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Light responses and eye regression in cavernicolous animals from the Jameos del Agua (Lanzarote, Canary Islands)

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Abstract: The crustaceans *Munidopsis polymorpha* and *Parhyale hawaiensis* inhabit Lanzarote, Canary Islands. They develop high population densities in the Jameos del Agua part of a volcanic cave system. In order to reveal special adaptations to cave life, their phototactic behavior was experimentally investigated. For comparison, another population of *Parhyale hawaiensis*, living outside the cave, was studied. From observations of the cave animals in their natural habitat we expected a negative phototaxis. Therefore, over a period of nine weeks, the phototactic behavior of nine animals of each of the three groups was observed in the laboratory under three different light intensities (620, 50 and 3 lux). In addition, histological sections of the eye of *Munidopsis polymorpha* were prepared. Results of these experiments show that: *Munidopsis polymorpha* exhibits negative phototaxis and its eyes are reduced. At a light intensity of 3 lux the preference for darkness was not statistically significant. The threshold for orientation towards darkness must lie between 3 and 50 lux. This general tendency is not true for all the specimens studied. Some of them exhibit a reaction independent of the light intensity used in the tests. *Parhyale hawaiensis* did not show these responses. A preference for the dark can be observed only at high light intensity (620 lux). Compared with the population of *Parhyale hawaiensis* living outside the cave, no differences were found. For both populations, the threshold for orientation towards darkness must lie between 50 and 620 lux. The orientation of *Parhyale hawaiensis* towards darkness depends on the light intensity.

Introduction

The Canary Islands are of volcanic origin and developed about 20 million years ago. They are located off the east coast of North Africa and consist of seven main islands, whereby the islands Lanzarote and Fuerteventura, which are situated to the east, belong to the African continental shelf. Lanzarote is the northernmost island of the Canary archipel (KENSOK 1989).

About 3000-5000 years ago the volcano Monte Corona, which is situated in the northern part of the island, broke out. With this eruption the stream of lava floating eastward pushed the coastline several kilometers into the Atlantic. During the volcanic activity a subterranean tunnel, reaching from the Monte Corona to the coast and beyond, was formed (PACHECO 1909, VILAR 1965).

Due to the contact with the ocean the floor of the tunnel is partly flooded. During the cooling process the fragile parts of the tunnel cap were damaged. These slumps are termed Jameos. The investigated part of the tunnel contains two closely adjoining slumps about 200 m apart. This part of the tunnel is called Jameos del Agua. Some light enters the tunnel through these slumps. The incident light has enabled the establishment of primary producers as a prerequisite for the formation of this biological community. The Jameos del Agua are accessible to the public and therefore exposed to regular disturbance.

Due to the photonegativity suggested by the results of our field studies on the crustaceans *Munidopsis polymorpha* and *Parhyale hawaiensis*, nine individuals of three test groups were exposed in the laboratory to light preference tests over a period of nine weeks. For the tests, light intensities of 620, 50 and 3 lux were chosen. In order to determine whether the phototactic behavior of *Munidopsis polymorpha* and *Parhyale hawaiensis* from the Jameos del Agua and *Parhyale hawaiensis* from the Charcos differs significantly, a comparison of the duration of stay under the provided light conditions has been made.

Material and Methods

Munidopsis polymorpha KOEBEL, 1892 (Galatheidae, Decapoda) is the only representative of the *Munidopsis* genus which normally lives in the deep sea (WILKENS and PARZEFALL 1974). This group of crabs is distinguished by the absence of epipods on the pereiopods. *Munidopsis polymorpha* reaches a maximum size of 4 cm (rostrum tip to end of telson) and develops a high population density in the cave. Its pigmentation is reduced. It is thus white, and small quantities of carotin pigments can impart a yellow or orange colouring. This species feeds mainly on diatoms and detritus. Field surveys have shown an omnivorous feeding habit (own observations).

Parhyale hawaiensis DANA, 1853 (Talitroidea, Amphipoda) is an amphipod with an approximate length of 2 cm. It shows pigmentation and its eyes are fully developed. Compared with other members of its own species, however, it appears to be more pale. *Parhyale hawaiensis* has been captured in the Charcos as well as in the waters of the Jameos del Agua caves and mostly dwells under stones or in clefts. On the fringes of its habitat it reaches a high density of individuals (WILKENS and PARZEFALL 1974). It probably feeds on diatoms and organic material.

The phototactic behavior, i.e., the orientation subject to light perception by the light sense organs, has been investigated in *Munidopsis polymorpha* and *Parhyale hawaiensis* from the cave tunnel Jameos del Agua and in individuals living outside the cave. During these investigations the duration of stay in the

light was recorded. The experiments were conducted in the laboratory of the Zoological Institute and Zoological Museum of Hamburg. As the reaction to light is hardly influenced by chromatic factors (THINES and KÄHLING 1957), ordinary light bulbs (60 watt) were used to illuminate the testing basin.

The entire experimental setup consisted of six basins and three lamps. One lamp was installed over two basins at a distance of 40 cm to the center of the basin. A black partition pane ending 5 cm above the bottom of the aquarium was installed in the middle of the basin. This established a connection between the two water bodies. One half of the aquarium was completely covered with black plastic foil, blocking all light from entering this part of the basin. The other part of the basin was left uncovered.

The experiments were carried out as follows: One animal at a time was transferred into an observation basin. The artificial lighting generated alternating light and dark periods lasting 12 h. The experiment was started with the highest light intensity (620 lux). After 2 d of acclimatization the crustaceans were observed three times a day for 5 min. One period of observation with each light intensity lasted 5 d. After 5 d, the light was reduced to 50 lux, and after another acclimatization phase of 2 d, the crustaceans were again observed three times a day. The experiment was terminated with a light intensity of 3 lux. All crustaceans were exposed to this procedure. Altogether, 9 animals of each species were observed for 5 min three times a day. Thus, each animal was observed 15 min under each light intensity, i.e., for a total length of 45 min.

Results

In Fig. 1 the average results of the surveys were determined and converted into percentage values. A percentage of 100 indicates absolute photopositivity and a value of 0 absolute photonegative behavior. The conversion enables a comparison between the groups and to literature values. The columns show the duration of stay in the light and the selected light intensities (620, 50 and 3 lux). The abscissa shows the different test groups.

All three test groups showed a photonegative behavior at 620 lux. *Munidopsis polymorpha* and *Parhyale hawaiensis* from the Charcos also behaved in this manner at 50 lux, whereas the *Parhyale hawaiensis* from the Jameos del Agua did not show this behavior at 50 lux. Their stimulus threshold with regard to light, i.e., the light intensity at which no photonegative reaction was evoked, was between 620 and 50 lux. In the case of *Munidopsis polymorpha* the threshold was under 50 lux .

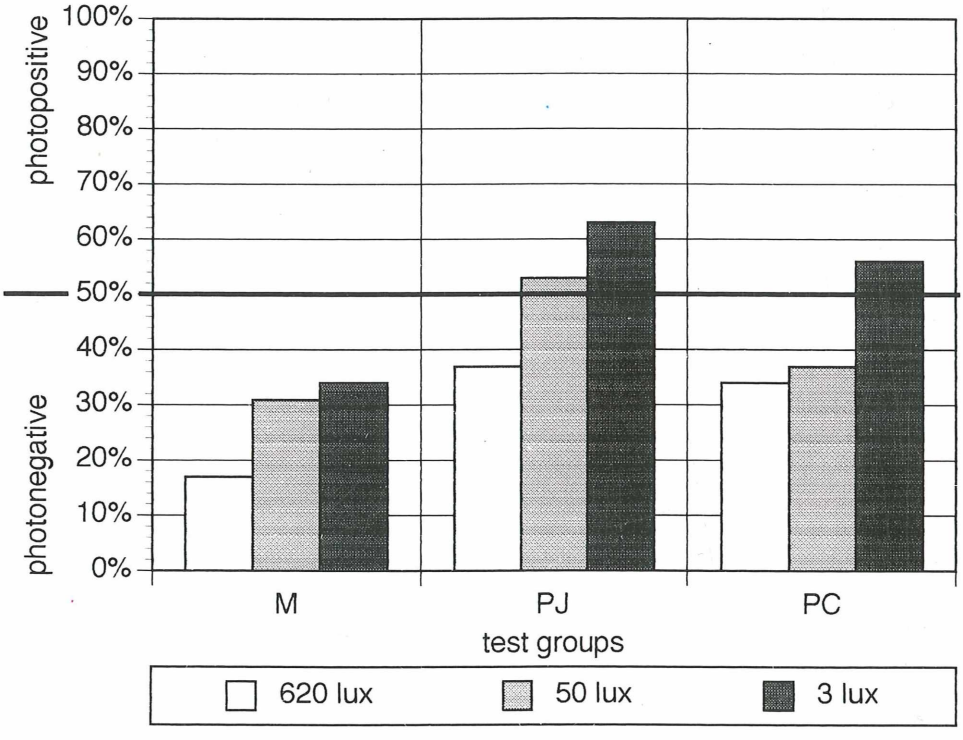

Fig. 1: *Munidopsis polymorpha* (top left) and *Parhyale hawaiensis* (top right); below: comparison of the preference behaviour of *M. polymorpha* (M), *P. hawaiensis* from the Jameos (PJ), and *P. hawaiensis* from the Charcos (PC) at different light intensities (lux). For this diagramm, the average results of the surveys were determined and converted into percentage values. A percentage of 100 indicates absolute photopositivity and a value of 0 absolute photonegative behavior.

Discussion

The experiments show that the phototactic reaction of *Munidopsis polymorpha* is negative and that its light sense organs are reduced (HARMS 1919). This is also in accordance with histological studies, which are treated elsewhere. *Munidopsis polymorpha* showed a clear preference for darkness throughout the test series, although at a light intensity of 3 lux this behavior was not statistically significant. Its orientation towards darkness does not always depend on light intensity, which could be due to the different states of eye reduction.

Parhyale hawaiensis from the Jameos, however, showed no such reaction. A preference for darkness was recognizable only at a high light intensity. Compared with the *Parhyale hawaiensis* population living outside the cave, a different behavior was visible at 50 lux. Both subpopulations have a light stimulus threshold between 620 and 50 lux for the orientation towards darkness . The orientation of *Parhyale hawaiensis* towards darkness is related to light intensity.

One explanation why *Parhyale hawaiensis* from the Jameos del Agua is less sensitive to light could be that the absence of predators there also allows activity during the light period.

The preadaptation of *Munidopsis polymorpha* for cave life could be due to their biological kinship to deep-sea species. According to LUDWIG (1942), the photonegative reaction not only plays an important role in the colonization of caves, but is also related to the characteristics that are typically developed by cave animals, such as the reduction of eyes and pigmentation. Following LUDWIG's thesis and his investigations, the results of the present experiments can be taken as a confirmation of his assumptions.

Summary

Lanzarote, Canary Islands, harbors the crustaceans *Munidopsis polymorpha* and *Parhyale hawaiensis*. Their phototactic behavior has been investigated in order to determine their specific adaptations to cave life. For comparison, the same experiments were conducted with another population of *Parhyale hawaiensis* living outside the cave in small pools (Charcos) near the coast.

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