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The impacts of scallop dredging on sponge assemblages in the Gulf of Kalloni (Aegean Sea, northeastern Mediterranean)

E. Kefalas, J. Castritsi-Catharios, and H. Miliou

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Concerns have been raised on the impact of bottom-fishing activities in the shallow Gulf of Kalloni (Lesvos Island, Aegean Sea). Fishing with demersal gears was banned in 1995, but the Gulf was reopened in 1998 only for scallop dredging using the "lagamna" gear. Two series of samplings were done with this gear in 1998 and 1999 (October) before the beginning of scallop-fishing period (from November up to March), aiming to investigate possible changes in sponge assemblages. Sponges (Porifera) were the most abundant meso-megafaunal benthic organisms in the Gulf, besides scallops and other bivalves. Total abundance, number of species, species diversity, species richness and evenness of sponge assemblages reduced significantly from the year 1998 to 1999. The population of the excavating *Cliona celata*, the only infaunal sponge species found in the Gulf, decreased. Multivariate analysis on the abundance data of epibenthic sponge species revealed a clear separation of samples collected during the 2 years, indicating changes in the structure of sponge assemblages. The distinguishing species included a variety of growth forms: massive (*Mycale massa*, *Suberites domuncula* and *Tethya citrina*), lobose (*Suberites massa*, *Tedania anhelans* and *Halichondria panicea*), erect branching (*Raspailia viminalis*), encrusting (*Crambe crambe*) and cushion-shaped (*Mycale contarenii* and *Chondrilla nuculla*) sponges. Among these species, only *S. massa* increased its abundance in 1999. All others decreased. No significant loss of information occurred when multivariate analysis was applied to abundance data of genera or families. This comparative study demonstrated that the time interval between two consecutive scallop-fishing periods was insufficient for the recovery of sponge assemblages. It is concluded that scallop dredging causes long-term changes in the structure and biodiversity of sponge assemblages in the Gulf of Kalloni. An improved strategy of fishery management is required in future for the conservation of living resources in this Gulf.

Keywords: sponge assemblages, dredging impacts, Aegean Sea, biodiversity, multivariate analysis.

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E. Kefalas, and J. Castritsi-Catharios: Section of Zoology and Marine Biology, Department of Biology, National and Kapodistrian University of Athens, University Campus, Athens 157 84, Greece. H. Miliou: Laboratory of Applied Hydrobiology, Faculty of Animal Production, Agricultural University of Athens. Iera Odas 75, Athens 157 84, Greece. Correspondence to J. Castritsi-Catharios: fax: +30 1 728 4622; e-mail: cathario@biol.uoa.gr.

Introduction

Bottom dredging with the fishing gear, "lagamna", is a common way of commercial fishing of scallops, *Proteopecten glaber* L., during winter in the Gulf of Kalloni. The "lagamna" has been designed to capture anything that stands out from the bottom by a few millimeters, but without scraping the surface of, or digging into, the seabed. Dredging or trawling operations inadvertently catch a range of unwanted species that are discarded into the sea. Although the alteration of benthic habitat by fishing activities has been the subject of intense research in recent years, it is not well understood. It is generally acknowledged that some fishing gears may influence species composition and diversity and alter the habitat complexity (Ball *et al.*, 2000; Bergman and van Santbrink, 2000; Frid *et al.*, 2000; Piet *et al.*, 2000). Recently, there has been a growing concern on the long-term effects of intensive bottom-fishing activities on the marine ecosystem, especially by destructive gears like scallop dredges (Hill *et al.*, 1999; Hall-Spencer and Moore, 2000).

The effects of dredging or trawling on benthic communities are difficult to ascertain for a number of reasons: ecosystems are dynamic, many systems already have a long history of harvesting and impacts may not be visible due either to inappropriate scales of observation or to a lack of adequate references sites (Auster *et al.*, 1996; Hill *et al.*, 1999; Hall-Spencer and Moore, 2000; Lindegarth *et al.*, 2000). In addition, most studies on the impact of mobile demersal gears on benthic communities have investigated changes in the abundance of small infaunal species, either because large infauna and epifauna are now too sparse to detect the effects of fishing disturbance, or because quantitative sampling of infauna is more easily and accurately achieved (Eleftheriou and Robertson, 1992; Kaiser *et al.*, 1998). However, the primary impact of bottom fishing seem to be on mega-epibenthic organisms (Kaiser *et al.*, 1998; Ball *et al.*, 2000; Bergman and van Santbrink, 2000; Freese, *et al.*, 2000).

The environment of the Gulf of Kalloni is favourable for the maintenance of a complex benthic community. Filter feeders characterize the seafloor habitat, reflecting the high levels of primary production in its nutrient-rich waters. Besides scallops and other bivalves, sponges are the most important epibenthic taxa, both in terms of species number and biomass, and constitute the most useful meso-megafaunal phylum for evaluating the ecological disturbance caused by scallop dredging. Some studies have included sponges in the by-catch species without, however, investigating the long-term effects of mobile fishing gear on sponge assemblages (Auster *et al.*, 1996; Freese *et al.*, 1999). Freese *et al.* (1999) found a decrease in population density and damage to sponges in trawled versus reference transects. They suggested that a follow-up survey might address the questions on the delayed mortality or, alternatively, recovery from the previous damage.

At the beginning of the past decade, alarm was raised with regard to the ecological effects of intensive commercial fishing in the Gulf of Kalloni. Fishing with demersal gears was banned in 1995 and the Gulf was reopened in 1998 only for scallop dredging using the "lagamna". During the period of closure, the ecosystem had been undisturbed, while during the fishing period, 1998–1999, the benthic communities suffered intense dredging. This offered a unique opportunity to determine if the time from one fishing period to the next was enough for the recovery of the ecosystem. Systematic surveys of benthic species abundance were conducted at the beginning of two consecutive fishing periods, 1998–1999 and 1999–2000. The aim of the present study was to evaluate the long-term effects of fishing gear, "lagamna", on sponge assemblages in the Gulf of Kalloni, focusing on the class of Demospongiae, the most abundant class of the phylum Porifera.

Materials and methods

Fishing gear

The fishing gear, "lagamna", (Figure 1), a local variation of the gear, "argalios", which is well known among the Greek fishermen, consists of a triangular metal frame with a 1–1.2 m iron bar on the bottom, sometimes with teeth of 4–5 cm height and width, and fitted with a 5 cm^2 mesh net. More than 50 vessels are involved in the harvesting of scallops in the Gulf of Kalloni. Each vessel shoots one or two "lagamnas" in every fishing trip. This gear is the only one used for scallop fishing in the study area. Every vessel is permitted by national regulations to catch a daily maximum of 30 kg of scallops having a diameter of at least 5 cm. In 1999, the production of scallops in the Gulf of Kalloni was about 40 t, while in 2001 it decreased to about 20 t.

Study area

The Gulf of Kalloni is a small oval gulf, which outflows in the south of Lesvos Island (Greece) and communicates with the northeastern Aegean Sea (Mediterranean Sea) by a strait, which is 700 m wide and 4000 m long (Figure 2a, b). The maximum length of the Gulf is 21.3 km whilst the maximum width is 8.2 km. It is a shallow Gulf (depth, 10 m average and 25 m maximum). The scallop-fishing ground (80 km^2) extends 50–150 m from the coast, covering 75% of the total Gulf area. The bottom over the fishing ground consists of mud, sand, gravel and biogenic detritus (shells, algae, etc.) of varying sizes. A small part of the fishing ground was covered by *Zostera* and was excluded from the present study.

Field sampling

The Gulf of Kalloni was surveyed in October 1998 (first sampling period) and in October 1999 (second sampling period), before bottom-fishing activities began. Fishing for scallops starts in November and lasts until March. During each sampling period, benthic samples were collected at six stations separated by hundreds of meters (Figure 2c). The water depth of sample stations ranged between 5 and 10 m, except stations D and E, which were deeper (15 m). Fishing effort was more intense at stations C, D and E due to the increased scallop stocks. At each station, samples were taken from eight sites separated by tens of meters. The same "lagamna" was towed once at each site. The swept area was kept similar (approximately 40 m^2) in all the samplings by adjusting the length of the warp according to the water depth.

Data analyses

For each sample, sponge species composition and abundance were assessed. The classification of Demospongiae was based on classical and recent literature (Pulitzer-Finali, 1983; Hooper, 1997). The terminology of sponge forms followed that given by Boury-Esnault and Rützler (1997).

Data for replicate sites were pooled and the counts of animals were standardized to numbers per 40 m^2. Various diversity-related measures were computed for each station: Shannon species diversity, H′; Margalef species richness, D; and evenness, J (Pielou, 1975). The differences in

Figure 1. The fishing gear, “lagamna”.

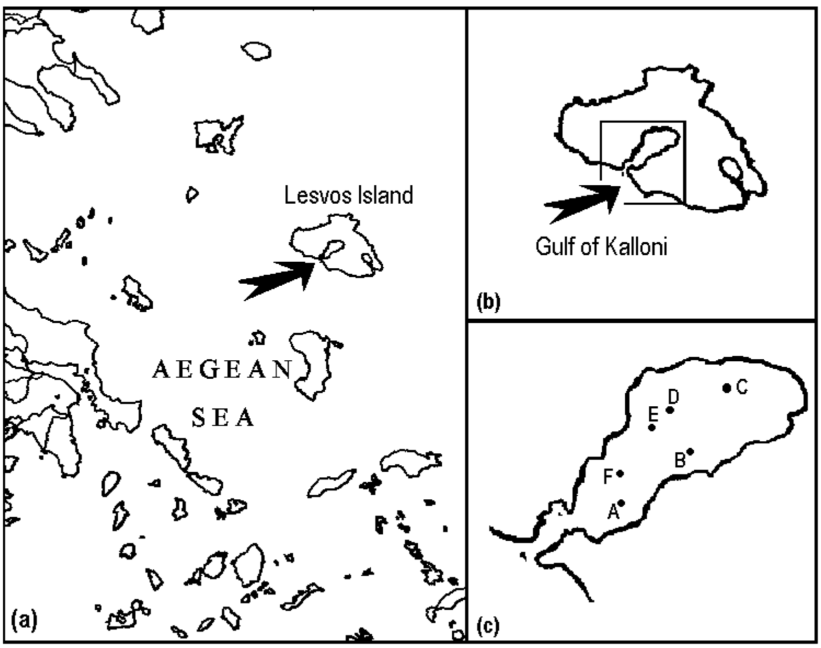

Figure 2. (a) Location of Lesvos Island in Aegean Sea. (b) Location of Gulf of Kalloni in Lesvos Island. (c) Sampling stations in Gulf of Kalloni.

univariate indices of sponge assemblages between the two sampling periods were ascertained using paired t-tests.

The PRIMER statistical software package was used to perform multivariate analysis on the species abundance data (Clarke and Warwick, 1994). A hierarchical cluster analysis using Bray–Curtis dissimilarity index was calculated and dendograms were formed using the group-averaged clustering method. The resultant similarity matrices were used to carry out non-metric multidimensional scaling (MDS), with differences between groups tested with an "analysis of similarities" randomization test (ANOSIM). The SIMPER routine was employed to establish as to which species contributed most to the average dissimilarity between *a priori* groupings of data. These multivariate techniques were also applied on the abundance data of genera, families and orders, for estimating the possible loss of information from aggregation of data in higher taxonomic levels.

Results

During the first sampling period, a total of 59 species were identified, which were divided into 38 genera, 26 families, 11 orders and three subclasses of Demospongiae (Table 1). The sponges identified during the second sampling period were represented by 48 species (47 species were also recorded during the first period), which belonged to 32 genera, 24 families, 11 orders and three subclasses of Demospongiae.

The form of the most common species found in the Gulf of Kalloni are given in Table 1. The excavating *Cliona celata* was the most prevalent in 1998 and was the only infaunal sponge species found in the Gulf. The population of this species reduced in the second sampling period. By contrast, the lobose *Suberites massa* exhibited an increase. Most of the other epibenthic species showed a lower abundance in 1999 compared with that in 1998. Moreover, erect branching sponges (e.g. *Raspailia*) were usually shorter, and many lobose (e.g. *Tedania*) and massive (e.g. *Tethya*) sponges collected during the second sampling period were malformed. For example, comparing the *Raspailia viminalis* fragments caught in 1998 (Figure 3) and in 1999 (Figure 4), the damage inflicted to this sponge species by the dredging of the study area is obvious.

The total number of species and individuals, species diversity, species richness and evenness significantly ($p < 0.05$) reduced, from the year 1998 to 1999 (Table 2).

Cluster analysis of epibenthic species abundance and subsequent non-metric MDS (Figure 5) showed two distinct groups of stations (average dissimilarity, 69.56), which were distinguished by the year of sampling, 1998 and 1999. ANOSIM revealed that the stations in the two data sets differed significantly with respect to species composition ($R = 0.956$, $p = 0.2\%$). SIMPER analysis revealed that two-thirds of the average dissimilarity of samples between the two consecutive fishing periods was contributed by the following species: *S. massa* (21.20%), *Mycale massa* (7.64%), *R. viminalis* (7.61%), *Tedania anhelans* (6.96%), *Suberites domuncula* (6.06%), *Halichondria panicea* (5.19%), *Mycale contarenii* (3.14%), *Crambe crambe* (2.87%), *Tethya citrina* (2.66%) and *Chondrilla nuculla* (2.58%). During the first sampling period (average similarity, 56.90), stations 1D and 1E were characterized by a high abundance *of R. viminalis*. In the group of stations surveyed, the second survey (average similarity, 65.26) *S. massa* was the most prevalent species. Specifically, in stations 2C, 2D and 2E a higher abundance of *S. massa* was recorded compared with that in stations 2A, 2B and 2F. In station 2A, the population of some other species, particularly of *T. anhelans*, *H. panicea* and *C. crambe*, was higher than that in 2B and 2F.

Cluster analysis on abundance data of epibenthic genera revealed a similar grouping of stations (average dissimilarity, 58.70). The ANOSIM test showed that the differences between the two groups became weaker, but remained significant at the same level ($R = 0.856$, $p = 0.2\%$). The SIMPER routine showed that the genera that contributed more than 3% each to the average dissimilarity were: *Suberites* (18.17%), *Mycale* (12.84%), *Raspailia* (9.04%), *Tedania* (8.27%), *Halichondria* (6.17%), *Haliclona* (4.40%), *Clathria* (4.27%), *Tethya* (3.44%), *Crambe* (3.41%) and *Chondrilla* (3.06%). Multivariate analysis on family level gave similar results, both in terms of separation of stations (average dissimilarity, 57.44) and the significance of differences between the two groups ($R = 0.867$, $p = 0.2\%$). The discriminating families were: Suberitidae (18.44%), Mycalidae (14.40%), Raspailiidae (10.35%), Tendanidae (8.47%), Halichondriidae (6.64%), Chondrilidae (5.45%) and Chalinidae (4.39%). At the ordinal level, average dissimilarity of the same groups of stations, as well as the significance of differences ($R = 0.804$, $p = 0.4\%$), dropped (49.24%).

Discussion

The results of this study demonstrated that scallop dredging reduced the total abundance and number of species of sponge assemblages in the Gulf of Kalloni. Previous studies have also shown that bottom trawling or dredging modifies the seafloor habitats by removing or damaging infauna and sessile organisms (Auster *et al.*, 1996; Kaiser *et al.*, 1998; Freese *et al.*, 1999).

Moreover, it seems that sponge species with specific morphological and ecological attributes are vulnerable to dredging. Many massive (e.g. *M. massa, S. domuncula* and *T. citrina*) and lobose (e.g. *T. anhelans* and *H. panicea*) sponges, which were within the reach of the "lagamna", showed an increased mortality. They may be captured in the nets or damaged by the passage of this gear. In contrast to creeping branching sponges, which remained almost

Table 1. Average abundance and form of sponge species identified in the first (1998) and second (1999) surveys belonging to three subclasses of Demospongiae: (1) Homoscleromorpha, (2) Tetractinomorpha and (3) Ceractinomorpha.

Order	Family	Species	Form*	Abundance (individuals 40 m^{-2}) 1998	1999
Homosclerophorida (1)	Plakinidae	*Oscarella lobullaris* (Schmidt, 1862)	En	0.33	0.00
Astrophorida (2)	Geodiidae	*Erylus discophorus* (Schmidt, 1862)	Cu	0.17	0.00
		Geodia cydonium (Jameson, 1811)	Ms	6.00	2.33
Hadromerida (2)	Clionidae	*Cliona celata* (Grant, 1826)	Ec	54.33	12.00
	Suberitidae	*Prosuberites epiphytum* (Lamarck, 1815)	En	0.50	0.00
		Suberites carnosus (Johnston, 1812)	Cu	1.00	0.50
		Suberites domuncula (Olivi, 1792)	Ms	17.67	3.33
		Suberites massa (Nardo, 1847)	Lb	5.00	54.00
	Tethyidae	*Tethya aurantium* (Pallas, 1766)	Ms	0.67	0.00
		Tethya citrina (Sarà and Melone, 1965)	Ms	6.67	0.67
	Timeidae	*Timea stellata* (Bowerbank, 1866)	En	6.00	0.33
Chondrosida (2)	Chondrillidae	*Chondrilla nuculla* (Schmidt, 1862)	Cu	7.33	4.00
		Chondrosia reniformis (Nardo, 1847)	Ms	5.00	3.33
Halichondrida (3)	Axinellidae	*Acanthella acuta* (Schmidt, 1862)	Be	0.17	0.00
		Axinella damicornis (Esper, 1794)	Be	0.17	0.00
		Axinella verrucosa (Esper, l794)	Be	0.33	0.17
	Halichondriidae	*Halichondria panicea* (Pallas, 1766)	Lb	17.33	7.00
		Hymeniacidon perlevis (Montague, 1818)	En	0.67	0.33
		Topsentia aurantiaca (Schmidt, 1868)	Cu	0.50	0.17
Poecilosclerida (3)	Raspailiidae	*Eurypon major* (Sarà and Siribelli, 1960)	En	3.33	0.50
		Raspailia viminalis (Schmidt, 1862)	Be	20.00	2.33
		Raspaciona aculeata (Johnston, 1842)	En	0.67	0.67
	Microcionodae	*Clathria* (*Microciona*) *cleistochela* (Topsent, 1925)	En	2.67	0.00
		Clathria (*Microciona*) *gradalis* (Topsent, 1925)	En	4.00	0.33
		Clathria (*Microciona*) *toxivaria* (Sarà, 1959)	En	0.50	0.00
		Clathria (*Thalysias*) *jolicoeuri* (Topsent, 1892)	En	2.00	0.17
	Tedaniidae	*Tedania anhelans* (Lieberkuhn, 1859)	Lb	26.67	10.33
	Myxilidae	*Myxilla* (*Myxilla*) *rosacea* (Lieberkuhn, 1859)	Cu	0.17	0.17
	Crambeidae	*Crambe crambe* (Schmidt, 1862)	En	10.00	3.00
	Coleosphaeridae	*Lissodendoryx isodictyalis* (Carter, 1882)	En	0.17	0.00
	Hymedesmiidae	*Hymedesmia peachi* (Bowerbank, 1882)	En	0.50	0.00
		Hymedesmia versicolor (Topsent, 1893)	En	0.33	0.00
		Phorbas paupertas (Bowerbank, 1866)	En	0.33	0.00
	Mycalidae	*Mycale* (*Aegagropila*) *rotalis* (Bowerbank, 1874)	En	0.50	0.33
		Mycale (*Aegagropila*) *contarenii* (Martens, 1824)	Cu	7.67	0.50
		Mycale (*Carmia*) *macilenta* (Bowerbank, 1866)	En	0.33	0.00
		Mycale (*Mycale*) *massa* (Schmidt, 1862)	Ms	21.33	2.67
		Stylinos stuposa (Esper, 1794)	Lb	2.33	0.33
		Stylinos tenellula (Pulitzer-Finali, 1983)	Lb	0.83	0.00
Haplosclerida (3)	Chalinidae	*Haliclona cinerea* (Grant, 1827)	Lb	1.00	1.17
		Haliclona elegans (Bowerbank, 1866)	Lb	6.00	2.67
		Haliclona fibulata (Schmidt, 1862)	Lb	3.50	0.17
		Haliclona implexa (Schmidt, 1868)	Bc	0.50	0.67
		Haliclona mucosa (Griessinger, 1971)	Lb	0.00	0.17
		Haliclona simulans (Johnston, 1812)	Bc	12.00	3.33
		Haliclona subtilis (Griessinger, 1971)	Bc	1.17	2.33
	Phloeodictyidae	*Ocenapia fistulosa* (Bowerbank, 1866)	Lb	0.83	0.67
	Petrosiidae	*Petrosia ficiformis* (Poiret, 1789)	Ms	6.00	0.33
Dictyoceratida (3)	Spongiidae	*Hippospongia communis* (Lamarck, 1813)	Ms	0.17	0.17
		Spongia officinalis (Schmidt, 1862)	Ms	6.00	0.67
		Spongia virgultosa (Schmidt, 1868)	Lb	1.33	1.50
		Spongia zimocca (Schmidt, 1868)	Lb	0.50	0.50
	Thorectidae	*Cacospongia scalaris* (Schmidt, 1862)	Ms	1.67	1.00
	Irciniidae	*Ircinia variabilis* (Schmidt, 1862)	Ms	5.33	2.67
		Sarcotragus foetida (Schmidt, 1862)	Ms	0.50	0.00
Dendroceratida (3)	Dysideidae	*Dysidea fragilis* (Montague, 1818)	Lb	6.00	2.67
		Dysidea incrustans (Schmidt, 1862)	En	0.17	0.00
Halisarcida (3)	Halisarcidae	*Halisarca dujardinii* (Johnston, 1862)	En	0.67	0.67
Verongida (3)	Aplysinidae	*Aplysina aerophoba* (Schmidt, 1862)	Lb	6.00	1.50
		Aplysina cavernicola (Vacelet, 1959)	Lb	1.67	0.33

*The most common form of sponge species in the Gulf of Kalloni (Bc, branching creeping; Be, branching erect; Cu, cushion shape; Ec, Excavating; En, encrusting; Lb, lobose; Ms, massive).

Figure 3. *R. viminalis* fragments caught in the Gulf of Kalloni before dredging (1998).

unaffected, erect branching species (e.g. *R. viminalis*) were sensitive to dredging. Adverse effects were also observed on the small excavating *C. celata* that could be partly attributed to a decline in the occurrence of bivalves, which provide a suitable substratum for this infaunal species. A significant mortality of large-sized, but not robust, species by bottom-fishing activities has been previously shown in other benthic populations (Ball *et al.*, 2000; Bergman and van Santbrink, 2000).

However, the response of sponge species to bottom fishing can not be described so simply. Small cushion-shaped sponges usually grow on unstable parts of the substratum (stones, shells, etc.), and encrusting species build a thin surface layer on the seabed. These sponges can be easily turned over or covered as a result of redistribution and suspension of surface sediments. Present results showed evidence of considerable impact due to this mechanical disturbance. The decrease in the population of some encrusting (e.g. *Crambe* and *Clathria*) and cushion-shaped (*M. contarenii* and *C. nuculla*) sponges after dredging is indicative of mortality occurring within the seabed. The consequences of this mechanical disturbance may be of great biological significance in terms of energy flow. Moreover, some of these sponges (e.g. *C. crambe*) have symbiotic organisms, such as Cyanophyceae, whose photosynthesis is inhibited if they are covered. The indirect mortality, as a result of redistribution and suspension of substratum, has been previously mentioned for small infaunal invertebrates and sensitive filter-feeding species (Hill *et al.*, 1999; Ball *et al.*, 2000). Bergman and van Santbrink (2000) also referred that the lack of light due to scallop dredging seems to affect maerl habitats, whose integrity depends upon the survival of a surface layer of algae.

The tremendous increase in the abundance of *S. massa* after dredging activities can be related to the general concept that some species benefit when structural complexity of benthic communities is reduced by bottom fishing (Pravoni *et al.*, 1998).

Scallop dredging exerted adverse effects on the biodiversity of sponge assemblages in the Gulf of Kalloni, since all the indices related to the species diversity decreased. Previous studies (Hill *et al.*, 1999) have also referred that benthic communities of undisturbed sites by bottom fishing had higher species richness and diversity.

Multivariate analysis of the faunistic data revealed detrimental effects of scallop dredging on the structure of epibenthic sponge assemblages. The scattering of stations within each group probably reflects mainly local variations in depth during the first survey and in fishing effort during

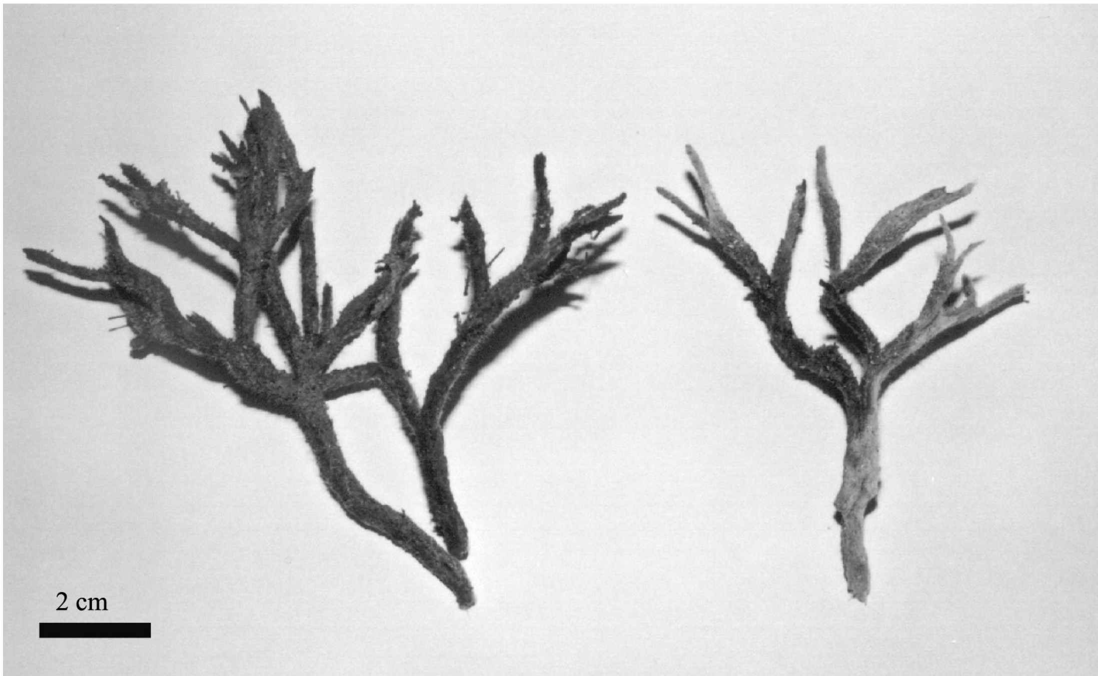

Figure 4. *R. viminalis* fragments caught in the Gulf of Kalloni after dredging (1999).

the second survey, as has been observed in other studies (Kaiser *et al.*, 1998; Piet *et al.*, 2000). A clear discrimination of samples collected in the two consecutive periods was revealed when analysis was performed at species level, with *S. massa* being the best distinguishing species. No significant loss of information was found, however, when multivariate analyses were applied to data on genera or families, although the increase in the abundance of *S. massa* was obscured by the decrease in the population of other species belonging to the same genus or family. This finding may greatly assist monitoring programmes for the assessment of bottom-fishing effects on epibenthic organisms, since the identification of species, even of genera, in Porifera is rather complex.

Sponges can grow after fragmentation, because of their ability to regenerate viable individuals from fragments (Bergquist, 1978). However, the current study demonstrated that the time interval between two consecutive fishing periods of scallops was insufficient for the recovery of sponge assemblages after intensive ‘‘lagamna’’ fishing in the Gulf of Kalloni. Cropper and DiResta (1990) found a long-term decline in a sponge population attributed to poor recruitment and significant vulnerability to harvesting. Another critical limitation may be the lowering in the density of breeding animals caused by fishing, since sponges are broadcast spawners, and in order to ensure fertilization, males and females must be surprisingly close together when they spawn (Dayton, 1996). Present

Table 2. Comparison (paired t-test) of some univariate indices of sponge assemblages at six stations surveyed in 1998 (previously unfished) and in 1999 (previously fished).

	1998		1999		
	Mean	s.d.	Mean	s.d.	p
Total number of species	33.50[a]	7.287	23.50[b]	7.120	0.0000
Total number of individuals	284.50[a]	89.509	129.83[b]	33.790	0.0019
Species diversity (H′)	2.90[a]	0.211	2.21[b]	0.494	0.0026
Species richness (D)	4.08[a]	0.638	3.20[b]	0.860	0.0005
Eveness (J)	0.83[a]	0.030	0.70[b]	0.100	0.0129

Means with different letter in superscript are significantly different.

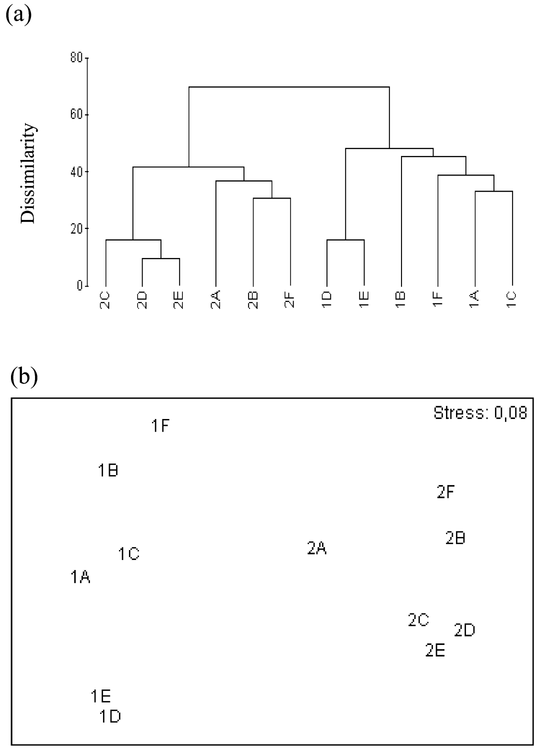

Figure 5. Bray–Curtis dissimilarity indices of sponge species abundance at six stations surveyed during the first (1A–1F) and second (2A–AF) surveys. (a) Dendogram using group averaged clustering. (b) MDS ordination.

observations referred to the changes in sponge assemblages between two consecutive fishing periods in an area previously closed to scallop dredging for several years. However, adverse long-term effects on sponge assemblages can be anticipated, since the major impacts of towed demersal fisheries occur the first time an area is subjected to fishing pressure (Hall-Spencer and Moore, 2000). Long-term changes due to bottom fishing have also been detected in benthic species with similar life-history characteristics, such as late reproduction, low reproductive rate and high longevity (Hall-Spencer and Moore, 2000; Piet *et al.*, 2000).

The results of this study revealed that scallop dredging causes long-term changes in the structure and biodiversity of sponge assemblages in the Gulf of Kalloni. The changes observed in these structural organisms reflect the degradation in the whole benthic community with possible implications on the survivorship and recruitment of juvenile commercial species (Kaiser *et al.*, 1998), as well as on the protection of the large bivalve *Pinna nobilis* (EC Habitats Directive, 1992). Hence, a better strategy of fishery management is required in future for the conservation of benthic habitat in this Gulf that would minimize catches of non-target animals while maintaining catches of target species. Encouraging results have been obtained in other heavily dredged areas by designating portions of them as habitat areas of particular concern (Hoffmann and Dolmer, 2000).

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