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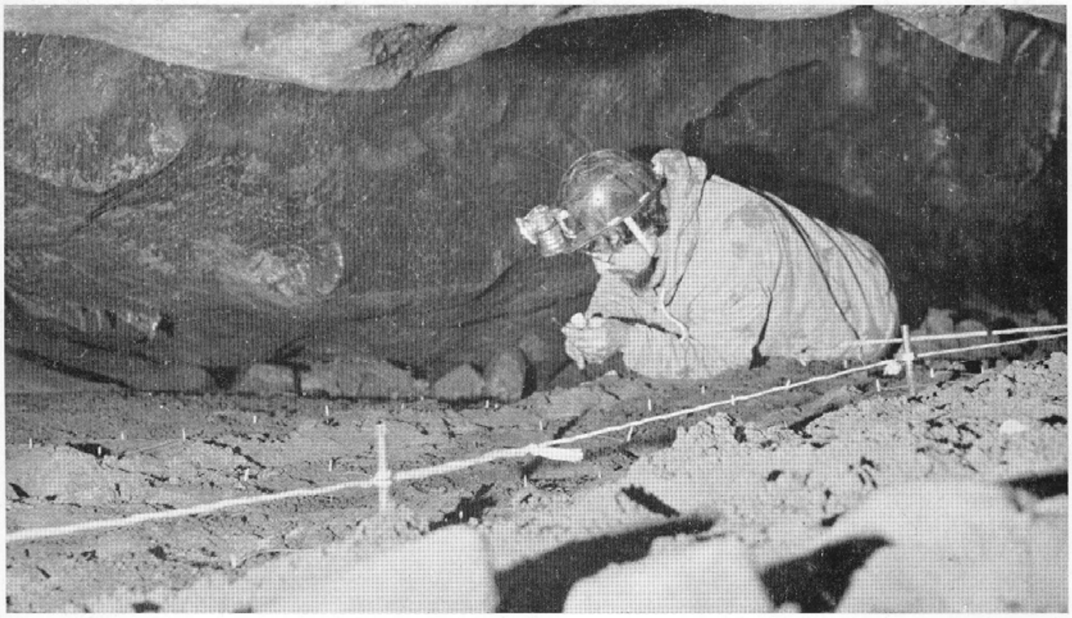

Studying worm casts in Ingleborough Cavern

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THE EFFECT OF LOW HUMIDITY ON THE DISTRIBUTION OF *HETEROMURUS NITIDUS* (COLLEMBOLA) IN RADFORD CAVE, DEVON

by Jane Wilson

Summary

Relatively large chamber heights seemingly allow a drop in cave humidity due to air circulation. Many cave dwelling invertebrates, particularly troglobites, can tolerate only a slight departure from a relative humidity of 100%. Thus there may be an indirect correlation between the height within caves and the absence from that chamber of organisms requiring humid conditions. The evidence presented herein is drawn from studies of the troglophilic insect *Heteromurus nitidus* from Radford Cave, near Plymouth, Devonshire.

Introduction

It is well known that, in temperate regions, caves of any appreciable size provide high humidity, constant temperature (Baldwin and Beatty 1941) stable habitats (Poulson and White 1969), usually at the average rock temperature of the area. Radford Cave near Plymouth, averages around 12-13°C while 'cave conditions' in the United States have been quoted as averaging 14°C (Christiansen 1969). Geographical differences account for this discrepancy.

Cavernicoles are generally heterotrophic, large numbers of the macrofauna feeding on micro-organisms (see also Caumartin 1963), which decompose allochthonous material such as inwashed vegetation, cavers' rubbish and bat guano. This limited energy input into the cave environment tends to lead to low population densities and hence fairly simple community structures (Barr 1967). Unfilled niches are not unknown in cave food webs.

Coping with food scarcity is a necessary adaption to life underground and food distribution may be expected substantially to influence population distributions of various species. However, investigation showed that in Radford cave humidity was more important than food scarcity in determining which areas populations were able to occupy.

Radford Cave

Radford Cave SX/503527 (Figure 1) was first described by Hooper in 1954 as being 'situated in a relatively small belt of limestone barely half a mile long, which runs in an east-west direction, immediately south of Hooe Lake. This narrow belt, which is little more than one eighth of a mile wide, encloses the greater part of Hexton Wood and the cave entrance lies at the western end of this wood. The entrance is about 600 yards' walk from the Plymstock to Hooe road in a long-disused quarry.' Hooper recorded the total passage length as about 600 feet (180 m) but with subsequent discoveries within the cave, its passage length is now nearly 2000 ft (600 m) (Jeffrey 1967).

Frequent measurements of the physical conditions within Radford Cave showed there to be few fluctuations in temperature and humidity although air movements could be detected (Barbour 1965). The relative humidity of the cave is 97% for most of the year except where the height of the chamber, greater than about 25 ft (7 m) allows air circulation to cause a marked fall in the humidity in that chamber. During preliminary surveys of the cave's fauna, it was noticed that the Boulder Slope and Canyon area (a chamber with a maximum roof height of about thirty feet (9 m), thus the highest in this cave) supported very little life despite the presence of abundant food in the form of fungi. An attempt was made to demonstrate that humidity variations within the cave play an important part in determining the population distributions of species that are intolerant of reduced humidity conditions.

The humidities at various sites in Radford Cave were measured at fortnightly intervals. Figure 2 shows the averages of readings noted between September 1974 and May 1975. During periods of dry weather it is not uncommon for the humidity in the Boulder Slope and Canyon to fall to as low as 80%. A housing estate has been built above the cave and it may have reduced seepage and drip water entering the cave so it is possible that this comparatively very dry area is quite a recent development.

Heteromurus nitidus

The Collembola are a class of wingless insects commonly known as 'springtails'. The sensitivity of some of the representatives of this group to dry, unsaturated air (at a relative humidity of less than 100%) has been shown to be quite marked (Milne 1959). An attempt was made here to relate this sensitivity in one of the nine species of Collembola recorded from Radford Cave (Hazelton 1967, 1975), to areas of low humidity within the cave.

The Collembolan studied was a species with eyes from the family Entomobryidae: *Heteromurus nitidus* Templeton (1835), see plates. This lightly pigmented lively insect is common in Radford and many other Devon caves and is also found above ground (Gough 1975). *H.nitidus* is therefore a troglophile. It is able to withstand comparatively large environmental fluctuations, breeds prolifically in the laboratory and can withstand handling. The adults which reach a maximum length of about 1.7 mm were cultured using the technique described by Goto (1961). The other Entomobryid that is commonly found in the cave is the blind *Pseudosinella dobati* (Gisen (1965) a species which is thought to be troglobitic, is less abundant, more difficult to culture and is less amenable to handling than *H.nitidus.*

Experimental Procedure

(a) Tolerance

It is known (Winston and Bates 1960) that, at a given temperature, solutions of certain salts produce standard relative humidity in the atmosphere above those solutions. Saturated solutions of eight of these salts were made up in crystallising dishes, sealed with greased glass lids and the atmosphere above each solution allowed to equilibriate to its respective humidity.

Ten groups of five *H.nitidus* were placed in petri dishes which were then floated on the standard solutions. The glass lids were replaced and the time taken for the Collembola to begin to show signs of distress and desiccation were noted. The reaction of a control group was investigated by repeating the procedure replacing the saturated solution with distilled water and noting the survival time of these Collembola at 100% humidity, while the effect of enclosed laboratory air (relative humidity 52%) was also examined.

Despite the difficulty experienced in deciding precisely when the Collembola had died and the seemingly great differences in the humidity tolerances of similar individuals, LD_{50} values (= lethal dose for 50% of the population) were calculated as a crude method of standardising the results. The 'lethal dose' in each case was expressed as the average survival time at a given humidity.

The results are shown in the table. Graphical representation of these values, figure 3, clearly shows the lethal effects of even short term exposure to humidities below 90% relative humidity.

Table: Survival times of *Heteromurus nitidus* at various humidities and 21°C

No.	Salt Soln. used to maintain the given humidity	Relative Humidity	Time taken before effect was noted, LD_{50}
1.	Laboratory air	52%	36 mins.
2.	Glucose	55%	35 mins.
3.	NH_4NO_3	65%	46 mins.
4.	NaC1	76%	75 mins.
5.	NH_4C1	79.5%	120 mins.
6.	$(NH_4)_2SO_4$	80.5%	130 mins.
7.	KBr	84%	160 mins.
8.	$MgSO_4.7H_2O$	90%	170 mins.
9.	KNO_3	93%	5 hours & longer
10.	H_2O	100%	no effect

(b) Behaviour

Both species of Entomobryid Collembola inhabiting Radford Cave can be shown to migrate up a humidity gradient. Individuals placed in a narrow bore (1 cm), air-filled tube with water at one end and a saturated solution of potassium hydroxide at the other, will aggregate at the end which is at the highest humidity, that is near the water. This behavioural response over-rides their tendency to move away from light. My previous experiments have shown *Pseudosinella dobati* and *Heteromurus nitidus* to be negatively phototactic*.

Milne (1960) demonstrated a thigmatactic* response in certain species of soil dwelling collembola when, during exposure to low (laboratory) humidity, they took shelter under microscope slides. Since these were glass slides this behavioural response is unlikely to be phototactic in origin. An attempt was made to demonstrate this thigmatactic behaviour in *Heteromurus nitidus* by placing cover slips in their culture vessels but no tendancy to shelter under these was noted. Even a reduction in humidity did not encourage this response so it could not be proved that adult *H.nitidus* avoid desiccation by taking refuge in high humidity cracks or under stones. However, the adults did show a strong preference for laying their eggs in grooves in their culture vessels, a fact which is of interest when it is realised that the eggs of *H.nitidus* are far less susceptible to damage from desiccation and high temperatures (greater than 25°C) than are the adults and immature instars. Without further physiological investigations, I am reluctant to attempt to explain why the eggs are more resistant to drought and high temperature. Analogy to the comparative resistance to environmental 'hardships' of a seed and an adult plant may help in understanding this. The resistance of seeds and some eggs (particularly those 'designed' to cope with an overwintering type situation) may be explained by one or more of the following:—

i) smaller surface to volume ratio in eggs
ii) lower exchange rate with the environment
iii) impervious 'skins'.

* Phototaxis is the response or organisms to light. Positive phototaxis means they move towards light; negative away from light.
Thigmataxis is the response of organisms regulated by a sense of touch.

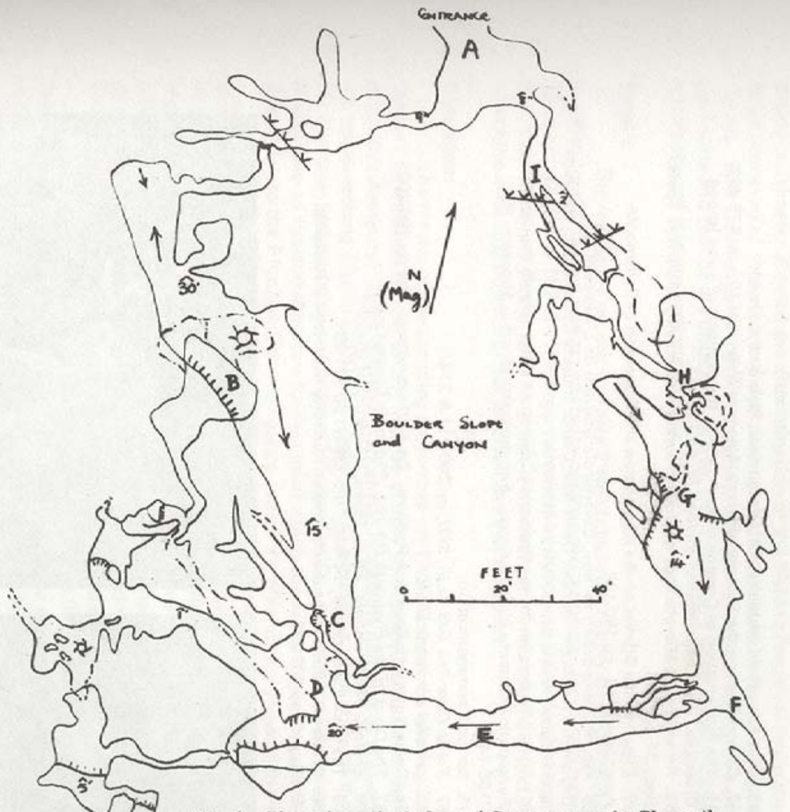

Fig. 1. Plan of Radford Cave (after a survey by Plymouth Caving Group - Jeffery 1967).

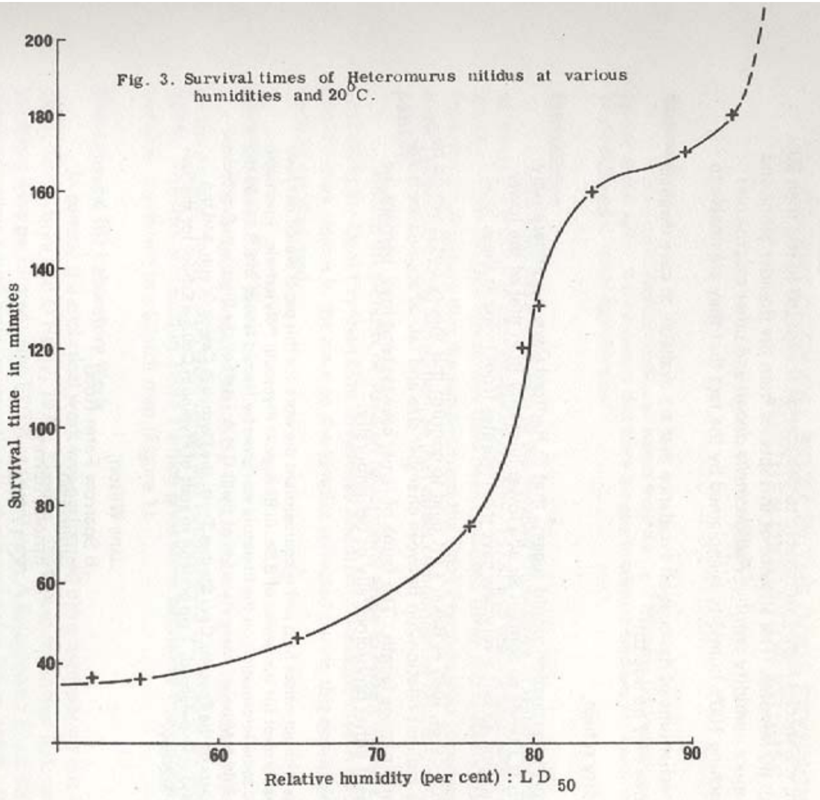

Fig. 3. Survival times of Heteromurus nitidus at various humidities and 20°C.

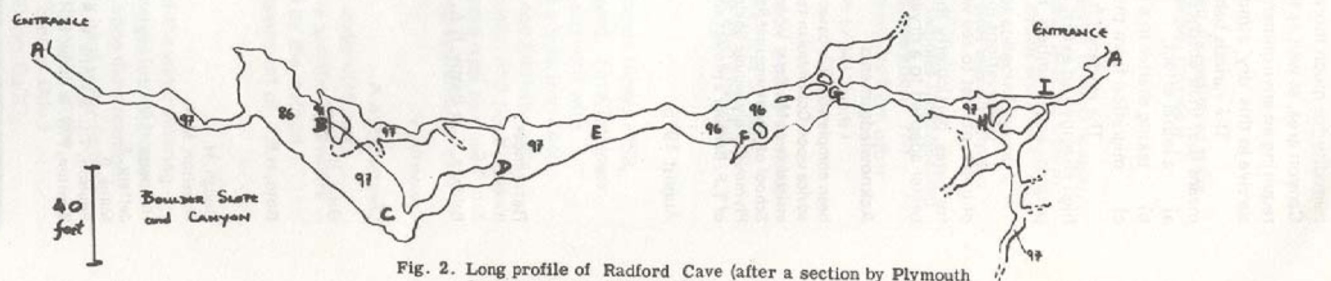

Fig. 2. Long profile of Radford Cave (after a section by Plymouth Caving Group - Jeffery 1967). Numbers indicate average relative humidities.

Conclusion

Heteromurus nitidus, then, is a species highly vulnerable to desiccation if exposed to less than 90% humidity for much more than about 80 minutes. The absence of this species from the Boulder Slope and Canyon area, as well as that of the more humidity sensitive *Pseudosinella dobati* and other cavernicoles requiring an environment of approaching 100% humidity is explained by the fact that they are unable to survive in this 'dry' atmosphere.

The various behavioural mechanisms of desiccation avoidance that are available to cave dwellers means that their absence from an area may be due to:

a) a lethal effect,
b) taking shelter in a high humidity refuge,
c) migration from the dry area.

The evidence from this short investigation would suggest that in Radford Cave, a comparatively high chamber (in excess of about 25 ft.) tends to contain air at a lower humidity than that of the lower passages and chambers, thus discouraging all but a very few cave invertebrates from living in these 'dry' areas.

Observations in other Devon caves, such as Baker's Pit tend to confirm this theory but it would be of great interest to see whether this indirect relationship between chamber size and faunal abundance holds for caves, particularly those of greater passage length. The fauna of larger cave systems may, perhaps, be better adapted to a dryer environment either physiologically or behaviourally.

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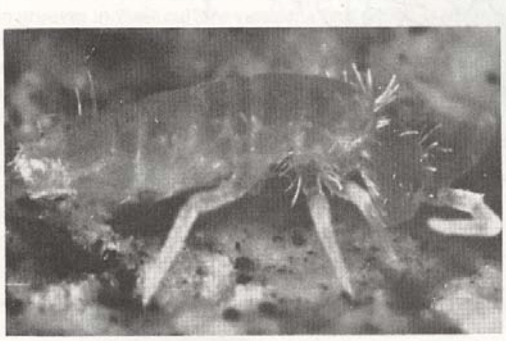

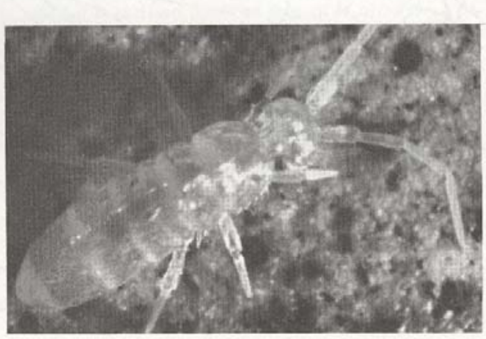

Heteromurus nitidus Templeton