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Mortality of commercial sponges: Incidence in two Mediterranean areas

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ABSTRACT

In 1986 a severe epidemic affecting horny sponges broke out in several areas of the Mediterranean Sea. The disease rapidly spread to species of marketing interest belonging to the genera *Spongia* and *Hippospongia*. Ultrastructural studies of *Spongia officinalis* evidenced two main features: 1) peculiar bacteria with irregularly dotted electron-dense walls within the tissue; 2) profound alterations of the skeleton with bacterial damage of fibres. These lesions made the sponges unsuitable for commercial purposes. Long-term investigation in the Marsala Lagoon (northwestern Sicily) and at the Portofino Promontory (eastern Ligurian coast) in 1986-1989 evidenced striking incidence of the disease on the abundance of sponges. Reparative processes were also present in specimens collected during the epidemic that affected even other demosponges besides horny sponges. The etiology of the disease is discussed.

KEY WORDS: Disease - Horny sponges - Bacteria - Mediterranean basin.

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INTRODUCTION

The skeleton of horny sponges has been utilized since ancient times. The Phoenicians and Egyptians collected stranded sponges along the seashore, while the Greeks started sponge harvesting from the beds. This triggered a florid commercial activity extending to several other Mediterranean areas such as Syria, Cyprus, Sicily etc. Until last century sponge harvesting remained an important economic resource in the Mediterranean, which held a monopoly on world demand. But in 1841 a French vessel first imported sponges from the Bahamas, and soon sponges from Florida invaded the European markets. By the turn of the century the supply of commercial sponges from the Gulf of Mexico and the Mediterranean met world demand. The commerce was so brisk that several projects in sponge culture were started in order to improve sponge fisheries (Bidder, 1896; Moore, 1910; Dubois, 1914).

The commercial success of the horny sponges of *Spongia* and *Hippospongia* genera is related to their meshwork of soft fibres with high capacity of fluid absorption. In spite of competition from cheaper synthetic material, horny sponges still represent a great economic resource in the traditional harvesting areas. Consequently, epidemic disease and mortality have a significant economic impact.

Spongia officinalis and *S. zimocca* are the most common species collected by fishermen in the Mediterranean basin. The southern Italian coasts are currently being exploited, mainly by Greek fishermen. The first diseased sponges were spotted at the island of Lampedusa at the beginning of summer 1986. Later (1987-1988), similar specimens were collected from the shores of Sicily proper, and the islands of Ustica and Pantelleria. Commercial sponge beds were severely reduced down to a depth of 30 m, while sponges from below that depth showed less damage.

The occurrence in the past of devastating epidemics involving sponges of commercial interest has been reported in several papers (see review in Lauckner, 1980). The major one took place in 1938-1939 in the southern Caribbean Region (Galtsoff *et al.*, 1939; Galtsoff, 1942), where fungus-like filaments were supposed to be the agents of the disease.

Recently *Spongia* and *Hippospongia* spp., disappeared from different habitats and depths in the Caribbean, as noted by Vicente (1989) who suggested a connection between sponge mortality and recent climatic anomalies. No other hypotheses on the cause of this epidemic were put forward.

In the Mediterranean basin, some epidemic events involving commercial sponge beds have been repeatedly reported. At the turn of the century, dead sponges were recorded along the North African coast, and more recently a heavy epidemic involved commercial sponges over the whole basin (Pronzato & Gaino, 1991). In a previous work on specimens of *Spongia officinalis* collected along the eastern Ligurian coast, damaged sponges were shown to shed skeletal fibres in the environment, leaving a meshwork of broken fibres contaminated by bacteria and unuseful for commercial purposes (Gaino & Pronzato, 1989). Several studies are now in progress to ascertain the cause of the disorder, which endangers the very existence of many species over wide areas.

The aim of the present paper is to forward the investigation in this field, gathering data on sponge damage and mortality along the Italian coasts and comparing, by electron microscopy, damaged and healthy specimens of *Spongia officinalis*, and thereby obtaining additional information on the sponge mortality.

MATERIALS AND METHODS

Long-term studies on the sponge population at the Portofino Promontory (eastern Ligurian coast) and in the Marsala Lagoon (northwestern Sicily) from 1986 to 1989 documented the onset of the disease and its further development. The presence, distribution, and variation of the sponge fauna have been studied by Scuba diving technique.

At the Portofino Promontory, surveys were carried out on two surfaces, each of about 25 m^2 at a depth of 12 m and 25 m, respectively (Fig. 1 A). In the Marsala Lagoon twelve stations of about 2 m^2 each, at a depth of 1-2 m, including hard substrata and rhizomes of *Posidonia oceanica*, were examined (Fig. 1 B). Surveys were performed seasonally over four years.

For ultrastructural investigation, specimens of healthy and damaged *S. officinalis* were collected in Spring 1987 only in the monitoring areas of the Portofino Promontory. In the same period *S. officinalis* had already disappeared from the Marsala Lagoon. Tissue samples were fixed in 2.5% glutaraldehyde artificial sea water buffer for 1 h (pH = 7.5), rinsed in the same buffer, and post-fixed in 1% osmium tetroxide artificial sea water buffer for 1 h. The material was dehydrated in a graded series of ethanol and embedded in Epon-Araldite mixture. Ultrathin sections were cut on a Reichert ultramicrotome, double-stained with uranyl acetate and lead citrate, and examined in a Zeiss EM 109 electron microscope.

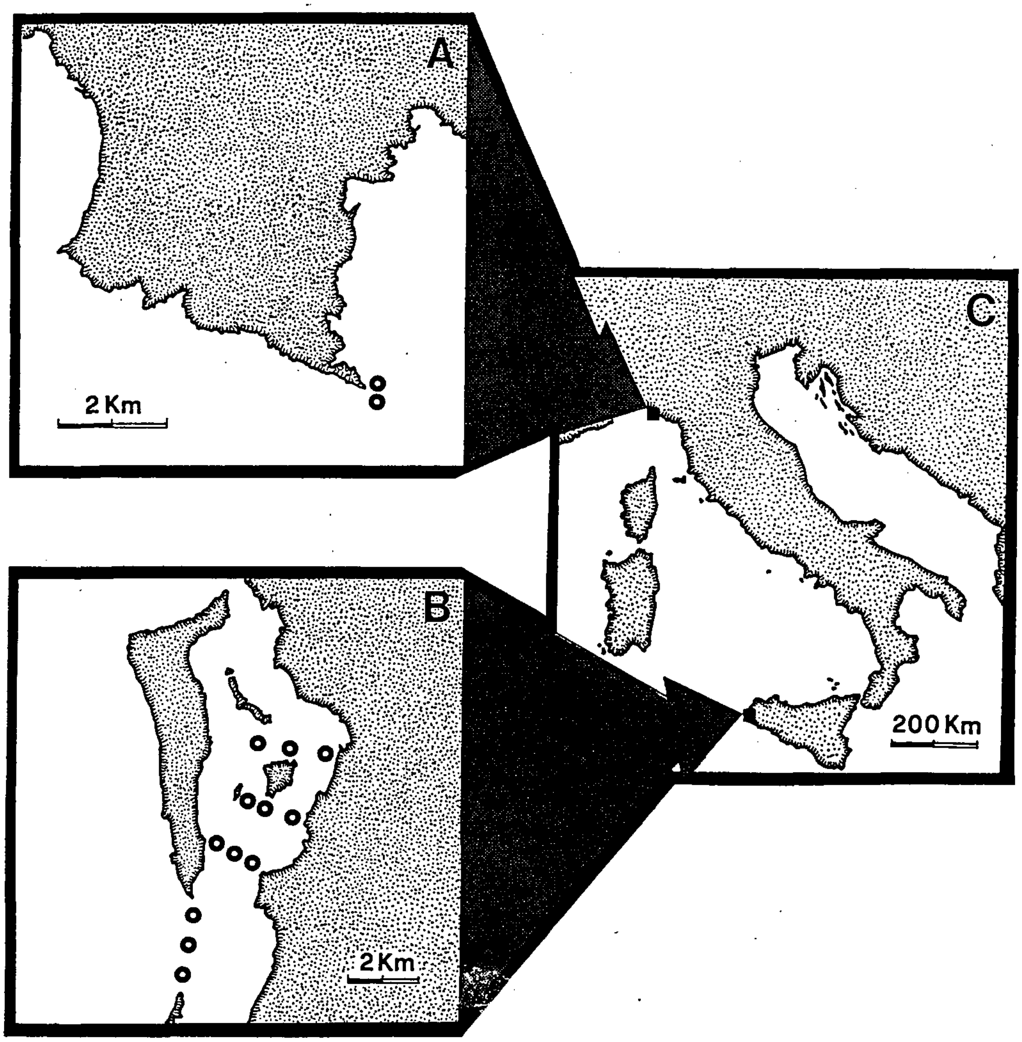


Fig. 1 - The monitored sites: A) Portofino Promontory and B) Marsala Lagoon, along the Italian coast (C). The circles indicate the sampling stations.

RESULTS

According to Lauckner (1980) microbial invasion has been considered the main cause of commercial sponge damage. Nevertheless, large bacterial populations are often symbiotic with sponge mesohyl, which makes the distinction crucial between symbiotic and pathogenic microorganisms. On comparing healthy and damaged specimens of *Spongia officinalis* some differences, concerning both bacteria morphology and skeletal fibre structure, could be observed.

Healthy specimens

In healthy specimens, a large population of mixed bacteria filled the mesohyl and exceeded the volume occupied by sponge cells (Fig. 2). Several morphologically distinct types were visible inside the collagenous matrix and differed both in size and shape (Fig. 2). Most of them showed a fine structure comparable to that of bacteria previously described in sponge species differing in mesohyl and aquiferous system development (Vacelet, 1975; Vacelet & Donadey, 1977).

The skeletal architecture consisted of a meshwork of fibrils regularly organized in two concentric layers, cortex and medulla (Fig. 3).

Damaged specimens

In damaged specimens an additional bacterial type, characterized by a discontinuous cellular wall and by electron-dense bodies densely packed along the peripheral border, was recognized (Fig. 4). These bacteria were ovoid and measured about 2-3 by 1.3-1.6 μm. Degenerative processes were recognized in the tissue, where the histolysis of the soft parts of the sponge body led to exposure of the skeleton to the environment; while no bacteria were found within fibres before their exposure, exposed fibres were characterized by a loose texture due to canaliculi filled with bacteria (Fig. 5). The penetrating ability of such micro-organisms was revealed by the connection of part of their surface to the fibrillary matrix of the fibres (Fig. 6).

Population dynamics in Portofino Promontory and Marsala Lagoon

In 1986, in spite of the occurrence of diseased commercial sponges along the eastern Mediterranean coasts (Pronzato & Gaino, 1991), no evidence of damaged specimens was detectable at the monitored areas of Portofino and Marsala, where *S. officinalis* covered 3.8% and 1.5% of the available substratum, respectively. In 1987, the epidemic burst out in both sites, with heavy consequences in the Marsala Lagoon where *S. officinalis* disappeared, no specimens being detected in 1988 and 1989 (Fig. 7).

The epidemic at the Portofino Promontory showed a different evolution (Fig. 8). In 1987, about 60% of *S. officinalis* specimens were affected; in 1988, most specimens had recovered and only about 5% of them were affected, while in 1989, 20% of the specimens were affected. The mortality was limited to about 5% of specimens within the monitored population of *S. officinalis*, owing to the ability of the sponge to shed the damaged parts and to regenerate.

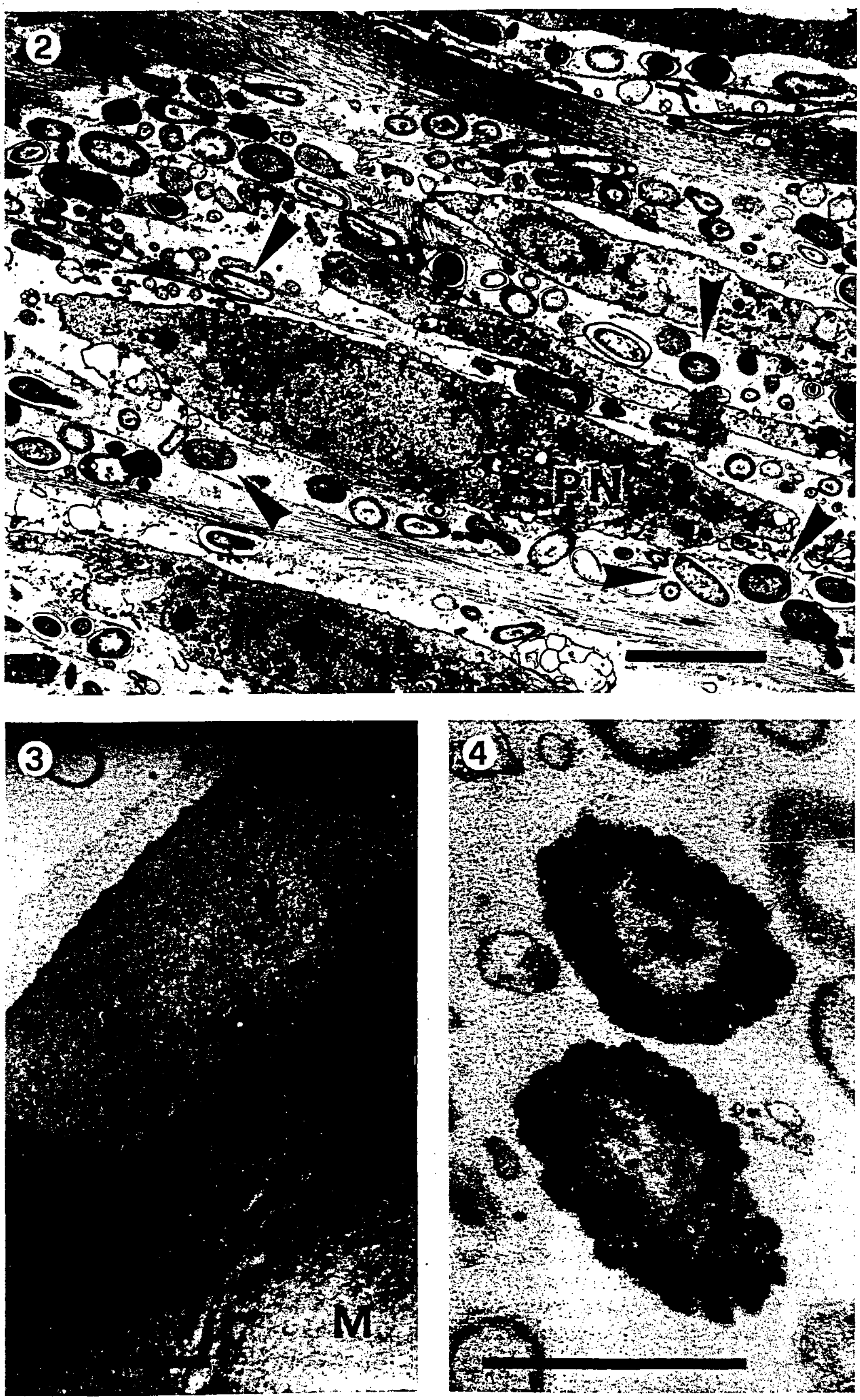
The 4-year follow up evidenced diseased specimens in other demosponges besides *S. officinalis*. At the Portofino Promontory, *Petrosia ficiformis* and *Ircinia variabilis* were occasionally affected. In the Marsala Lagoon the disease often involved *Anchinoe paupertas* and *Ircinia variabilis*, causing the former to disappear in 1987 and the latter to decrease gradually over the monitoring years (Fig. 7). According to the observations of Galtsoff (1942), the disease was clearly recognizable owing to the presence of white patches on the surface of the affected specimens.

DISCUSSION

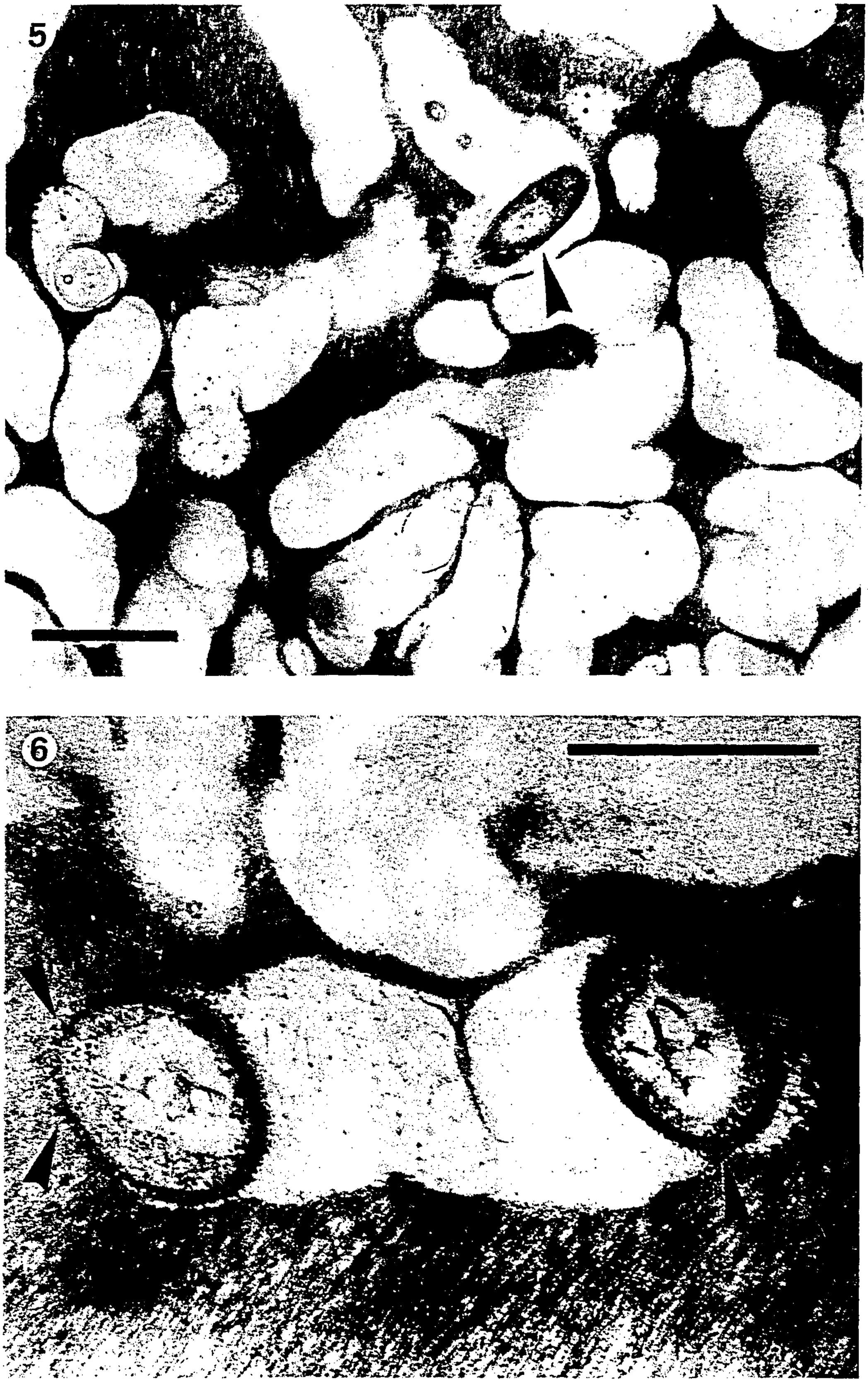
Comparing healthy and damaged specimens of *Spongia officinalis* living together in the same area and investigated in the same period revealed two main features in damaged *S. officinalis*: (i) the occurrence of peculiar bacteria in the mesohyl, and (ii) severe damage to the skeletal meshwork with bacterial-filled fibres.

Bacteria were intimately associated with the mesohyl of *S. officinalis*, which hampered the distinction between physiological or pathological microflora. *Geodia*-associated cyanobacteria occasionally increase over the normal tolerance level causing histolysis of the tissue (Rützler, 1988). Several morphological types among associated bacteria have been tentatively distinguished at ultrastructural level on the basis of bacterial organization (Vacelet, 1975; Vacelet & Donadey, 1977). Bacterial strains have been isolated from sponge body of several species (Wilkinson, 1978a, b).

The mixed bacterial population results both in specific bacterial symbionts and transient members. All these species may also live in other sponges or in the ambient water (Wilkinson *et al.*, 1981). Specific symbionts cannot be identified on the basis of morphology alone. However, comparative investigation on both healthy and damaged *S. officinalis* showed peculiar bacteria in the latter specimens. Similar microorganisms characterized by a peripheral ring of electron-dense bodies have been reported in *Aplysina*, *Agelas*, *Plakina*, *Petrosia* as normal components of the bacterial population living in the intercellular spaces. This peculiar ultrastructural morphology has been considered to be an artifact (Vacelet & Donadey, 1977). In *S. officinalis*, the presence of similar bacteria probably represents a pathological condition, since healthy specimens were devoid of them. The penetration of exogenous, morphologically charac-



Figs. 2-4 - ***Fig. 2*** - Healthy specimen of *Spongia officinalis* showing a mixed population of bacteria (arrows) in the mesohyl. PN, pinacocyte-like cells. Bar, 5 µm. ***Fig. 3*** - Part of a fibre of healthy *Spongia officinalis*, consisting of medulla (M) and overlying cortex (C). Note the diffuse fibrillary organization. Bar, 2 µm. ***Fig. 4*** - Peculiar bacteria living in a damaged specimen of *Spongia officinalis*. Electron-dense granules border the discontinuous bacterial wall. Bar, 1 µm.



Figs. 5-6 - Damaged specimen of *Spongia officinalis*. ***Fig. 5*** - Part of skeletal fibre exposed to the environment, showing a loose texture. A bacterium (arrow) is located within a canaliculus. Bar, 1 μm. ***Fig. 6*** - Detail of a canaliculus with bacteria. The bacterial walls are connected to the fibrillary matrix (arrows) constituting the fibre. Bar, 0.5 μm.

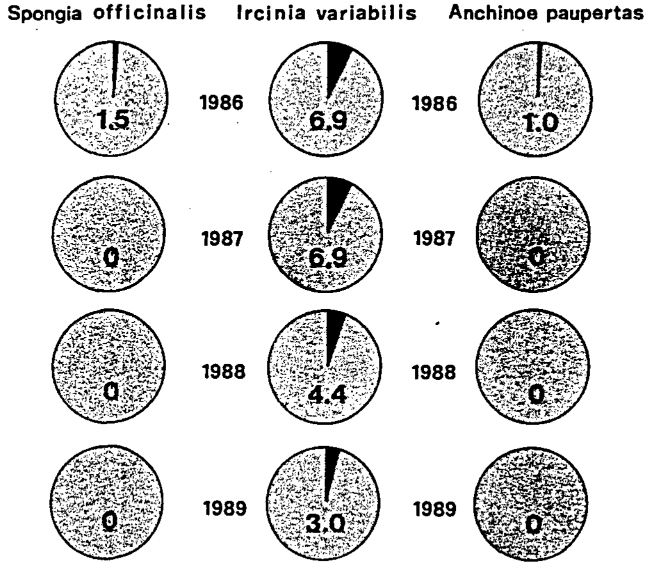


Fig. 7 - Decrease and disappearance of the three monitored species in the Marsala Lagoon. The values represent percent coverage of available substrata (see «Materials and Methods» section).

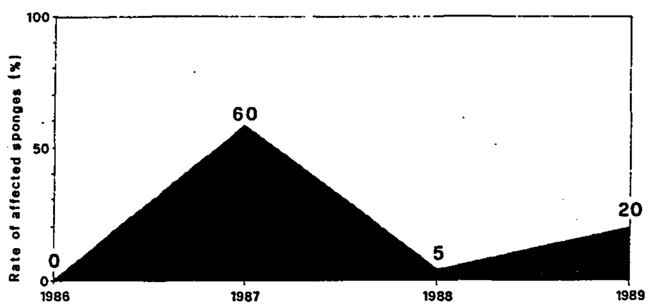


Fig. 8 - Trend showing the fluctuation of the epidemic over 4 years in the monitored population of the Portofino Promontory (see «Materials and Methods» section).

teristic bacteria in sponges has been experimentally tested in *Chondrilla nucula* during its degenerative process (Gaino & Pronzato, 1987). Endocellular vacuoles, fibrils and spore production were considered characteristics of non-symbiotic microflora. Likewise, bacteria with electron-dense dots at the periphery of the wall could represent a marker for non-symbiotic microbial populations which supposedly penetrate the damaged sponge body as a result of the fall of normal defenses.

The most remarkable trait of sponge disease was represented by bacteria penetrating fibres. These bacteria differed in shape from the electron-dense ones. The ability to excavate the skeletal fibres could be related to their metabolical activity, in agreement with recent findings on skeletal remodeling due to bacteria (Vacelet *et al.*, 1988). Histolytic processes have been described as a result of endobiotic cyanobacteria invading sponge tissue (Rützler, 1988). The finding of bacteria penetrating fibres of *S. officinalis* suggests the question as to whether such microorganisms are sponge symbionts or filtered from the sea water. Sponge death is difficult to discern owing to the primitive structure of these organisms. Noticeable degeneration may occur in a living sponge body, with fragmentation and merging processes, as proved by a long-term underwater study in *Cacospongia* (Pansini & Pronzato, 1990). This feature suggests that affected and healthy parts may coexist in the specimen.

Bacteria closely attached to the fibrillary matrix of the sponge skeleton are most likely responsible for collagen digestion and consequently for the excavation of canaliculi. Although the cause of the disease is still unknown, our data suggest that tissue degeneration precedes bacterial invasion in both mesohyl and skeletal fibres.

Long-term investigation carried out at the Portofino Promontory and in the Marsala Lagoon evidenced that disease may affect not just horny sponges, but also other species, and lead to their disappearance. In the Marsala Lagoon, *Ircinia variabilis* is the most resistant species: in fact weathered the epidemic and survived, whereas *S. officinalis* disappeared. *Hippospongia communis*, recorded in the past in this habitat (Bullo *et al.*, 1899; Cavallaro *et al.*, 1974; Cefali & Andaloro, 1979), has also disappeared in the last decade (Corriero, 1990).

The disease trend in the sponge populations of Portofino and Marsala suggests a correlation between mortality and depth of sponge beds. In agreement with Vicente (1989), who suggested that shallow-water populations disappeared from the West Indies at increased temperature values, the disappearance of *S. officinalis* and *H. communis* could be related to the warming of the Marsala Lagoon during summer. By contrast, at Portofino, where the sponge beds are located in deeper water, the summer temperatures are lower and sponge populations, even though seriously affected, could recover by the healing process of isolating damaged parts with subsequent shedding (Gaino & Pronzato, 1989).

Commercial sponges have by now become so scarce in the eastern Mediterranean basin that Greek fishermen have moved to the Italian coasts, where their activity depletes the sponge beds and could lead to an impoverishment of local sponge fauna. Coordinated international programes of management of marine life and resources are needed to save natural stock populations.

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