CASE STUDIES AND REVIEWS

Damage by fishing activities to the Gorgonian coral Paramuricea clavata in the Ligurian Sea

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ABSTRACT

1. The analysis, by means of line transects, of a *Paramuricea clavata* (Anthozoa: Gorgonacea) population forming a facies of the Mediterranean coralligenous community along the Portofino Promontory (Ligurian Sea, Italy) evidenced a high per cent of lesions inflicted to the gorgonian coenenchyme by anchoring and fishing activities.

2. This damage favours the development of aggregates of epibionts (mainly hydroids and bryozoans) which leads to greater mechanical stress through increased resistance of the colonies to water movement; where polychaetes and nematodes colonize the denuded skeleton, their burrowing activity weakens the colony.

3. *In situ* tissue regeneration experiments suggested that aggregation of epibionts can develop only if the injuries result, from continuing abrasion.

4. Injuries caused by anchoring and fishing can therefore be considered the major cause of mortality of *Paramuricea clavata* in the Portofino Promontory.

5. *Paramuricea clavata* re-colonizes experimentally denuded areas slowly and colonies take many years to reach the size of existing individuals and can be damaged easily by fishing and anchoring.

6. Special protection is needed for this key species of Mediterranean coral at Portofino Promontory, which is proposed as a Natural Marine Park. © 1997 John Wiley & Sons, Ltd.

INTRODUCTION

In the Western Mediterranean, anthozoans account for up to 95% of the total biomass in coralligenous communities (Gili and Garcia, 1985) and the gorgonians can characterize entire facies of the circalittoral and bathyal biocoenosis (Weinberg, 1980; Gili and Ros, 1985). *Paramuricea clavata* (Risso, 1826) is a structuring key-species of the coralligenous biocoenosis and, due to its attractive shape, impressive size (H > 150 cm), and density (up to 70 colonies m^{-2}), it contributes greatly to the aesthetic value of the Mediterranean underwater landscape (Harmelin and Marinopoulos, 1994).

Data on its distribution (Rossi, 1965; Weinberg, 1978; Peirano and Tunesi, 1989; Peirano and Sassarini, 1991), growth, fractal arrangement (Burlando *et al.*, 1991), population structure and secondary production (Mistri *et al.*, 1992; Mistri and Bergamini, 1993; Mistri and Ceccherelli, 1994; Coma *et al.*, 1995a; 1995b)

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are available, but few studies have dealt with other aspects of its life history such as mortality (Harmelin and Marinopoulos, 1994; Coma and Zabala, 1994) and recruitment. Massive mortalities, the causes of which are still uncertain, have contributed to the reduction of Mediterranean populations of this species (Rivoire, 1991; Bavestrello et al, 1994). The development of epibionts, such as filamentous algae and mucillage during the summer season, mainly in the Southern Tyrrhenian Sea, may play a negative role.

The cliff of Portofino Promontory (Ligurian Sea) is an oligocene puddingstone which reaches down to a depth of approximately 50 m (Tortonese, 1958, 1961; Morri et al., 1986). A large P. clavata population lives between 20 and 50 m deep (Bavestrello et al., 1994).

This area is very busy, especially with diving and coastal sport fishing (trolling, casting, jigging) during the summer. Moreover gill nets, traps and 'palamiti' (a type of long-lining) are employed (up to 1 gear/day per 10 hectare). There is also a very large incidence of anchoring. Observations suggest that all these activities seem to have a strong impact on the upper layers of the benthic communities.

In the Caribbean, the epibiosis on gorgonians, assumed as a result of mechanical injuries (Bayer, 1973), is particularly significant. Although the initial damage involves small portions of the coenenchyme, it may have devastating effects leading to a lower number of reproductive, trophic and defensive polyps and a major alteration in the anatomo-physiological integrity of the entire colony (Wahle, 1980, 1983). Epibiont development is hindered by coenenchyme regeneration which tends to cover the denuded skeleton (Lang da Silveira and van't Hof, 1977; Wahle, 1983; Theodor, 1967; Bavestrello and Boero, 1986).

In contrast to tropical gorgonians, in which asexual reproduction contributes to the maintenance of the population structure (Jackson et al., 1985), P. clavata shows exclusively a yearly synchronous sexual reproduction (Coma et al., 1995a, 1995b). This species is characterized by a low metabolism and slow turnover (Mistri and Ceccherelli, 1994) and, consequently, damage to the colony integrity can be more significant.

Along the North-Eastern cliff of the Portofino Promontory (Ligurian Sea, NW Italy), a rich P. clavata population shows a general state of disease with high percentages of branches without coenenchyme and large complex aggregations of epibionts settling on these portions. Moreover, several fallen colonies can be found at the foot of the cliff, with still viable portions of coenenchyme not yet covered by sediments.

The aim of this study was to evaluate the extent of epibiosis on P. clavata colonies living along the Portofino Promontory cliffs, its role in the colonies' mortality and the ability of the coenenchyma to regenerate after wounds caused by fishing gear and anchoring. Experimental tests were also conducted on the capability of this species to resettle in areas where it had been artificially removed.

MATERIALS AND METHODS

Epibiosis was assessed on 14 colonies collected on the cliff of the Portofino Promontory (Figure 1) in July 1993. After the inspection in the laboratory, all the sessile organisms were identified at specific level, and their per cent presence evaluated (Table 1).

The involvement of fishing gear was evaluated by counting the colonies enveloped by lines or nets along four different vertical transects within the gorgonian population.

To investigate the regeneration ability of P. clavata, five colonies were artificially wounded with lesions (5 cm long) along the axis, and then the subsequent coenenchyme growth periodically documented by photos.

The recruitment capacity of P. clavata was tested experimentally by removing all colonies in July 1992, from a 70×50 cm area at 35 m depth on the Portofino Promontory (San Fruttuoso Bay) within a population with an average density of 20 colonies m^{-2}. After four years, the colonies settled in this area were counted, collected and measured.
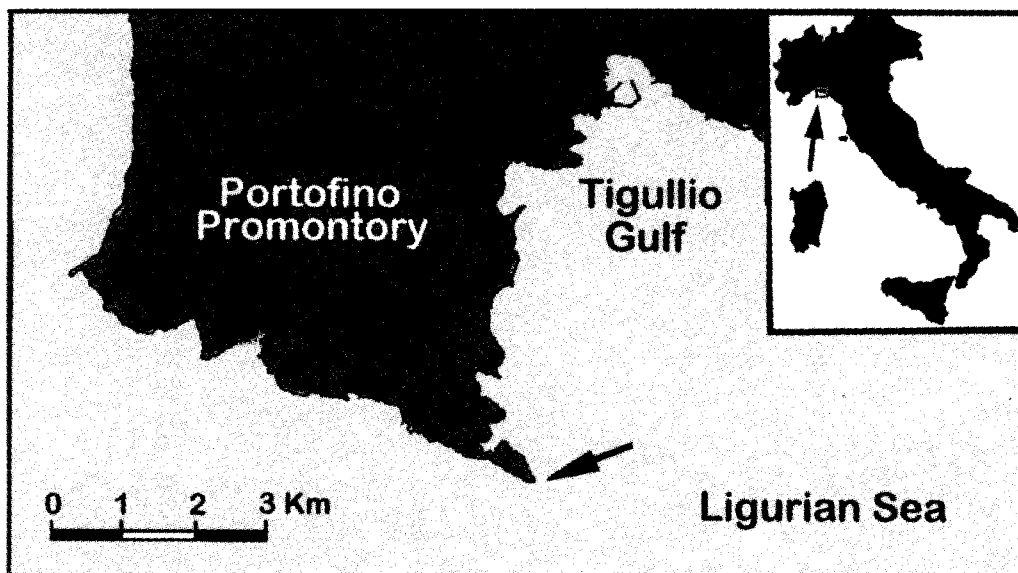
Figure 1. The Portofino Promontory. Arrow indicates the sampling area.

RESULTS

Diving observations have shown that gorgonian colonies are seriously damaged by fishing activities which can affect the coenenchyme. This action is significantly increased by fish which, trying to escape from the hook, entangle the gorgonian with the fishing line. Severe damage is also caused by lost fishing gear, which may affect tens of colonies, through their continuing abrasive action. The stretched lines, under the action of sea currents, mechanically excoriate the coenenchyme as long as the lines are cast (Figure 2(a)–(d)).

The per cent of colonies entangled by fishing lines or showing damage decreases with depth: the highest values are found in shallow waters (20–30 m) where smaller colonies live and a low density occurs (Figure 3).

Several epibionts settle on the stripped branches, forming large aggregates. A check-list of the collected sessile epibionts is given in Table 1. Hydroids (*Garveia grisea, Obelia dichotoma*) are the first to colonize the denuded branches, but they are then replaced quickly by stronger competitors, like various species of bryozoans (*Turbicellepora avicularis, Bugula fulva*), serpulids (*Filograna* spp.), and the horny sponge, *Pleraplysilla spinifera* (Figure 2(c), (d)). *Parerythropodium coralloides*, when present, can constitute large colonies. Among macroalgae, *Dictyota dichotoma* is dominant during the summer. In these aggregates, a complex vagile fauna, mainly composed of amphipods and harpacticoids, feeds on the trapped detritus.

Another type of association due to abrasion is that of polychaetes and nematodes which erode the axial skeleton forming small crevices at the colony base, which become occupied by ophiuroids. Their burrowing activity produces a weakening of the skeleton and possible detachment of the colony. At the base of the cliff, below the *Paramuricea* population, many detached colonies can be found (0.46 ± 0.3 colonies m^{-2}). Some are completely buried by sediments and totally denuded (about 10%), others show small portions of living coenenchyma (Figure 2(e)). These colonies show a different aggregation of epibionts compared with those living on the cliff: in particular small specimens of the sponge *Chondrilla nucula* and numerous spirorbids were settled on the skeleton. Completely detached colonies with no obvious signs of damage to

Table 1. Taxonomic list of the epibionts found on *Paramuricea clavata* along the Portofino Promontory cliff. The commoner species are reported in bold with, in brackets, their per cent frequency on 14 colonies.

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RHODOPHYTA		*Frondipora verrucosa*	
Pseudolithophyllum sp.	(28%)	(Lamouroux, 1821)	(7%)
Peyssonnelia squamaria (Gmel.)	(14%)	*Hippodiplosia* sp.	(14%)
		Scrupocellaria reptans L., 1758	(14%)
PHAEOPHYTA		*Scrupocellaria scruposa* L., 1758	(14%)
Dictyota dichotoma (Huds.)	(42%)	*Bugula fulva* Ryland, 1960	(35%)
Halopteris filicina Kütz.	(7%)	*Bugula* sp.	(14%)
		Cellaria salicornoides	
FORAMINIFERA		Audouin, 1826	(14%)
Globigerina sp.	(100%)	*Cellaria fistulosa* Auctt.	(21%)
		Adeonella calveti	
PORIFERA		(Canu & Bassler, 1930)	(14%)
Pleraplysilla spinifera		**Turbicellepora avicularis**	
(Schultze, 1878)	(57%)	(Hincks, 1867)	(57%)
Dysidea sp.	(7%)	*Nolella gigantea*	
		(Prenant & Bobin, 1956)	(14%)
CNIDARIA, HYDROZOA		*Sertella septentrionalis*	
Campanularia hincksi Alder, 1856		(Harmer, 1933)	(14%)
	(21%)	*Schizomavella auriculata*	
Eudendrium glomeratum		(Hassall, 1842)	(14%)
Picard, 1952	(21%)	*Escharina vulgaris* (Moll, 1803)	(7%)
Eudendrium capillare Alder, 1856	(28%)	*Aetea truncata*	
Eudendrium armatum		(Landsborough, 1852)	(7%)
Tichomiroff, 1887	(21%)	*Aetea sica* (Couch, 1844)	(7%)
Eudendrium ramosum (L., 1758)	(7%)	*Pentapora* sp.	(7%)
Obelia bidentata (Clarke, 1875)	(21%)	*Beania magellanica* (Busk, 1852)	(14%)
Obelia dichotoma (L. 1758)	(28%)	*Plagioecia patina* (Lamarck, 1816)	(7%)
Garveia grisea		*Tubulipora liliacea* (Pallas, 1766)	(7%)
Motz-Kossowska, 1905	(71%)	*Escharina vulgaris* (Moll, 1803)	(7%)
Halecium tenellum Hincks, 1861	(14%)		
Halecium mediterraneum			
Weismann, 1883	(14%)	**MOLLUSCA, BIVALVIA**	
Filellum serpens (Hassall, 1848)	(14%)	*Pteria hirundo* (L. 1758)	(28%)
Bimeria vestita Wright, 1859	(7%)	*Arca noae* L. 1758 (juv.)	(7%)
Bourgainvillia ramosa		*Lima lima* (L. 1758)	(42%)
(Van Beneden, 1844)	(14%)	*Hiatella arctica* (L. 1767)	(35%)
		Chlamys sp.	(7%)
CNIDARIA, ANTHOZOA		*Spondylus gaederopus* L. 1758	(7%)
Parerythropodium coralloides			
(Pallas, 1766)	(7%)	**ANNELIDA, POLYCHAETA,**	
		SERPULOIDEA	
		Serpula vermicularis L., 1767	(7%)
NEMATODA n.c.	(21%)	*Filograna* sp.	(35%)
		Protula sp.	(14%)
ENTOPROCTA			
Pedicellina cernua (Pallas, 1771)	(35%)	**ECHINODERMATA,**	
		OPHIUROIDEA	
		Amphipholis squamata	
BRYOZOA		(Delle Chiaje, 1828)	(21%)
Cellepora pumicosa (Auctt.)	(7%)	*Ophiothrix fragilis*	
		(Abildgaard, 1789)	(7%)
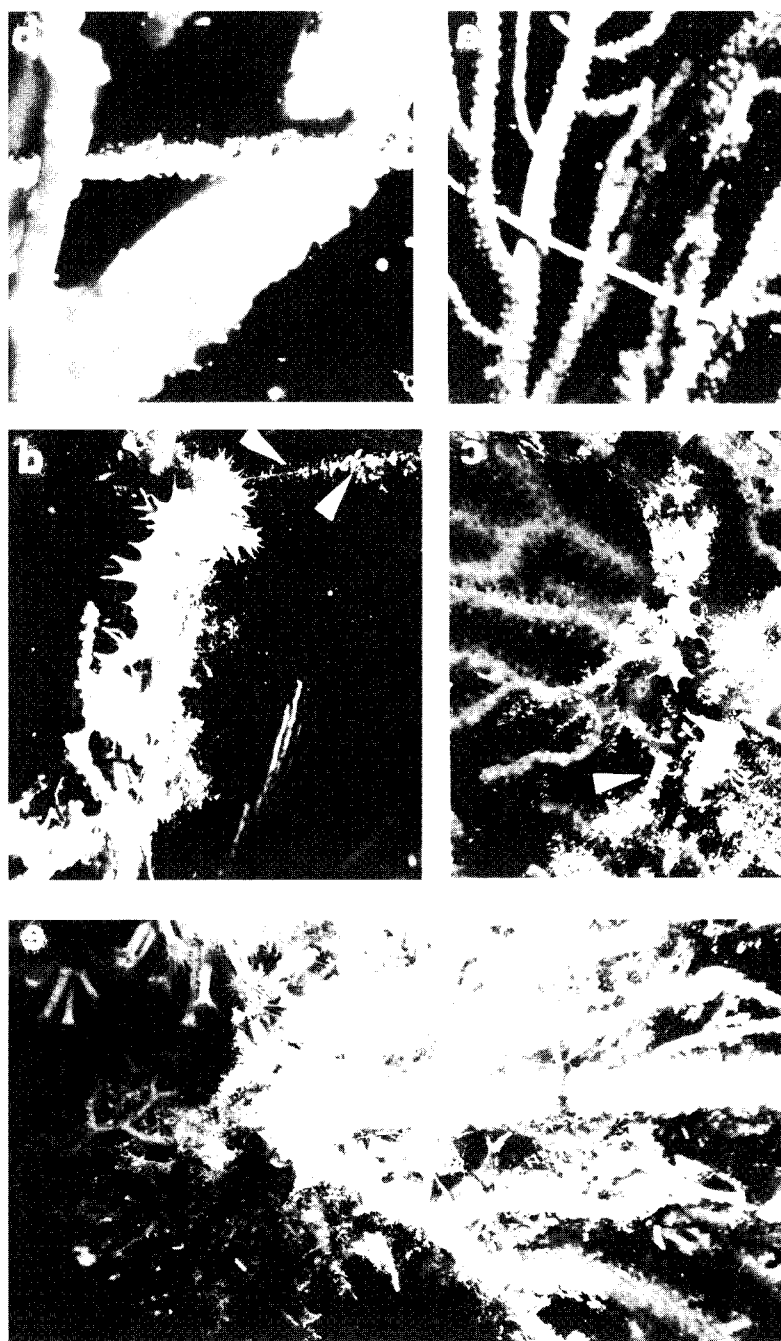
Figure 2. Mechanical injuries caused by fishing activities on colonies of *P. clavata* in the Portofino Promontory. a b Coenenchyme erosions caused by lines of abandoned 'palamito' fishing gear; c d, Different phases of growth of the sponge *Pleraplysilla spinifera* on the eroded portions of two colonies. Arrowheads indicate the fishing lines that produced the original abrasions. e, A broken colony at the base of the cliff showing small portions of living coenenchyma. Arrowheads indicate the fishing line producing the gorgonian detachment.
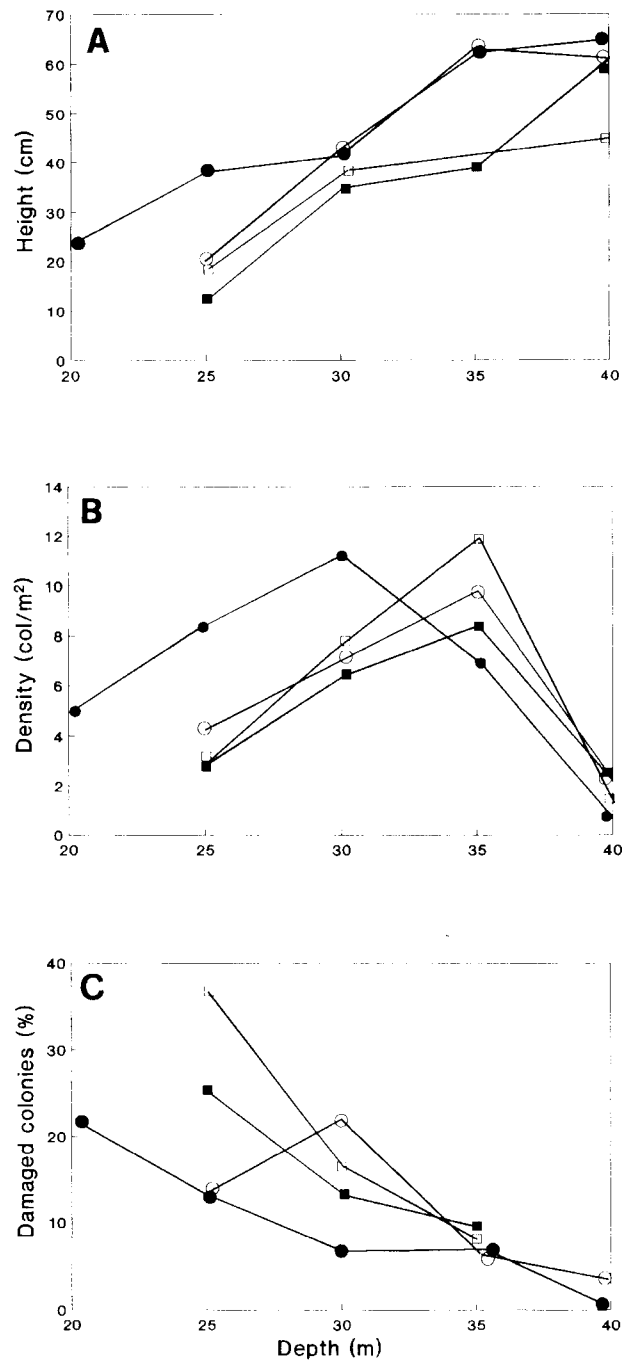
Figure 3. Height (A), density (B) and per cent of gorgonians wrapped by fishing gear (C) at different depths along four transects in the studied area.

coenenchyme have been observed along the cliff, suggesting detachment due to a single physical event such as an anchor dragging.

A fast coenenchyme regeneration was noted with *in situ* experimental observations (Figure 4). All the artificially stripped coenenchyme had newly formed in about 1 month, indicating a growth rate of 0.15–0.2 cm day^{-1}. When the coenenchyme is stripped off, the expansion and contraction rates of polyps in the isolated portions of the colony become asynchronous (Figure 4(b)).

The recolonization experiment has shown the difficulty of this species re-establishing. At the start of the experiment 23 colonies with a height ranging from 5 to 45 cm were detached from the study area. After four years, only two new colonies, 5 and 7 cm high, were observed.

DISCUSSION

Fishing activities and anchors can cause serious injuries to every type of hard bottom community. In particular, gorgonians, the main erect organisms characterizing the benthic communities along Mediterranean cliffs, are severely damaged by these activities as are benthic organisms in other protected areas (Balduzzi *et al.*, 1994)

On the Portofino Promontory, it is concluded that the major cause of mortality in *Paramuricea clavata* is damage to the colonies by fishing line, followed by the attachment of numerous epibionts. This phenomenon leads to a drastic change in the mechanical structure of the colonies in two main ways: (i) the tunnels dug in the skeleton medulla due to polychaetes and nematodes severely weaken the skeleton which is more likely to break; (ii) the weakening of the bearing structure is exacerbated by colonies becoming more resistant to water movement owing to the epibiont masses. The branch shape and density in gorgonians are known to be a compromise between the need to maximize filtration efficiency through the finest possible mesh and the colony's mechanical resistance to water friction (Köhl, 1984). Yoshioka and Yoshioka (1991) reported breakage of the axial skeleton as one of the main causes of mortality among Caribbean shallow-water gorgonians in physically highly disturbed habitats. Moreover, the occurrence of an abundance of epibionts can hinder water circulation among polyps, leading to the death of colony portions (Mistri, 1994).

In case of momentary and minor injuries, gorgonians are capable of rapidly healing the wound by inhibiting fouling growth through the fast growth of a new coenenchyme. The same has been observed in other octocorals (Riegl and Riegl, 1996). Conversely, in the case of more extensive damage, pioneering species, such as hydroids, settle quickly and are replaced by bryozoans which can no longer be removed by the newly growing coenenchyme.

Although *P. clavata* appears to be the gorgonian species which makes the highest investment in sexual reproduction in terms of number of mature oocytes produced per polyp (Coma *et al.*, 1995b), clearance and colonization experiments have shown re-population to be extremely slow. In addition, this is important in the context that the facies characterized by this species represents the climatic status of exposed cliffs in the Mediterranean coralligenous, reached after a complex pattern of successional stages and a very large time span (Mistri and Bergamini, 1993; Mistri and Ceccherelli, 1994).

In compliance with recent regulations in several countries for the protection of coralligenous biocoenosis in relation to the establishment of marine parks, fishing is allowed only with fixed fishing gear, like 'palamiti'. The investigations conducted on *P. clavata* in the Portofino Promontory, which is the site of a planned marine park (Diviacco *et al.*, 1992), have shown evidence of the damaging effects of palamiti fishing gear on the upper biocenotic layer. With time, these effects are likely to have a greater impact on the community. Consequently, before such fisheries are permitted inside a marine park, their potential impact on the benthic communities must be fully assessed.
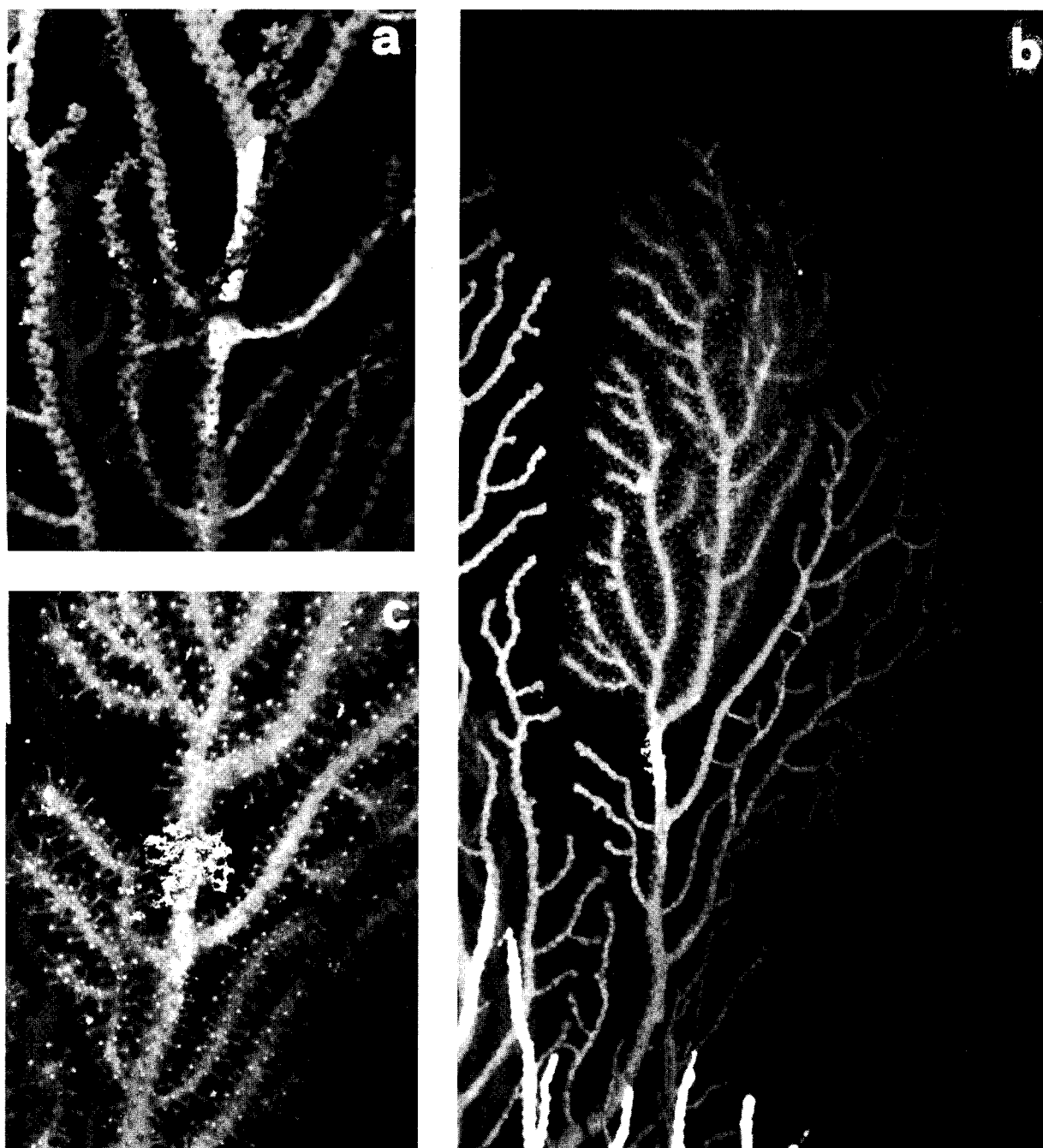
Figure 4. Regeneration experiment on central branches of a *Paramuricea* colony, artificially stripped of its coenenchyme. a, Beginning of experiment. b, 15 days later and c, 1 month later. Asyncronous polyp expansion at both sides of the injury can be observed (b).

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