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Damage and partial mortality in the gorgonian *Paramuricea clavata* in the Strait of Messina (Tyrrhenian Sea)

Dommage et mortalité partielle chez la gorgone Paramuricea clavata *dans le détroit de Messine (mer Tyrrhénienne)*

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ABSTRACT

Mistri M., V.U. Ceccherelli, 1995 - Damage and partial mortality in the gorgonian Paramuricea clavata *in the Strait of Messina (Tyrrhenian Sea).* Mar. Life, **5** (1) : 43-49.

A massive development of mucilage and a case of partial mortality in the Mediterranean gorgonian Paramuricea clavata *is reported. Mucilage affected the benthic biocoenosis and particularly a gorgonian population on a shoal off the small town of Scilla (Reggio Calabria, southern Italy) at the end of summer 1993. A mass of Ionian water rich in nutrients was probably isolated along the Calabrian coast in summer 1993. The meteorological conditions in August and September led to the warming of the water mass, and induced a bloom in mucilage producers. Smothering due to macroflakes entangled in gorgonian branches for several weeks caused the progressive necrosis of the underlying coenenchymal tissue. The entire population was affected by tissue necrosis: about 5 000 colonies, living in the 29 to 39 m depth range, underwent severe degeneration.*

RÉSUMÉ

Mistri M., V.U. Ceccherelli, 1995 - [Dommage et mortalité partielle chez la gorgone Paramuricea clavata *dans le détroit de Messine (mer Tyrrhénienne)].* Mar. Life, **5** (1) : 43-49.

Un développement massif de mucilage pendant l'été 1993 a provoqué un cas de mortalité partielle de la gorgone méditerranéenne Paramuricea clavata *dans un haut-fond près du détroit de Messine (sud de l'Italie). Une masse d'eau riche en nutriments venant de la mer Ionienne est probablement restée isolée le long de la côte calabraise. A cause de conditions météorologiques particulières, un développement d'algues productrices de mucilage s'est produit. L'étouffement provoqué par le mucilage déposé sur les gorgones (et qui a duré quelques semaines) a causé la nécrose du coenenchyme. La population entière a été frappée par la nécrose des tissus : environ 5 000 colonies vivant entre 29 et 39 m de profondeur ont été gravement touchées.*

INTRODUCTION

Octocoral gorgonians are common and conspicuous members of hard-substrata benthic communities of the Western Mediterranean (Weinberg, 1979, 1980; Gili *et al.*, 1989). While the autoecology, pattern of growth and productivity of these colonial organisms have been quite thoroughly studied, causes of mortality in natural populations are still poorly understood (Bavestrello *et al.*, 1994). Gorgonian populations seemingly show absence of senescence (Coma *et al.*, 1995), and it is generally accepted that the life span of such organisms is ecologically, rather than genetically, limited (Sebens, 1987).

Paramuricea clavata (Risso, 1826) is a sciaphilic gorgonian which lives on vertical and overhanging surfaces and forms large colonies with thick, irregu-

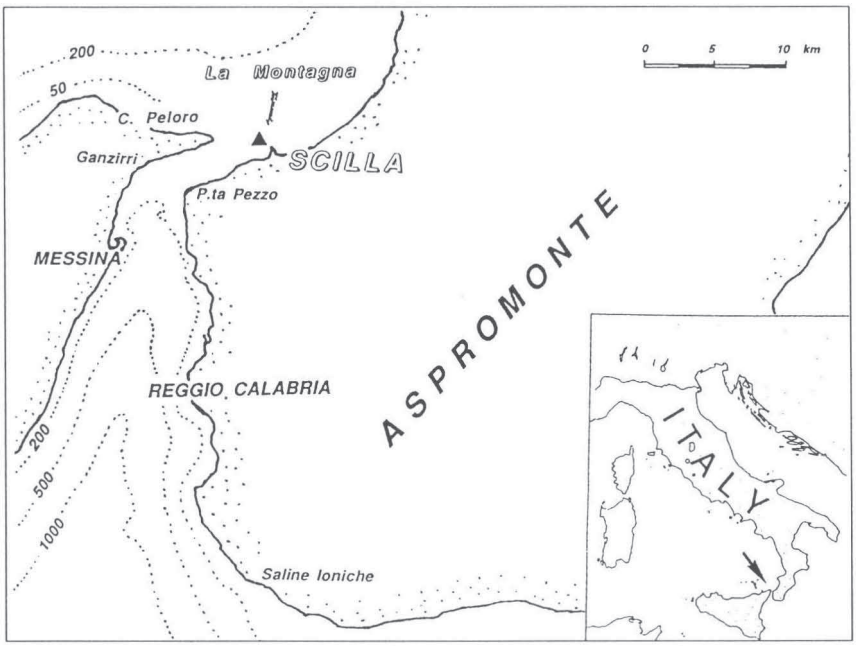

Figure 1 - *Paramuricea clavata*: study site location / *Localisation du site d'étude.*

larly ramified branches. A dense, patchy population of this gorgonian occurs off the small town of Scilla (Reggio Calabria, southern Italy). The patch living on the shoal called "La Montagna" has been under observation by us since 1991. As demonstrated in a previous study (Mistri, Ceccherelli, 1994), this local population of *P. clavata* is characterized by a low *P/B* ratio, indicating a low metabolism and a slow turnover time. This implies that occasional mass mortality might have prolonged effects on the *P. clavata* population.

In the Mediterranean Sea, a number of studies have reported the occurrence of flocculent, amorphous aggregates known as mucilage. The effect of mucilage on benthic communities has been particularly studied in the Adriatic Sea (Stachowitsch, 1984; Stachowitsch *et al.*, 1990). In the Tyrrhenian Sea, along the western Italian coast, detailed information on the occurrence of mucilage is still scarce, probably because extended macroscopic phenomena of surface accumulation of floating gelatinous masses (like those occurring in the northern Adriatic) have never been observed. Nevertheless, mucilage is also often present in the Tyrrhenian Sea. In fact, Tuscan fishermen refer to as "bromo" a filamentous, viscid, gelatinous material that obstructs fishing nets to a varying degree, depending on the year and season. In recent years (1990, 1991) large scale occurrence of mucilage was observed in the central and southern Tyrrhenian Sea (Cinelli, 1992; Innamorati, 1992), along the coasts of Sicily (Giaccone, 1992), and in the Lavezzi Archipelago (Corsica) (Mistri, Bergamini, personal observations). Moreover, more or less conspicuous patchy occurrence of mucilage was also observed along the Sicilian coasts in 1993 and 1994 (Giaccone, personal communication). In the summer season, mucus aggregates often settle on the sea bottom and thus exert a great impact on benthic biocoenoses: when benthic organisms are covered by mucilage for a particularly prolonged time, they can die (Stachowitsch *et al.*, 1990). Benthic mucilaginous aggregates are metaphytonic associations characterized by the constant presence of Tribonematales and Ectocarpales algae, together with heterogeneous assemblages of macroalgae fragment, blue-green algae, diatoms, dinoflagellates and inorganic sediment (Sartoni, Sonni, 1991).

The massive development of mucilage that affected benthic communities along Tyrrhenian and Ionian coasts of Sicily in 1991 (the phenomenon was sufficiently severe, as along the Tyrrhenian coasts it virtually stopped fishing activities) was not observed on the Calabrian side of the Strait of Messina, where mucilage appeared and affected benthic communities at the end of summer 1993. Benthic biocoenoses, and particularly erect organisms, suffered quite heavy coverage due to mucilaginous aggregates entangled in projecting structures. The gorgonian population at "La Montagna" was among them.

Aim of this paper is to describe the development pattern over time of the mucilage phenomenon that took place at the end of summer 1993, and the consequence of the interaction between mucilage and gorgonians. We also quantify the partial mortality of gorgonians due to mucilage-induced smothering.

MATERIAL AND METHODS

In situ, observations on the *Paramuricea clavata* population were carried out at "La Montagna" (38°15'00 N, 15°43'18 E), a cone-shaped, granitic shoal located some hundreds of meters off the Rock

of Scilla (Reggio Calabria, southern Italy), at the northern entrance of the Strait of Messina (Figure 1). The walls of the shoal descend steeply downwards from the top at 18 m depth to a depth of 39 m. The top of the shoal is dominated by algae, particularly Dictyotales. Scuba diving surveys have made it possible for the distribution of *P. clavata* to be mapped and data to be collected for the characterization of both its population structure and ecology.

In mid-September 1993, we started direct observation of the mucilage phenomenon. Two divers visited the shoal and the *Paramuricea clavata* population daily for a week, and recorded the patterns of development over time of the gorgonian coverage. Mid-September temperatures of the water column at "La Montagna" were recorded daily at about 12:00 for a week with a digital thermometer during dives. Other surveys were carried out between the end of September and the first ten days of October 1993, when water samples were collected in order to determine the presence of ammonium nitrogen, which is an indicator of progressive decay. Samples were analyzed in the laboratory by means of an Orion 960 Autochemistry System, equipped with a Model 95-12 Ammonia Electrode. The electrode uses a hydrophobic gas-permeable membrane to separate the sample solution from the electrode internal solution (ammonium chloride). Dissolved ammonia in the sample diffuses through the membrane until the partial pressure of ammonia is the same on both sides of the membrane; the potential of the electrode sensing element with respect to the internal reference element is described by the Nernst equation. Once collected, water samples were immediately acidified to pH=2 with sulphuric acid to prevent loss of ammonium nitrogen, and stored at 4°C. Since water samples were preserved with acid, preliminary distillation was required: to 500 mL of each sample, 25 mL of borate buffer were added, and the solution was adjusted to pH=9.5 with 6N sodium hydroxide; 0.04N sulphuric acid was used to trap the distillate.

In November 1993, immediately after the disappearance of mucilage from the gorgonians, in order to estimate of the scale of damage to the colonies, the population was sampled by means of quadrat-census. Four 1 m^2 quadrats were arranged along a depth transect (30 to 37 m), and the colonies within each quadrat were photographed with a Nikonos V underwater camera, with a white plastic 50 cm-sided graduated square behind each colony. In the laboratory, slides of the colonies were viewed with a projector equipped with a built-in monitor, and the perimeters of the colonies were traced. For each colony, we measured total height (*i.e.*, the distance between the base and the furthest point of the tip of the longest branches of the colony), and the linear development of bare branches.

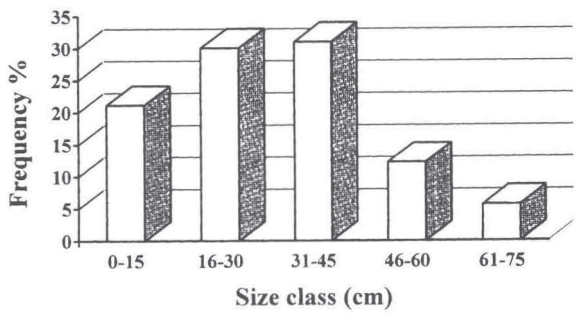

Figure 2 - *Paramuricea clavata*: size height structure of the "La Montagna" population / *Composition de la population de la gorgone selon des classes de taille (hauteur).*

RESULTS AND DISCUSSION

At the "La Montagna" shoal, the gorgonian *Paramuricea clavata* grows below 29 m water depth. It is reported (Weinberg, 1978) that low irradiance and high water turbulence are the most important limiting factors governing species distribution. The *P. clavata* population was quite dense (about 19 colonies m^{-2}) and occupied an area estimated to be *circa* 1000 m^2. It was exposed to a wide range of hydrodynamic conditions. The shoal is directly subjected to strong tidal currents that flow through the Strait: current velocity ranges between 0.07 and 0.9 m s^{-1} depending on season and on lunar phase, with exceptionally high values (2-3 m s^{-1}) at spring tide (Magazzù *et al.*, 1981; Guardiani *et al.*, 1988). Colonies showed an abrupt change in orientation below 36 m depth: colonies growing between 29 and 36 m depth were oriented perpendicular to the sea surface, while at the foot of the shoal colonies were oriented parallel to the sea surface. A turbulence zone caused by the current flowing downslope along the bottom is likely to be the main factor responsible for this 90° change in orientation (Mistri, 1994). The majority of colonies of *P. clavata* were relatively large. The height size structure of the population (Figure 2) is characterized by central size classes comprised between 15 and 45 cm height.

The massive development of mucilage that we observed in September 1993 was probably the last stage of a phenomenon originating some time before. The Strait of Messina is subject to a semidiurnal tide which regularly transfers nutrient rich deep water from the Ionian Sea to the Tyrrhenian Sea (Magazzù, Andreoli, 1971). During the so-called "rema montante" (tidal current flowing northward), levantine intermediate water reaches the upper layers and mixes with surface water. As the result of the upwelling of deep Ionian water, primary production in the South Tyrrhenian Sea (Calabrian coasts) is remarkably enhanced, and higher values of nitrates and phosphates have been observed at the sill of the Strait, where upwelling intensity is the greatest (Magazzù, 1980). After current reversal, the Tyrrhenian water flows southward ("rema scendente") and is entrained in the surface cyclonic circula-

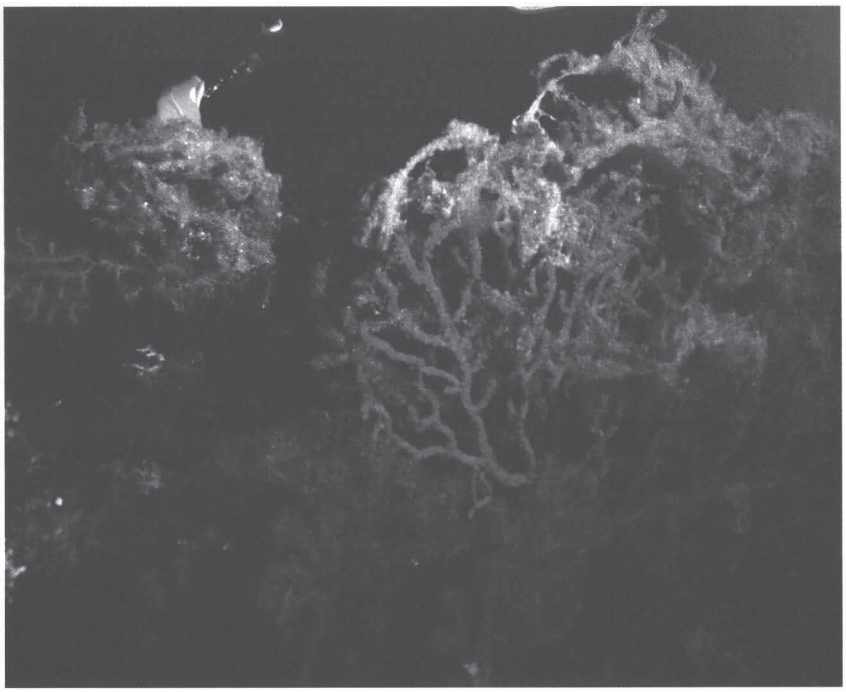

Figure 3 - Entangled mucilaginous stringers on *Paramuricea clavata* branches / *Filaments de mucilage accrochés aux branches de* Paramuricea clavata.

tion of the Ionian Sea. The above mentioned tidal mixing generates a water mass (called C water) whose hydrological characteristics are intermediate between Ionian and Tyrrhenian waters. C water occupies a region bounded by a northern border (within 10 km north of the sill of the Strait) and by the Calabrian and Sicilian coastlines (Bohm *et al.*, 1987). With particular meteorological conditions, masses of C water can be segregated along the coastline (Grancini, Magazzù, 1973). It is possible to hypothesize that a mass of C water was segregated along the Calabrian coast at the northern entrance of the Strait of Messina in summer 1993. Meteorological conditions during August and September (*i.e.* weather very hot and calm, with no wind or waves) led to the warming of that mass rich in nutrients, and induced mucilage producers (mostly *Tribonema marinum*; Sartoni, Sonni, 1991) to bloom.

The mucilage phenomenon took the form of the appearance of gelatinous masses suspended in the water column. Sport divers began to notice free floating flakes ("like thin snow"; Barone, Turano, personal communication) at the beginning of September. Due to horizontally fluctuating water movements, mucilaginous aggregates became entangled on projecting benthic structures, especially in those areas most exposed to currents. The "La Montagna" shoal was one of those areas. When we started direct observation of the phenomenon, in mid-September, suspended "thin snow" had turned into larger aggregates. Unlike the Adriatic mucilage that concentrates and often piles up on the sea surface as creamy or gelatinous layers, in the Tyrrhenian Sea the mucilage phenomenon seems to be confined only to deeper waters (Rinaldi *et al.*, 1995). At "La Montagna" and the nearby areas subjected to the phenomenon, mucilage was observed only below 15-18 m depth. Macroaggregates still suspended in the water column had the appearance of comet-like, white-yellowish stringers; in a few days, entangled flakes on *Paramuricea clavata* branches turned into a green-brownish, cobweb-like cover, obstructing spaces through the fan, and preventing polyps from extroverting (Figure 3).

The analysis of thermal profiles showed significant

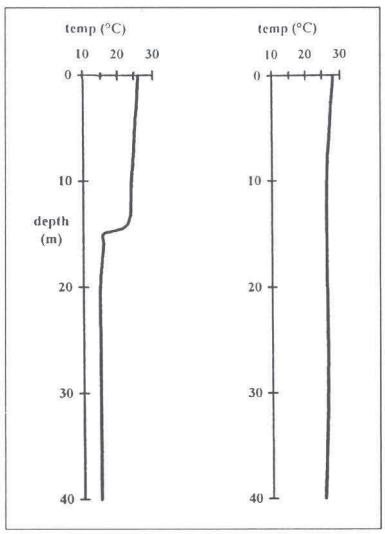

Figure 4 - Depth distribution of average water temperature in September 1992 and September 1993 / *Distribution en profondeur de la température moyenne de l'eau en septembre 1992 et septembre 1993.*

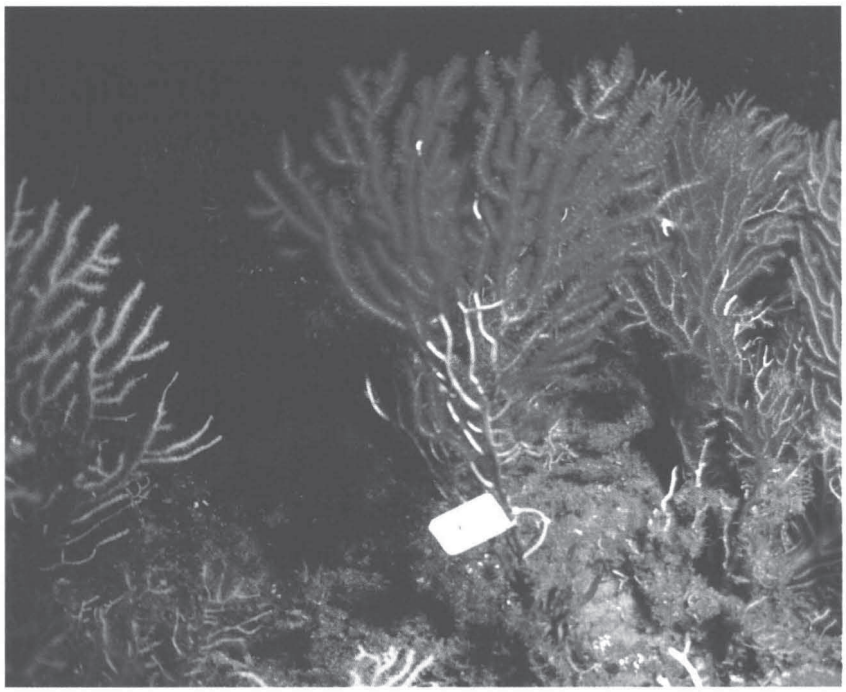

Figure 5 - *Paramuricea clavata*: mucilage-induced coenenchymal smothering resulting in the denudation of the axial skeleton / *Le mucilage a provoqué la dénudation du squelette.*

temperature differences within the first 40 m of depth between September 1992, characterized by colder water, and September 1993 (Figure 4). At the end of summer, the thermocline is generally stabilized at shallow depth (Magazzù, Andreoli, 1971), and the *Paramuricea clavata* population at "La Montagna" constantly thrives in colder water (14-15°C). In September 1993, the thermocline was considerably deeper, and exceptionally warm temperatures (>25°C) were recorded at the foot of the shoal. Harmelin, Marinopoulos (1994) suggested that abnormal temperature rise might have a deleterious effect on gorgonians by diminishing their resistance to stress. At the "La Montagna" shoal, abnormally high temperature was most likely responsible for the triggering of promoted algal activity: it is known (Giani *et al.*, 1992) that high temperature conditions may favour the photosynthetic activity of the autotrophs which produce mucilage.

The stiffling coverage of the gorgonians lasted a few weeks. At the end of September, suspended aggregates disappeared from the water column, and mucilage could be observed only on erect macrobenthic organisms (invertebrates and algae). The direct observation of mucilage from gorgonian branches revealed that stringers were constituted of different layers, probably settled at successive phases. At least two layers were quite clearly recognizable: an outermost, viscid, brownish layer, which flaked when touched, and an innermost, thicker layer. During October, the phenomenon gradually decreased and, around mid-October, mucilage had almost completely disappeared from benthic organisms. Subsequent observations did not reveal signs of decay in the benthic biocoenosis on the shoal: only *Paramuricea clavata* exhibited damage to the coenenchyme. As a consequence of prolonged anoxic conditions, the coenenchyme which had been covered by mucilage became necrotic and decayed.

Besides morphological observations, chemical analyses of the surrounding water confirmed that the decay of the gorgonians was caused by mucilage. On the 6th of October, we collected a 1 L water sample on the shoal, very close to gorgonians (34 m depth), and another at the distance of about 50 m from the shoal, at a depth of around 28 m. The concentration of ammonium nitrogen was found to be <0.2 mg/L in the sample collected in the water column at 28 m depth, but increased to 5.8 mg/L in the water sample taken among the gorgonian population. Rinaldi *et al.*, 1995 found a significant presence of ammonium nitrogen (160 times higher compared with other depths) in water samples collected close to gorgonians affected by mucilage in the Monte Argentario Promontory (Tuscany, Italy).

The general morphology of a gorgonian is no doubt an example of a growth shape allowing optimal contact between living colony tissues and ambient water. The principal effect of mucilage, entanglement of the branches, was to prevent the polyps from extroverting, thus inhibiting metabolic exchanges with the ambient water. Mucilage-induced coenenchymal smothering resulted in the denudation of more or less extensive portions of the axial skeleton (Figure 5).

The entire *Paramuricea clavata* population was heavily affected by mucilage. Immediately after the disappearance of mucilage from the colonies, in November 1993, the majority of gorgonians exhibi-

Table I - Damaged *Paramuricea clavata* colonies (N = 58) in the 33 to 37 m depth range. Classification according to 4 vitality levels (% of colony total branch length denuded). Percentage of measured colonies in each category, and corresponding mean height (H ± standard deviation) are also given / *Pourcentage de colonies endommagées de* Paramuricea clavata *entre 29 et 39 m de profondeur selon 4 niveaux de dénudation des axes, et hauteur moyenne des colonies (H ± écart-type) correspondante.*

	%	H ± S.D. (cm)
Denuded axis: 0-10 %	28	23.0 ± 14.5
Denuded axis: 11-30 %	28	28.0 ± 14.7
Denuded axis: 31-60 %	24	23.9 ± 8.6
Denuded axis: 61-100%	20	14.9 ± 4.2

ted areas in which the bare skeletons were exposed. Between 29 and 39 m depth, almost all colonies were involved: from a sample of 161 colonies, taken along a depth transect, 31.7 % showed bared parts for more than 50 % of the total branch length of the fan. We estimated that more than 5 000 colonies were affected by heavy tissue loss.

A total of 58 colonies were photographed and measured inside the 4 quadrats in the 33 to 37 m depth range. In Table I, the pattern of colony damage according to four vitality levels is reported. Smaller colonies exhibited the heaviest damage. Injuries exhibited complex variability in both frequency and pattern between colonies, as shown in Figure 6. Many injuries were limited to a few cm of tissue, while others involved the majority of the colony. The extent and the duration of the effects of damage are determined by the time required by the living portion of the colony to regenerate the lost tissue and cover the axis before encrusting organisms can overgrow it. Variables affecting rates of tissue regeneration will affect the overall survival ability of the colony (study in progress).

On gorgonian colonies from "La Montagna", smothering due to entangled macroaggregates left extensive portions of exposed skeletons. In benthic communities, where there is a strong competition for space, such bare branches will constitute an immediately available, free substratum on which overgrowing organisms can settle. Later inspections carried out in June 1994 showed that bare skeletal parts of gorgonians had been colonized by overgrowing invaders, mainly hydroids, bryozoans and algae (study in progress).

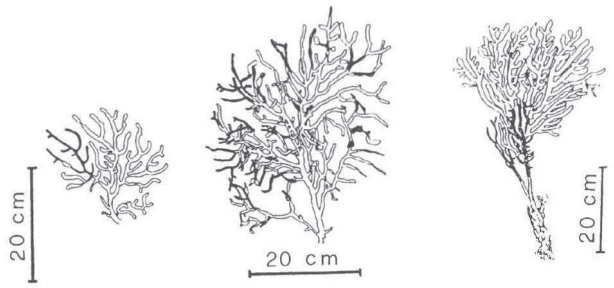

Figure 6 - Drawing of *Paramuricea clavata* colonies showing different locations and extent of tissue damage (in black) / *Dessin des colonies montrant la position différente et l'amplitude des tissus endommagés (en noir).*

Tissue damage is a quite common event among Mediterranean gorgonians. Harmelin and Marinopoulos (1994) suggested that major causes of tissue loss in colonies of *Paramuricea clavata* in the marine park of Port-Cros (southern France) were mutual abrasion by water turbulence and mechanical man-induced factors. In the Ligurian Sea, in the very same period in which gorgonians at "La Montagna" were affected by mucilage, many local populations were heavily damaged by unidentified exogenous factors (Bavestrello *et al.*, 1994).

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