various other Mediterranean areas, and differences with species of Atlantic-tropical origin.

In Italy, *C. monotis,* which produces the toxin "cooliatoxin" with its haemolytic effect (Giacobbe et al., 2000), was first identified in the Venice Lagoon (Tolomio and Cavolo, 1985) and along the Eastern Sicilian coastline (Gangemi, 2000).

The microalgae *Ostreopsis* was discovered in Italian waters. Tognetto et al. (1995) reported the presence of *O. ovata* in the Tyrrheanian Sea. The presence of this species was later confirmed along the Apuan coastline by Sansoni et al. (in press). Di Turi et al. (2002) identified *Ostreopsis*, presumably *ovata*, in the Southern Adriatic Sea. Gangemi (2000) noted that along the Eastern Sicilian coastline the dinoflagellate *Ostreopsis* existed, the author, however, was not able to identify the species. Tindall et al. (1990) consider that *O. ovata* is not toxic underlined, however, following Tindall et al. (1990) that the *O. ovata* species is not toxic.

Ostreopsis lenticularis has never been described in Italian waters. Its harmful qualities, due to the neuro-toxic action of ostreotoxin, was proved by experiments on rats by Tindall et al. (1990).

The presence of *Prorocentrum mexicanum* was unexpectedly noted. This dinoflagellate, which produces a fast-acting toxine with ahaemolytic effect, has not been previously found in the Mediterranean. Until now, it had been found in the Caribbean (Faust, 1995), the Virgin Islands (Carlson and Tindall, 1985), the Hawaiian waters (Carbonnière), Canada (Levasseur et al., 2003), Puerto Rico (Ballantine et al., 1988), Mexico (Gárate-Lizárraga et al.), Colombia (Medina), Vietnam (Nguyen et al.), Tasmania (Pearce et al., 2001) and in Australia (Murray and Patterson).

Thus, while it has not been possible to carry out tests on the toxins yet, the presence of dinoflagellates, both in marine organisms and sampled water, may suggests that they are responsible for the sporadic episodes of sudden death of sea creatures and the symptoms felt by bathers in recent years. Further analyses are necessary in order to establish the toxic-level of the species sampled along the

coast, which is regularly monitored; the sporadic nature of the events, and the frequency of toxic species belonging to the *Ostreopsis, Coolia* and *Prorocentrum* genera in the micro-phytoplankton population.

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