TROPHIC STRUCTURE IN AN AQUATIC TROGLOBITIC COMMUNITY BASED UPON CHEMOAUTOTROPHIC CARBON FIXATION

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The trophic relations between aquatic troglobites that inhabit a thermomineral sulfurous cave are analysed. The "Peştera de la Movile" Cave (Dobrogea, Romania) contains a rich sulfur-based chemoautotrophic microbiota. The trophic preferences of the aquatic troglobites are studied and the trophic levels of the community are described: producers, primary consumers, predators and decomposers. A scheme of the suppositional aquatic trophic chain is presented, encompassing representatives of all trophic levels.

INTRODUCTION

The "Peştera de la Movile" Cave is located in Southern Dobrogea, 3 km from the Black Sea shore (Constantinescu, 1989). The cave consists of a network of dry and submerged passages developed in Sarmatian limestones[1] (Lascu, 1989). The presence of mesothermal sulfurous waters[2] in the lower level of the cave created conditions for the existence of a unique troglobiotic community with a characteristic trophic structure which feeds upon the cave's rich chemoautotrophic microbiota (Lascu and Sârbu, 1987; Sârbu, 1990).

Both the aquatic and terrestrial faunas discovered in the cave are very rich and unusual (Sârbu, 1991). Thorough collections in the submerged level of the cave permitted the identification of a rich aquatic fauna and led to the discovery of three new taxa (Grossu and Negrea, 1989; Pleşa, 1989; Sârbu, 1990; 1991).

The trophic structure of the aquatic troglobiotic community of the "Peştera de la Movile" cave was analysed in an effort to better understand the ecology and evolution of the subterranean fauna associated with the extensive phreatic reservoir of thermomineral water present in southern Dobrogea. The ecology and the origin of the terrestrial troglobiotic community are currently being studied and will represent the object of a future publication.

METHODS

Qualitative and quantitatives samples were harvested in the lower level of the "Peştera de la Movile" Cave between August 1990 and March 1991. Dip nets. plankton nets, and suction bottles were used for qualita-

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[1] The lumachelle limestones hosting the "Peştera de la Movile" Cave were deposited in the brackish epicontinental sea that covered southern Dobrogea during the Sarmatian transgression (13 million years ago) (Lascu, 1989).

[2] The water temperature in the Movile Cave is 20—21° C and the concentration of H_2S is 7—30 mg/l (Boghean and Racoviţa, 1989; Sârbu, 1991).

tive sampling, permitting the identification of the various species present in the aquatic community. The quantitative sampling was done with Patalas apparatus.

The trophic spectrum of isopods and amphipods was determined each time by analysing [3] gut contents (Swynnerton and Worthington, 1940; Frost, 1943; Hynes, 1950). Observations regarding the foraging behaviour of some of the invertebrates (e.g. Hirudinea, Heteroptera) were made in the cave and in laboratory in order to determine what they feed upon. Microscopic observation of the ingested food was possible in the small sized species that have a transparent body (e.g. Nematoda, Oligochaeta, Rotatoria, Harpacticoida, Cyclopoida). Information from the literature was used for some of the taxa.

RESULTS AND DISCUSSION

Abundant and diverse communities of microbes, protistans and invertebrates are present in the lower level of the "Peştera de la Movile" Cave, despite the absence of an input of food from the surface. The cave has no natural entrance to permit a direct input of vegetal or animal detritus (i.e. logs, leaves, guano, etc.). Additionally, the thermomineral water flowing through the cave comes from a very deep aquifer (Lascu, 1989; Sârbu, 1991) and contains no dissolved organic carbon.

A characteristic of this cave is the presence of floating microbial mats that cover the water surface in the air bells of the submerged gallery (Sârbu et al., 1991). The mats are 1—2 mm thick, soft, have a brown color, and are kept afloat by gas bubbles (probably CO_2 and H_2S).

The limestone walls of the air bells are covered by an organic layer that resembles the floating microbial mats. The walls of the submerged cave passage are covered by a thin black deposit, the result of the activity of anaerobic microbes.

The identification of the species of microbes living in the watercolumn, in the sediment, and in the microbial mats is currently being conducted. Initial investigations indicate that the bacteria inhabiting this cave belong to three ecological groups : heterotrophs, aerobic chemoautotrophs (e.g., *Beggiatoa sp.*), and anaerobic chemoautotrophs. The aerobic and anaerobic sulfur-oxidizing chemoautotrophic bacteria wich represent the primary producers in this system, are present in the floating microbial mats, in the detritus, and on the walls of the air bells, and are very rare in the water column. Heterotrophic microbes are present in the floating mats (where they occur together with various fungi) and in the sediment, and belong to the trophic category of decomposers.

The protistans present in the cave are flagellates and ciliates. The flagellates are very small (6 microns long) and live in the immediate vicinity of the microbial mats, but can be also found in smaller numbers in the water column. They probably feed upon detritus and bacteria (Lepsi, 1965; Zinevici and Teodorescu, 1985). The ciliates are abun-

[3] The taxa is expressed in % of the food volume found in the stomach of the examined specimens.

dant near the microbial mats. It is believed that they belong to two trophic levels: primary consumers feeding on bacteria and detritus (e.g., *Blepharisma undulans*, *Spirostomum teres*, *Cyclidium* sp., *Oxytricha* (?*falax*). *Paramoecium aurelia*, *Uronema marinum*, and *Drepanomonas* sp.); and secondary consumers that feed upon fagellates and small ciliates (e.g., *Euplotes curystomus*, *Stentor coeruleus*) (Lepsi, 1965; Bick, 1972; Fenchel, 1986; Anderson, 1987).

Seventeen species of aquatic troglobitic invertebrates have so far been identified in the cave (Table 1). With some exceptions (e.g. Heteroptera, Hirudinea), they belong to taxa that have previously been reported from subterranean environments (Dubouttteville, 1960; Ginet and Decou, 1977; Botoşăneanu, 1986). *Planaria* sp. seems to be carnivorous probably feeding upon rotifers, nematodes, snails and crustaceans. Very large numbers of nematodes are present in the floating mats. Microscopic examinations showed that they feed on detritus (mats) and bacteria, which is consistent with observations made in epigean aquatic systems (Edmondson and Winberg, 1971; Winberg, 1971). A few specimens are present in the sediment also. *Aeolosoma hyalinum* and *A. litorale* (Oligochaeta) live in the microbial mats feeding most likely on detritus and probably bacteria. *Haemopsis* n. sp. (Hirudinea) is a typical predatory organism that feeds on large terrestrial oligochaetes inhabiting the microbial layer wich cover the walls of the air bells, crustaceans, gastropods, and other invertebrates. *Habrothocha rosa* and *H. bidens* (Rotatoria) live under the microbial mats where they feed on bacteria and detritus (Rublee, personal communication). *Paladilhia dobrogica* is a small (3.6 mm long) gastropod present on the wet limestone walls at the edge of the water and sometimes 1—2 cm above the water level, despite the fact that is breathes through gills. The bentic sediments con-

Table 1

Aquatic invertebrates found in the "Peştera de la Movile" Cave

TURBELARIA	— *Planaria* sp.
NEMATODA	— gen. sp.
OLIGOCHAETA	— *Aeolosoma hyalinum*
	— *Aeolosoma litorale*
HIRUDINEA	— *Haemopsis* n.sp.
ROTATORIA	— *Habrotrocha rosa*
	— *Habrotrocha bidens*
GASTEROPODA	— *Paladilhia dobrogica* n.sp.
OSTRACODA	— *Pseudocandona* sp. aff. eremita
CYCLOPOIDA	— *Eucyclops subterraneus scythicus* n.ssp.
	— *Tropocyclops prasinus*
HARPACTICOIDA	— *Parapseudoleptomesochra italica*
AMPHIPODA	— *Niphargus dobrogicus*
	— *Niphargus* cf. *kochianus* n.sp.(?)
	— *Pontoniphargus racovitzai*
ISOPODA	— *Asellus aquaticus aquaticus*
HETEROPTERA	— *Nepa* n.sp.

tain only empty, partially decomposed shells. It is believed that this gastropod feeds on detritus (Grossu and Negrea, 1989). It is often found above the water level, where it avoids the high concentrations of H_2S. *Pseudocandona* sp. (Ostracoda) is a benthic species feeding on detritus (Danielopol, 1975). *Parapseudoleptomesochra italica* (Harpacticoida) is a necto-benthic species mostly found in holes that it bores the microbial mats. The examination by transparency of the intestinal content indicates that it feeds on detritus (mixed probably with bacteria). *P. italica* wich was described from brackish ponds in Italy, has not been found previously in Romania. *Eucyclops subterraneus scythicus* and *Tropocyclops prasinus* (Cyclopoida) swim close to the water surface (at a depth of 1–2 cm) or "rest" under the water surface. Our investigations indicate that their first larval stages (Nauplii and copepodites 1—3) are primary consumers that feed on bacteria and detritus, while the copepodites 4—5 and the adults are secondary consumers feeding on flagellates and ciliates. The results of our observations in this cave correspond to the results of similar studies in epigean communities (Zinevici and Teodorescu, 1985; Ricker, 1968). *Asellus aquaticus aquaticus* (Isopoda) is a benthic species that lives in small cracks and fissures in the limestone walls of the cave, in the immediate vicinity of the water surface, probably due to its preference for higher concentrations of oxygen. Its food consists of 93.8% detritus and 6.2% adult copepods. Two genera of amphipods are present in the cave: *Niphargus* and *Pontoniphargus*. The food of the two *Niphargus* species (*N. dobrogicus* and *N. kochianus*) consists of 47.5% detritus and bacteria and of 52.5% zooplancton (44.2% detritus. 3.3% Beggiatoa, 2.5% ciliates, 3.3% nematodes, and 46.7% copepods), whilst *P. racovitzai* feeds on detritus (41.6%), *Beggiatoa* (5%), ciliates (1.7%), and copepods (51.7%). *P. racovitzai* has been described from springs near the sea shore (Dancău, 1970) wich drain the thermomineral sulfurous phreatic reservoir located in the Mangalia region. *Nepa sp.* (Heteroptera, Nepidae) is a predator. It attacks large invertebrates (Isopods, Amphipods, etc.) consuming their haemolymph.

The analysis of the trophic preference of the various species inhabiting the "Peştera de la Movile" Cave permitted a representation of the trophic structure of the aquatic subterranean community (Table 2). Unlike the epigean communities where the producers are green plants and the detritus consists of dead leaves, branches, etc., in this subterranean community the producers (i.e. heterotrophic microbes) forming material mats on the surface of the water and on the walls of the cave, which represent the first compartment in the trophic pyramid. Thus separating detritivores from primary consumers it is difficult if not impossible, as they feed on both producers and detritus at the same time.

The energy flow in the aquatic community of the "Peştera de la Movile" Cave starts in the chemoautotrophic producers land passes through the detrital component either directly on through consumer components (Fig. 1). Respiration reduces the energy levels of all compartments.

The trophic network identified in the aquatic community of the "Peştera de la Movile" Cave (Fig. 2) is very complex compared to most aquatic hypogean communities. The largest biomass is contained in the

Table 2

Trophic structure of the aquatic community in the "Peştera de la Movile" Cave

SECODARY CONSUMERS

Heteroptera
Isopoda (6%): Amphipoda (aprox. 53%)
Hirudinea; Cyclopoida (Copepodites 4—5 &Adults)
Ciliata (predatory species): Turbellariata

DETRITIVORES AND PRIMARY CONSUMERS

Amphipoda (aprox. 47%)	Isopoda (94%)
Cyclopoida (Nauplii & Copepodites 1—3)	Harpacticoida
Gasteropoda	Ostracoda
Nematoda	Oligochaeta
Ciliata (detritivore species)	Rotatoria
Heterotrophic bacteria	Flagellata

PRODUCERS

Autotrophic aerobic bacteria
Autotrophic anaerobic bacteria

DETRITUS

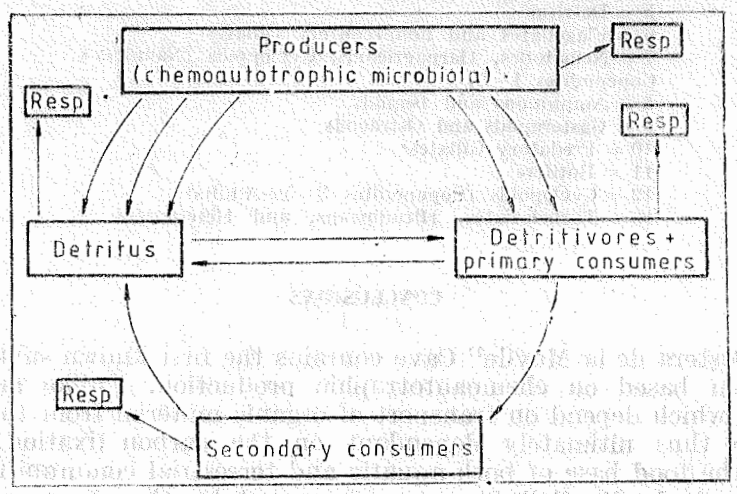

Fig. 1. — Energy flow in the aquatic community of the "Peştera de la Movile" Cave is presented using the schema proposed by W u l f et al. (1989). The figure represents the principal compartments and the main activity of each one.

microbial mats on the water surface and on the cave walls. Unlike the trophic networks of other subterranean ecosystems (D e l a y and J u b e r t h i e, 1981; G i n e t and D e c o u, 1977), the aquatic troglobitic community in the "Peştera de la Movile" Cave includes "in situ" microbial producers, able to use H_2S as an energy source for carbon fixation.

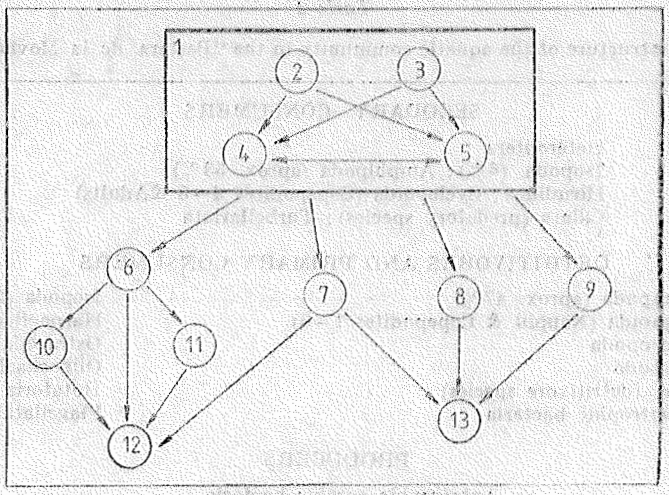

Fig. 2. — Schema of the trophic relations in the aquatic community of the "Peştera de la Movile" Cave.
1 = Microbial mats floating on the surface of the water
2 = Autotrophic anaerobic bacteria
3 = Autotrophic aerobic bacteria (Beggiatoa)
4 = Heterotrophic bacteria
5 = Detritus
6 = Flagellates and nonpredatory Ciliates
7 = Nematodes, Harpacticoids, Cyclopoids (Nauplius+Copepodites 1—3)
8 = Amphipods and Isopods
9 = Gasteropods and Ostracods
10 = Predatory Ciliates
11 = Rotifers
12 = Cyclopoids (Copepodites 3—5+Adults)
13 = Turbelariates, Hirudineans, and Heteroptera

CONCLUSIONS

"Peştera de la Movile" Cave contains the first known subterranean ecosystem based on chemoautotrophic production. Unlike most cave systems which depend on transport of organic material from the surface and are thus ultimately dependant on the carbon fixation in green plants, the food base of both aquatic and terrestrial communities of the "Peştera de la Movile" Cave is represented by the chemoautotrophic production of the microbiota, which uses H_2S as an energy source. Future research is intended to decipher the eco-physiology of this cave's unique troglobitic microbial community.

Detritivores and primary consumers cannot be separated in the aquatic community of the "Peştera de la Movile" Cave as they feed on both producers and detritus. Unlike the vast majority of cave communities that contain no producers and are thus oligotrophic systems, the large biomass of the microbial mats present in this cave supports rich aquatic and terrestrial communities characterized by very complex trophic networks.

The troglobitic community of the "Peştera de Movile" Cave resembles the deep sea communities associated with thermomineral vents wich are also based on chemoautotrophic production (with H_2S) and consists of very unusual faunas (E d m o n d and D a m m , 1983; C h i l d r e s s et al., 1989). Thus the "Peştera de la Movile" Cave may serve as a model system to understand the functioning of these chemoautotrophic systems wich are less accessible and therefore less amenable to experimental work.

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