Preliminary observations on a dense population of *Phyllochaetopterus socialis* Claparède at the sulphurous water boundary in a Mediterranean submarine cave

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ABSTRACT

The Grotta Sulfurea (Sulphurous Cave) at Capo Palinuro, southern Tyrrhenian Sea, is characterised by the presence of springs of sulphide-rich water. The issuing water accumulates below the roof of the cave and supports thick mats of *Beggiatoa* -type sulphur bacteria. A dense assemblage of *Phyllochaetopterus socialis* was found in the inner part of the cave, where the sulphurous water extends to the bottom. Specimens showed peculiar morphological features. They occurred immediately below the sulphurous boundary and their tubes extended into the sulphurous water. There was a thick layer of filamentous sulphur bacteria on the tubes. The abundance of the *P. socialis* assemblage in the Grotta Sulfurea appeared to be related to the presence of the sulphide springs and the growth of sulphur bacteria. Preliminary results of stable carbon isotope analyses on *P. socialis* support the hypothesis that most of the worm's carbon comes from bacteria.

RÉSUMÉ

Observations préliminaires sur des populations denses de *Phyllochaetopterus socialis* Claparède à la limite des eaux sulfureuses dans une grotte sous-marine méditerranéenne

La grotte "Grotta Sulfurea" (Cap Palinuro, Mer Tyrrhénienne méridionale) est caractérisée par une circulation d'eau riche en sulfures qui s'accumule au-dessous de la voute de la grotte et permet le développement d'une épaisse couche de bactéries chimiosynthétiques. Dans la partie la plus interne, où le fond de la grotte remonte au niveau de l'eau sulfureuse, un peuplement dense à *Phyllochaetopterus socialis* a été découvert. Les individus vivent immédiatement en dessous des eaux sulfureuses; leurs tubes sont recouverts de bactéries. On pense que la forte densité du peuplement à *P. socialis* est en relation avec la présence de la source sulfureuse. Les résultats préliminaires de l'analyse des sources de carbone sur *P. socialis* confirment cette hypothèse.

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INTRODUCTION

The biological communities inhabiting hydrothermal vents at mid-ocean ridges have been studied intensively in recent years (DESBRUYÈRES *et al.*, 1985; GRASSLE, 1985; JANNASCH, 1985; SOUTHWARD, 1989; TUNNICLIFFE, 1991; CHILDRESS & FISHER, 1992). Hydrothermal environments that occur in shallow-water provide an opportunity to study such complex systems at sites with easier access than mid-ocean ridges (TARASOV *et al.*, 1990). We carried out preliminary surveys of a marine cave system at Capo Palinuro (southern Tyrrhenian Sea) in connection with an international co-operative study devoted to shallow-water hydrothermal communities. This system includes several caves characterised by the presence of underwater sulphurous springs (ABBIATI *et al.*, 1992) which support dense mats of *Beggiatoa*-like sulphur bacteria. During our surveys a dense assemblage of the tube-dwelling chaetopterid polychaete *Phyllochaetopterus socialis* Claparède was found in the Grotta Sulfurea where it occurred at the boundary between sulphurous water and sea-water.

Submarine caves are usually considered to be oligotrophic environments with reduced fauna and flora and low biomass (OTT & SVOBODA, 1976; HARMELIN *et al.*, 1985; FICHEZ, 1990). The abundance of *P. socialis* in the Grotta Sulfurea appeared unusual. It was hypothesized that this abundance was related to bacterial chemosynthetic production which was supplementing the meagre input from photosynthetic sources. Investigations are in progress to verify this hypothesis and to study the complex trophisms of the Grotta Sulfurea and similar sulphurous caves.

The abiotic and biological features of the cave and the morphological variability and possible food sources of *P. socialis* are presented in this paper.

ECOLOGY AND DISTRIBUTION OF *PHYLLOCHAETOPTERUS SOCIALIS*

Phyllochaetopterus socialis Claparède 1868 is a gregarious species belonging to the family Chaetopteridae. In the original description from the Gulf of Naples CLAPARÈDE (1868) pointed out that it occurred in high densities and considered it to be the most abundant polychaete in the Gulf of Naples. *P. socialis* occurs from 10 m to more than 300 m in depth on different substrates (muddy bottoms, organogenic sand and hard bottoms) where it often forms dense mats. It has been reported from several different geographical regions: Mediterranean Sea (FAUVEL, 1927; BELLAN, 1964; LAUBIER, 1966; REYSS, 1971; BHAUD, 1974, 1977; BHAUD & AMOUROUX, 1975), Atlantic Ocean (DAY, 1967, 1973; Mc CARTY, 1974; GETTLESON *et al.*, 1985), Pacific Ocean (GIBBS, 1971), Indian Ocean (DAY, 1967). This wide geographic and bathymetric distribution indicates a cosmopolitan species (GETTLESON *et al.*, 1985) although there are questions concerning the validity of some records (BHAUD, 1977).

MATERIAL AND METHODS

STUDY SITE. — The Grotta Sulfurea is located at Capo Palinuro (southern Tyrrhenian Sea) (Fig. 1). It is a narrow sloping tunnel that opens into carboniferous rocks. It is characterised by the presence of springs of sulphide-rich water, normally warmer than ambient sea-water and of lesser salinity. This less dense water accumulates below the roof of the cave giving rise to a thermal oxic-anoxic interface. Preliminary data on the speleological characteristics of the cave are reported by MUSCIO (1985) and MUSCIO & SELLO (1989).

SAMPLING METHODS. — The Grotta Sulfurea cave was sampled in May 1991 and May 1992 by SCUBA diving. A detailed survey of the cave as far as 40 m inside the entrance was carried out following the procedures of ALVISI (1991). A permanent 40 m long transect was established by means of a tape line. Changes in the composition and richness of the biological community along the transect were investigated by visual and photographic surveys. Outside-inside light gradient was measured by means of an irradiance meter (Biospherical Instruments Inc., QSI 140). Temperature and salinity vertical gradients across the sulphurous water boundary were surveyed at point D (Fig. 1). Temperature was measured from 5.5 to 9.5 m in depth by means of an underwater digital thermometer (Idronaut Srl). Water samples for salinity measurement were collected across the sulphurous water boundary by means of eight 20 ml syringes spaced every 15 cm on a one meter long Plexiglas bar. Salinity of the samples was estimated from readings of a portable sodium electrode (Horiba Compact Salt Meter, C-121). Dissolved sulphide in water samples from the sulphurous layer was estimated by the method of CLINE (1969). Specimens of *P. socialis* were collected and fixed in buffered 4 % formalin for later analysis. Other

specimens and samples of the bacterial mats were treated with 10 % HCl, dried at 50 °C and powdered for stable carbon isotope analysis.

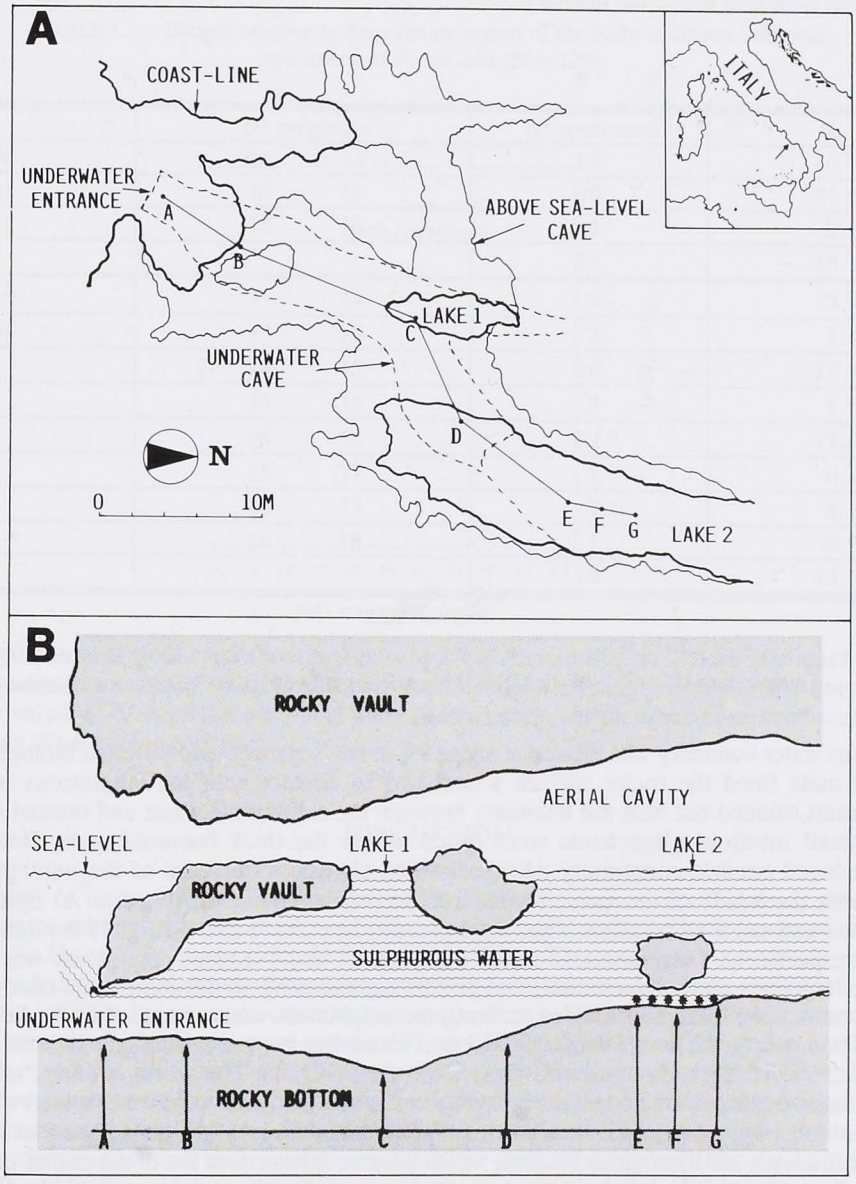

FIG. 1. — Location of Grotta Sulfurea cave (Tyrrhenian Sea, Italy). A, plan of the cave and location of the transect. B, longitudinal section of the cave (plotted along points A, B, C, D, E, F, G).*P. socialis* assemblage (asterisks) occurs at points E, F and G.

RESULTS

The peculiarity of the Grotta Sulfurea is the occurrence of sulphide-rich waters. The source of the sulphurous spring outlets was not determined since they arise in the innermost part of the cave which is difficult and dangerous to explore. The sulphurous water, which was lower in density than normal sea-water, accumulated

below the vault of the cave (Fig. 1,B). The temperature and salinity measurements across the sulphurous-water/sea-water interface indicated a sharp thermo- chemocline. Temperature and salinity values ranged from 18.7 °C and 36.5 P.S.U. to 25.9 °C and 30 P.S.U. in the sea-water and in the sulphurous water, respectively (Fig. 2). Preliminary analyses of the sulphurous water in May 1992 indicated millimolar levels of dissolved sulphide compared with zero below the interface.

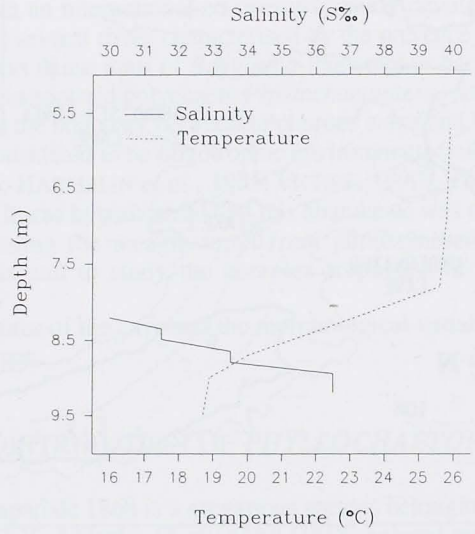

FIG. 2. — Temperature (°C) and salinity (P.S.U.) vertical gradients at the sulphurous boundary level.

The sulphurous water boundary was located at about 8.7 m and separated two different biological assemblages. White bacterial mats lined the rocky surface which was in contact with the sulphurous water. The thick *Beggiatoa*-like mats thinned out near the boundary between the sulphurous water and normal sea-water. Large numbers of a small tubificid oligochaete were found within the thick bacterial mats. Below the thermo-chemocline a reduced benthic community occurred which showed a decrease of the number of species and specimens towards the inside of the cave. At the entrance of the cave (Fig. 1, point A) light was 3.88 E 14 quanta. cm^{-2}. sec^{-1} and crustose coralline algae were present. At point B and C (Fig. 1) the light was reduced to 5 % and to 1%, respectively. Total darkness occurred at point D, and a reduced community was observed on the walls of the cave (sponges and scleractinians) and bottom (ophiuroids). In the completely dark inner part of the tunnel (Fig. 1, points E, F, G) at about 8.7 m in depth the sulphurous water extended to the bottom. Just to the seaward of this level, where the tunnel deepened and the chemocline began to lift off the bottom, there were thick aggregates of *P. socialis* on the bottom and sides of the cave (Fig. 1). The worm colonies were composed of several hundred individuals and covered all the boundary belt where the sulphurous water mixed with the sea-water. The tubes were about 10 cm long, and the worm's tentacles extended just into the sulphurous water. The tubes were covered with a layer of filamentous bacteria which became thicker near the distal end of the tubes. Beyond point G (Fig. 1) the walls and the bottom were completely covered by bacterial mats inhabited by oligochaetes. One specimen of the anthozoan *Alicia mirabilis* was found on the bottom.

Morphological analysis of the specimens agreed with the original description of *P. socialis* (CLAPARÈDE, 1868) and with the redescription by BHAUD & AMOUROUX (1975) and BHAUD (1977). *P. socialis* is characterised by one stout specialised seta on setiger IV. The morphology of the modified seta agreed with the description by BHAUD (1977: 210, Fig. 1c-d). However, variability in the number of the stout setae was observed in the Grotta Sulfurea specimens; a few individuals (about 5 %) had two stout setae at the setiger IV or one stout setae in both the setigers IV and V. When two setae were present in the same segment, the second seta appeared slightly thinner and longer than the typical one. The number of setigers in the anterior region of *P. socialis* ranges from 10 to 18 with 13-14 usually present (FAUVEL, 1927; DAY, 1967; BHAUD & AMOUROUX, 1975). In the population the

number of setigers ranged from 13 to 18 with 15 the most common. About 60% of the individuals had a different number of setigers on the left and right side of the body (Table 1). The number of setigers in the posterior region of the body ranged from 10 to 20 which agreed with previous descriptions (CLAPARÈDE, 1868; FAUVEL, 1927; DAY, 1967; BHAUD & AMOUROUX, 1975).

TABLE 1. — Setiger number in the anterior region of the body in Grotta Sulfurea specimens of *P. socialis* (N = 129)

	N° parapodia		N° specimens	%
Symmetric	14	14	14	10.8
specimens	15	15	40	31.0
	16	16	5	3.9
Total			59	45.7
Asymmetric	13	14	5	3.9
specimens	13	15	2	1.6
	14	15	30	23.2
	14	16	2	1.6
	15	16	22	17.0
	15	17	1	0.8
	16	17	7	5.5
	16	18	1	0.8
Total			70	54.3

Carbon isotope analyses were carried out in Texas by Dr M.C. KENNICUTT. There was much depletion of the heavy isotope in the tissues of *P. socialis*, and a similar depletion was shown by the bacterial mats. The similarity of the values (^{13}C depletions of -30.1 and -30.9, as parts per thousand compared with the usual PDB standard) indicates close trophic coupling.

DISCUSSION

The high density of *P. socialis* in the inner part of the Grotta Sulfurea is unusual for a submarine cave. As already noted, typical submarine caves show a reduction in the biota along a gradient from outside to inside (OTT & SVOBODA, 1976; HARMELIN *et al.*, 1985; FICHEZ, 1990, 1991). This decrease corresponds to the decrease in photosynthetic production and of penetration of food particles from the sea. This biological gradient was noted on substrata in contact with the sea-water. In contrast, surfaces washed by the sulphurous water were covered by thick mats of sulphur bacteria. The bacteria were mostly different kinds of the genus *Beggiatoa* and contained much elemental sulphur which is typical for the group. The preliminary assumption is that there is high chemoautotrophic production by the bacteria which use energy obtained by oxidation of sulphide.

We can presume that the high biomass of *P. socialis* is related to the bacterial production which provides a food source. The abundant biota at other deep sea and shallow-water hydrothermal habitats are also supported by chemoautotrophic production either by free-living bacteria or by symbiotic bacteria, based on the mixing of vent water containing reduced sulphur with oxygenated sea-water (SOUTHWARD, 1987; FISHER, 1990; CHILDRESS & FISHER, 1992). In the Grotta Sulfurea the localised position of the colonies of *P. socialis* in the transition zone between the sulphurous water and sea-water points to the need for a combination of the same extremes - reduced sulphur and oxygen - for sustenance. The stable carbon isotope values indicate that the bacteria provide the main or only food source for *P. socialis*; however, it is not yet clear exactly how the worms feed on the bacteria.

The Grotta Sulfurea population of *P. socialis* showed considerable morphological variation. The specialized stout setae on the setiger IV is one of the primary taxonomic characters in *P. socialis*. It is considered to be unaffected by morphological variations in relation to different geographic localities (BHAUD, 1977). The variability in the number of stout setae and the asymmetry of the number of parapodia in the anterior region is a

peculiar feature of Grotta Sulfurea specimens. The cause of such a high morphological variability is unknown. However, enhanced levels of morphological variation have been reported for polychaetes from physically-stressed environments (ZUNARELLI VANDINI, 1971; COGNETTI, 1978).

Vent ecosystems are characterised by sharp temperature and salinity gradients and high concentrations of toxic compounds (CHILDRESS & FISHER, 1992). The occurrence of *P. socialis* population in this extreme environment suggests a high adaptive capability of this species. However, many marine polychaetes with wide ecological distribution have been demonstrated to be complexes of species (GRASSLE & GRASSLE, 1976; GUÉRIN & KERAMBRUN, 1984; ABBIATI, 1989). The same condition may be occurring in *P. socialis* as in these other species.

Further studies are in progress on the ecology and population genetics of *P. socialis*, and on the role of chemosynthesis in the trophic webs of the Grotta Sulfurea and other sulphurous caves at Capo Palinuro (ABBIATI *et al.*, 1992).

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