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Morphology, physiology, and ecology of the fish inhabiting highly alkaline environments in Oman

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Hyperalkaline hot springs (pH11-12) occur in and beside the rivers in the mountain area of the Sultanate of Oman. The aim of this study is to identify the species of fish inhabit the highly alkaline environments around the springs, and to reveal the histological and physiological mechanisms for the adaptation of these vertebrates, which would be important for the understanding of not only the ability of adaptation in vertebrates, but also the ecosystem in Oman. In December, 2009, and December, 2010, we carried out field research at Bat, Faydh, Fizh, and Hilti, and identified *Garra barreimiae*, *Cyprinion microphthalmum*, and *Aphanius dispar*. *G. barreimiae* and *C. microphthalmum* were very common at Bat, Faydh, Fizh, and Hilti, and *Aphanius dispar* was found in Fizh. To examine the tolerance of *G. barreimiae* to high alkalinity, we transferred the fish to the mixtures of hot spring water and river water. It was revealed that *G. barreimiae* died in the 80% alkaline spring water, but survived in the 70% spring water. Intriguingly, after exposed to the 70% spring water for 24 hours, the fish tended to survive even in the 80% spring water, suggesting that crucial physiological changes occurred in the fish exposed to the 70% spring water.

In the morphological analysis of *G. barreimiae*, whole fish and scales were stained with alizarin red and alcian blue. The material of vertebral column was found to be bone. The head skeleton mainly calcified, whereas the surface area and lower jaw appeared to consist of cartilage. For fins, the proximal part ossified, while the distal part was cartilaginous. Remarkably, the scales were cartilaginous, in contrast to the bony ones of other teleosts such as goldfish and medaka. However, the scales of the fish around alkaline hot springs also were not different from those of the fish upstream of the river. Further study is needed to elucidate whether cartilaginous scales have any physiological roles in the adaptation of *G. barreimiae* to the highly alkaline water. Staining histological sections of the skin with hematoxylin and eosin localized mucus cells in the epidermis. The gills were also analyzed by staining histological sections with hematoxylin and eosin. Mucus cells and/or chloride cells were detected in the gill filaments, and localized beside the base of lamellae. The gill filaments were further examined using a transmission electron-microscope. Chloride cells and mucus cells were observed beside the base of lamellae, confirming the localization of these cells by hematoxylin-eosin staining. It would be important to study the physiological roles of chloride cells and mucus cells in the adaptation of the fish to highly alkaline environments.

Keywords: Oman, highly alkaline environment, fish, animals