

## Mysids from a submarine cave emerge each night to feed\*

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**SUMMARY:** The nycthemeral migration of *Hemimysis speluncola* Ledoyer (1963) (Crustacea: Mysidacea) from a western Mediterranean cave to the open sea was studied in July and September 1985 and September 1986. Light was the initiating factor. Feeding is the main activity outside the cave. A mixture of assorted small organisms and detritus makes up the mysids diet.

**Key words:** Migration, mysids, *Hemimysis speluncola*, diel cycle, gut contents, submarine caves.

**RESUMEN:** MISIDÁCEOS DE UNA GRUTA SUBMARINA EMERGEN CADA NOCHE PARA ALIMENTARSE. — Se ha estudiado la migración nocturna de *Hemimysis speluncola* Ledoyer (1963) (Crustacea: Mysidacea) de una cueva del Mediterráneo Occidental al exterior durante julio y septiembre de 1985 y septiembre de 1986. La luz era el factor desencadenante de la migración. La alimentación era la principal actividad fuera de la cueva. Una mezcla de diversos pequeños organismos y de detritos constituye la dieta de los misidáceos.

**Palabras clave:** Migración, misidáceos, *Hemimysis speluncola*, ciclo diario, contenido estomacal, cuevas submarinas.

### INTRODUCTION

Mysids have been reported to occur in great abundance in some submarine caves from the western Mediterranean Sea (LEDOYER, 1963; MACQUART-MOULIN and PATRITI, 1966; MACQUART-MOULIN, 1979). *Hemimysis speluncola*, Ledoyer 1963, one of the most abundant mysid species seems to migrate each night outside the caves and return at dawn. This migratory pattern was proposed on the basis of indirect evidences provided by vertical plankton catches near the cave mouths (MACQUART-MOULIN and PASSELAIGUE, 1982; PASSELAIGUE and BOURDILLON, 1985). But no direct evidences has been reported from cave interiors of the cave. What happens inside the cave at night? Is it true that all mysid swarms leave the caves

or do we remain behind? The special configuration of a small cave in Medes Islands (Catalonia; western Mediterranean) which is provided with both a terminal air-filled chamber and a wide chimney at the entrance to the open sea is an ideal situation to answer these questions.

The horizontal migration of *Hemimysis speluncola* Ledoyer 1963, resembles and is probably related to the vertical migration of zooplankton (LONGHURST, 1976). In this sense it may provide a useful control of previously proposed hypotheses on vertical migrations (HUTCHINSON, 1967; McLAREN, 1963; ENRIGHT, 1977) since it occurs in different environmental conditions. In the laboratory, *Hemimysis speluncola* movements have been showed to respond to light intensity (MACQUART-MOULIN, 1979; BOURDILLON *et al.*, 1980), but nothing has been reported about the ultimate causes of these migrations. The expected explanation —a food-related migration—

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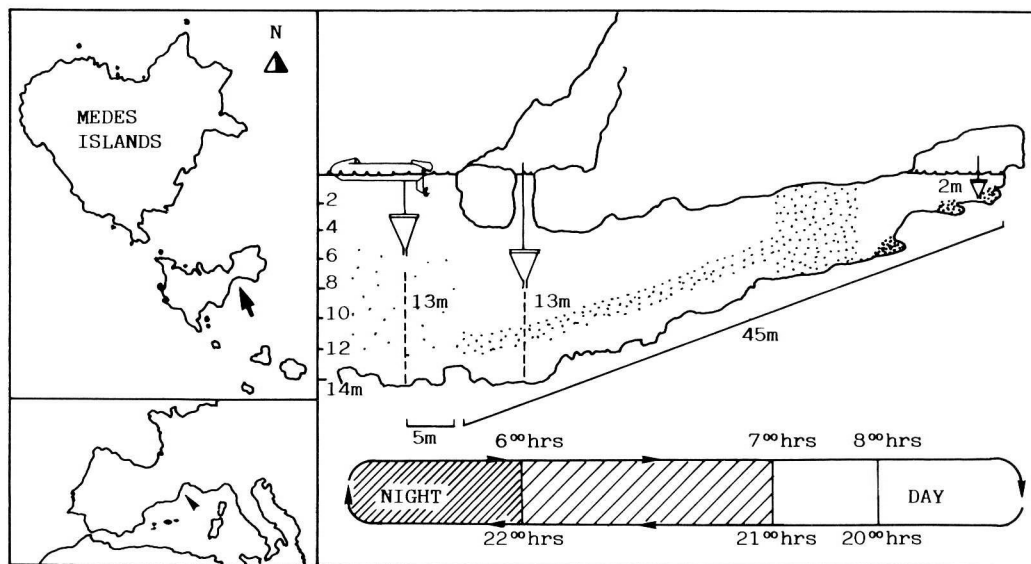


FIG. 1. — Sketch of study cave. A) General location in the western Mediterranean. B) Medes Islands site. C) Diagrammatic section showing sampling points and positions of *Hemimysis spelunco-la* as a function of time of day. During the light period, *Hemimysis spelunco-la* remained in the innermost part of the cave, the whole population being divided in a sparse array of very dense swarms. Migration movements start with decreasing light intensity by regrouping of small swarms in a single large swarm. During a period of 1/2 h to 1 h the mysids occupied the entire back part of the cave. After this sequence, the mysids form a long column throughout the length of the cave, moving to the exit close to the walls. They overnight in the vicinity of the cave mouth. As the sun rises, this migration pattern is reversed.

can be easily checked in the same cave, by studying the gut fullness of individuals caught at different sites (inside and outside the cave) and different times throughout a 24 h cycle.

The present results confirm the validity of the migrational pattern previously described; they demonstrate also that this migration is undertaken for feeding purposes. In a further work we try to demonstrate that *Hemimysis spelunco-la* migrations contribute greatly to the exchange of materials and energy between this submarine cave and outside waters.

## MATERIALS AND METHODS

### *The site*

Sampling was carried out in a western Mediterranean cave in Medes Islands (Costa Brava, Catalonia, Spain) during July and September 1985 and September 1986.

The cave is a karstic hole, roughly cylindrical in shape, less than 50 m long, 4-7 m in diameter, about 756 m<sup>3</sup> in volume (GILI *et al.*, 1986). It opens to the East side of the Meda Petita Island between 8 (upper) and 12 (lower) m depth. For 35 m from the entrance the "tube" runs straight E-W and rises slowly (the boulder-rocky bottom rises from 12 m depth to 6 m). The inner 10 m are characterized by a turn to

the N (45°) followed by a sudden increase in bottom slope, which rises from 6 m depth to reach sea level just at the end of the cave where an air-filled room develops (Fig. 1). Light penetration in the cave displays a sharp gradient, 99 % of PAR disappearing within the first 10 m from the opening (GILI *et al.*, 1986).

### *Methods*

A 13 m<sup>3</sup> water column was sampled with a zooplankton net (250 µm mesh) in the back, the middle, and the mouth of the cave every 2 h throughout a 24 h period, and all individuals of *Hemimysis spelunco-la* were sorted out and counted (often more than 2000 individuals per sampling; Fig. 2).

Gut condition (full/empty) of more than 200 individuals was determined on each occasion. For full guts, the number and position of the segments containing food were also recorded. Replete individuals were maintained alive, and their evacuation rates were recorded over a period of 2 h. The contents of the fecal pellets were observed under the microscope; chlorophyll content was determined by standard methods (STRICKLAND and PARSONS, 1968; ZIEGLER and EGLE, 1965). Chromatographic analysis were also carried out to ascertain the qualitative composition of the pigments (FALKOWSKI and SUCHER, 1981).

## RESULTS

### Gut fullness

During the light periode, *Hemimysis speluncola* remained in the innermost part of the cave, the whole population being divided into a sparse array of very dense swarms. Recent estimates assume that a single swarm can concentrate more than 1 million individuals, and the whole population of mysids inhabiting the cave ranges between one million (autumn) and fifteen million (spring-summer) (ZABALA *et al.*, in press). With decreasing light intensity, the mysids began to leave the cave, perhaps in response to an endogenous clock (BOURDILLON *et al.*, 1980). Migration movements start by the regrouping all small swarms (where mysids remained densely packed) in to one large swarm. The mysids are now somewhat regularly spaced and occupy the entire back part of the cave for a period of 1/2 h to 1 h. After this sequence, the mysids form a long column throughout the length of the cave, with higher densities close to its walls. As the

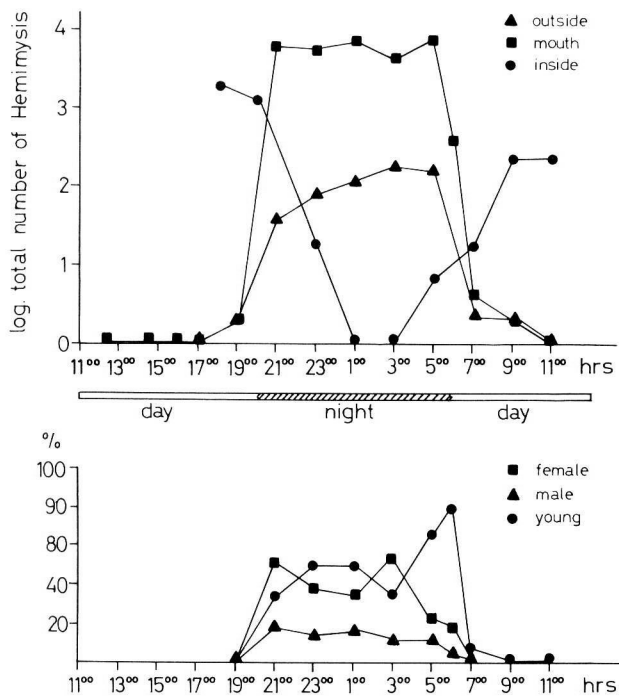


FIG. 2. — *Hemimysis speluncola*. A) Total number of mysids collected at different times of day inside the cave, in the cave mouth, and outside. Differences in absolute values between catches inside and outside the cave result from both the different volumes of samples and changes in behavioural aggregation patterns: dense swarms inside, long caravans in the mouth and dispersed schools outside, as drawn in figure 1C. B) Percentage of juveniles and adults (males and females) in cave mouth as a function of time of day.

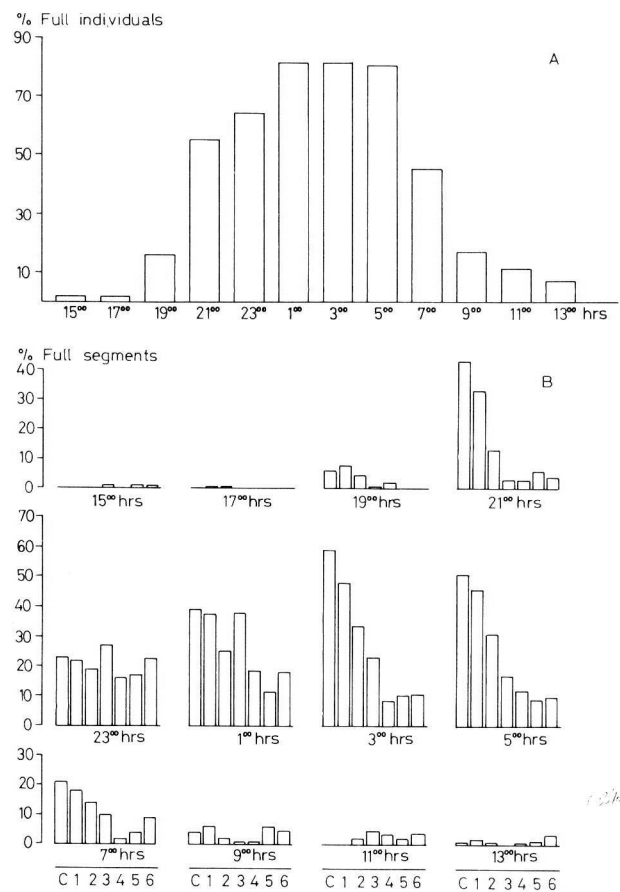


FIG. 3. — *Hemimysis speluncola*. A) Percentage of fed individuals (those with at least one full body segment) as a function of time of day. B) Percentage of fullness of each body segment as a function of time of day; C: cephalothorax; 1, 2, 3, 4, 5, 6: abdominal segments (more than 200 individuals per sampling occasion).

sun rises, this migration pattern is reversed (Fig. 2). The time taken to return to the cave (= 4 h) was only half that taken to leave the cave (= 8 h), probably reflecting a high sensitivity to light. Similar behaviour has been observed for this species in French Mediterranean caves (BOURDILLON *et al.*, 1980, MACQUART-MOULIN and PASSELAIGUE, 1982), and for other mysid species in this cave too (own observations) and in caves on Majorca Island (RIERA *et al.*, 1985). Adults were the first to leave and also the first to return. Juveniles left and returned later. Males and females displayed the same pattern although there were far fewer males than females (Fig. 2).

Upon leaving the cave at night, most mysids had empty guts (Fig. 3); they returned with full guts before daybreak. These results disagree with the report of MACQUART-MOULIN (1979) of a primarily diurnal

feeding pattern. In the early morning hours (03.00 hrs) when the mysids began to return, more full stomachs were observed in adults than in juveniles, possibly in accordance with differences in their migration behaviour (juveniles return later) (Fig. 2).

#### Gut-residence time

In order to calculate feeding rates and spatial and temporal fluctuations in feeding intensity, we determined the gut-residence times and their dependence of environmental conditions.

There are suggestions in the literature that the evacuation rates in mysids may be extremely variable (0.5 to 10 h: MURTHAUGH, 1984; RYBOCK, 1978), but these studies dealt with carnivorous species living under conditions of low prey density. This does not apply to our study cave, where detritus and phytoplankton are plentiful (GILI *et al.*, 1986; ZABALA *et al.*, 1989). Figure 3 shows the progressive filling of all body segments, beginning in the cephalic ones. Evacuation rates were high: within 2 h half the individuals with full guts had completely evacuated (Fig. 4). Analysis of degrees of fullness for the various segments revealed a 1 h passage/evacuation time for each segment (Fig. 4).

#### Food composition

Microscopic observation of the fecal pellets revealed a mass of macerated, degraded, and for the most part unidentifiable material. A few diatoms were present and, surprisingly, some sponge spicules. Since these spicules probably sink rapidly, with only a short residence time in the water column, this suggests that the mysids browse on the sponges. The fecal pellets suggest an important detritivorous component of feeding as described for many other mysid species (MAUCLINE, 1980). Nevertheless, phytoplankton also made up part of their diet. Gut chlorophyll content was  $5.4 (\pm 0.56 \text{ SE}; n = 9)$  mg Chl  $\text{g}^{-1}$  dry weight during migration out of the cave at the end of the day; and  $18.24 (\pm 1.8 \text{ SE}; n = 9)$  mg Chl  $\text{g}^{-1}$  dry weight when returning at the end of the night (however, chromatographic analysis showed that most of this was made up of degraded chlorophyll). If we consider both a chlorophyll: dry phytoplanktonic biomass conversion factor of 1.5 % and an assimilation efficiency of 60 % (this value averages those currently reported for herbivorous zooplanktonic crustaceans MARGALEF, 1974, 1983) we can deduce that phytoplankton ingested by a *Hemimysis speluncola* individual can double their own biomass in 2 d.

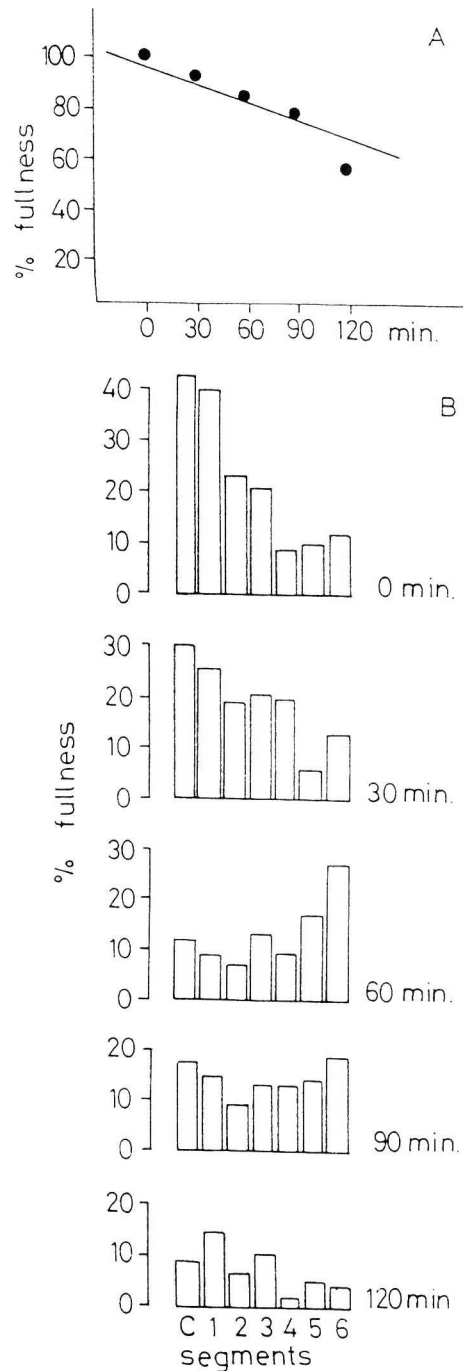


FIG. 4. — *Hemimysis speluncola*. Evacuation rates measured as decreasing gut fullness. A) Over time. B) For different body segments (at left the segments placed close to the stomach).

## DISCUSSION

### Migration causes

Why do these mysids live inside the cave, leaving it only to feed at night? The reason may be similar to that proposed to explain the vertical migration of

zooplankton by HUTCHINSON (1967) i.e. natural behavioural selection aimed at limiting predatory pressure by carnivorous fishes (LAMPERT, 1987), which are less abundant inside the cave and display maximum activity, related to better vision, during the daytime (ZARET and SUFFERN, 1976; WRIGHT *et al.*, 1980). The study of *Hemimysis speluncola* horizontal migrations provides new arguments to discuss some of the currently accepted alternative explanations of this phenomenon. The hypothesis that vertical migration and temporary residence in deep low-temperature water reduces metabolic costs (MCLAREN, 1963) is not applicable to our study since the water inside the cave is almost at the same temperature as that outside (GILI *et al.*, 1986), and since there is no significant difference between day and night temperatures. It has also been postulated that algae are more nutritious at night, since it is then that they synthesize proteins (ENRIGHT, 1977). This also would not seem to be applicable to our case study, since the mysid population under study has ample time to feed and plentiful food resources (i.e., is under no constriction to select for high-nutrition food sources). Thus, the most plausible explanation for migration of the population studied would appear to be predator avoidance.

There is indirect evidences which seem to strengthen this hypothesis. Fishes surrounding the mouth of the cave have been observed to feed with avidity on *Hemimysis speluncola* individuals. As shown by stomach contents, *Hemimysis speluncola* makes up the preferred diet of a population of Blunt-headed holy fishes, *Anthias anthias* (L.) which stay permanently in the opening of the cave. This diurnal visually-directed predator is able to penetrate into the cave but it needs the light of the SCUBA diver's lamps to feed (unpublished data).

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