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UNUSUAL STABLE MORPHOTYPE OF *ACROPERUS HARPAE* (BAIRD, 1834) FROM LAKE MÝVATN, ICELAND (CLADOCERA: ANOMOPODA: CHYDORIDAE) REVEALED BY PALAEOLIMNOLOGICAL STUDIES

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Abstract
A new unusual morphotype of *Acroperus harpae* (Baird, 1834) was found in Lake Mývatn and its neighbouring Lake Budlungaflói in Iceland. This form, *A. harpae* f. *multidentata* is characterized by a very large head keel and by 5–9 denticles on the posterovental angle of the valves instead of 1–3 common for *A. harpae*. The new form did not differ from typical *A. harpae* in the morphology of the postabdomen, head pores or any appendages. A study of Lake Mývatn sediments reveled that this form existed in the lake for at least two thousand years.

Key words: Subfossil Cladocera, *Acroperus harpae*, new macrophototype description, paleolimnology

INTRODUCTION

Cladocera of the genus *Acroperus* Baird, are a common component of the littoral fauna of freshwater lakes, being especially numerous in the Holarctic region. Remains of these animals frequently appear in lake sediments and are useful for palaeolimnological studies (Szeroczyńska, Sarmaja-Korjonen 2007). For all the 20th century, the taxonomy of the genus was in a poor state, four taxa were listed for Europe (Smirnov 1971), but only one species, A. *harpae* (Baird 1834), was recorded in most ecological works (Sinev 2009). Tropical populations of *Acroperus* usually were indiscriminately identified as *A. harpae* (Sinev 2009; Sinev, Elmoor-Loureiro 2010).

Palaearctic species of *Acroperus* were recently revised by Sinev (2009), who found that only two valid species of the genus are present in the region, *A. harpae* and *A. angustatus* Sars 1863, two other taxa listed for Europe, *A. alonoides* Hudendorff 1876 and *A. neglectus* Lilljeborg 1900 are synonyms of the latter. *A. angustatus*, while rarely mentioned in ecological works, was found to be as common as *A. harpae*, and these two species frequently coexist. These two species can be clearly distinguished by the morphology of the antenna, denticles of the valves, and details of thoracic limb morphology, as well as by male morphology (Sinev 2009).

The main reason for such long-term confusion was the high degree of variability in body shape, the development of head keel and the shape of rostrum in both species. Such variability is common for pelagic genera of Cladocera like *Daphnia* or *Bosmina*, but is unique among substrate-associated Chydoridae. Sinev (2009) speculated that the head and body keel of *Acroperus* are defensive structures, like head keel and fornices of *Daphnia*, and their development depends on invertebrate predation level.

A study of South American populations of *Acroperus* (Sinev, Elmoor-Loureiro 2010) revealed that instead of *A. harpae* this region is inhabited by an endemic species, *A. tupinamba* (Sinev, Elmoor-Loureiro 2010). The taxonomic status of Nearctic and Palaeotropical populations of *Acroperus* is still unclear (Sinev 2009; Sinev, Elmoor-Loureiro 2010).

Subfossil valves and head shields of *Acroperus* with unusual morphology were found during the studies of sediments in Lake Mývatn (Iceland). The main feature of the form was numerous (5–9) denticles on the posteroventral corner of the valves, a higher number of denticles than ever recorded for any *Acroperus* species. Studies of the sediments reveled that this form existed in the lake for at least two thousand years. A collection effort in Lake Mývatn enabled us to find and describe the morphology of an extant population of the form.

STUDY SITE

Lake Mývatn (65°35' N, 17°00' W, altitude 277 m a.s.l.) in northern Iceland is a shallow spring-fed, naturally eutrophic lake. It is 37 km^2 in area and divided into two main basins. The South Basin is the larger of the two; it is mostly be-

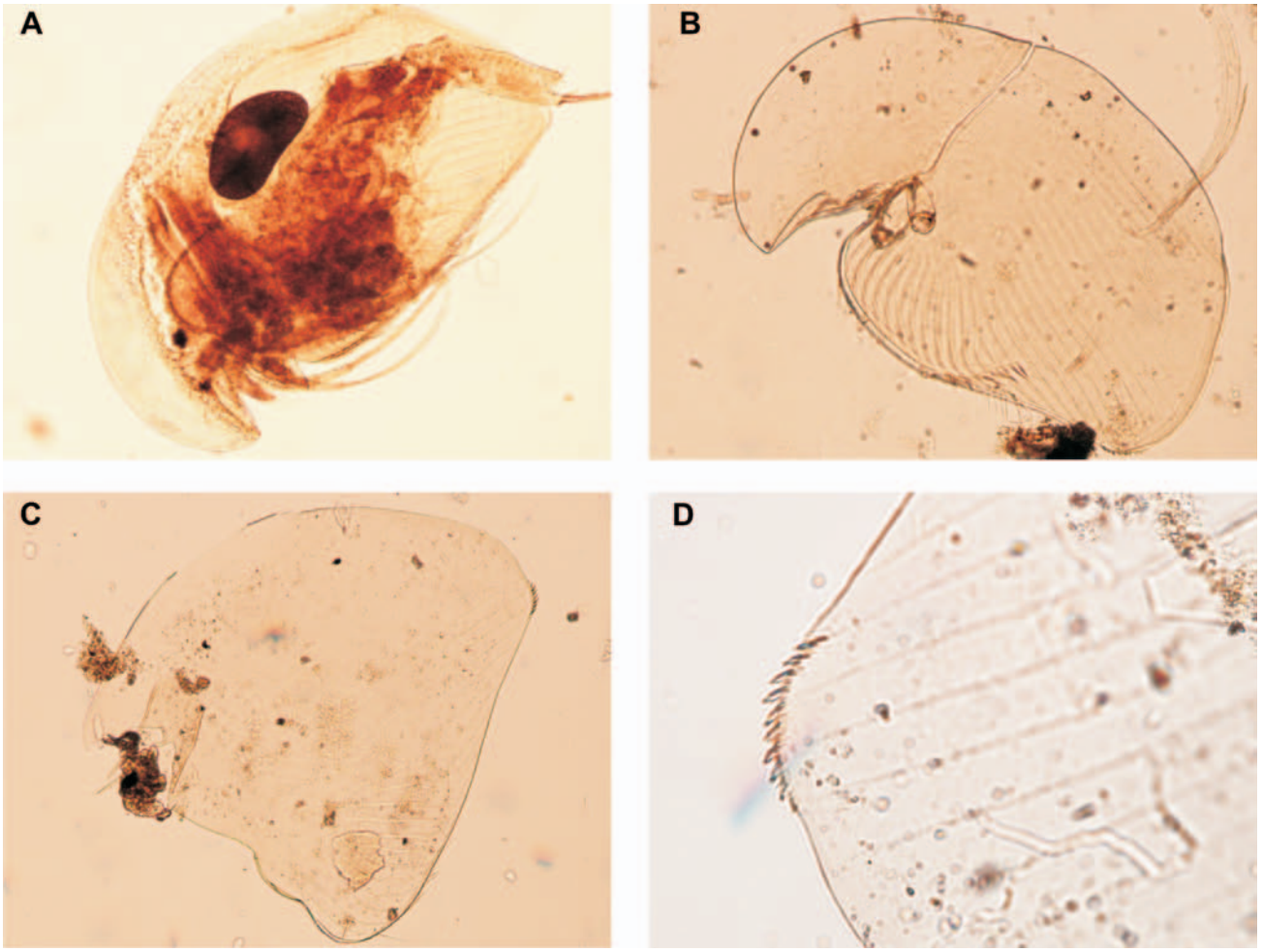

Fig. 1. Photo of *Acroperus harpae* f. *multidentata*, a whole animal sampled from the littoral zone and remains from the sediments of Lake Mývatn, Iceland. **A** – whole animal (parthenogenetic female) (magnification ×40), **B** – headshield and shell (mag. ×100), **C** – shell (mag. ×100), **D** – a detail of shell, denticles (mag. ×200).

tween 2 and 3.2 m deep and receives most of its water from cold-water springs along its east shore. The South Basin also receives water from the North Basin which in turn is fed by both cold and tepid springs. The North Basin is 1–2 m deep except for a part, 2–6 m deep, where the sediment has been dredged. Lake temperature is usually above 8°C in summer (May–September) with a maximum of about 18°C. The lake is mostly ice-covered from October to May. The water column is thoroughly mixed during the summer months, but thermal stratification develops locally in mid winter (Ólafsson 1979a). External loading of phosphorus and nitrogen has been estimated to be 1.5 g m^{-2} $year^{-1}$ and 1.4 g m^{-2} $year^{-1}$, respectively (Ólafsson 1979b), but nitrogen fixation by Cyanobacteria and internal loading from sediments are important in the total nutrient budget. Primary production has been estimated to be 3800 kcal m^{-2} $year^{-1}$ (Jónasson 1979), of which 600 kcal m^{-2} $year^{-1}$ come from phytoplankton. Most of the primary production therefore takes place on the bottom of the lake, mainly by diatoms, but also by filamentous green algae (*Cladophora glomerata* (L.) Kütz. and *Aegagropila linnaei* Kütz.), which cover a large part of the floor of the South Basin. Cyanobacterial blooms, formed by *Anabaena flos-aquae* (Lyngb.) Bréb., occur regularly, but fail to develop in some years.

The benthic cladocerans have been studied by Adalsteinsson (1979), Örnólfsdóttir and Einarsson (2004) and Einarsson and Örnólfsdóttir (2004). A palaeolimnological record of the Cladocera has been presented by Einarsson and Haflidason (1988) and Hauptfleisch *et al.* (2010; see also Einarsson *et al.* 2004). The main predators on Cladocera in Lake Mývatn are three-spined stickleback (*Gasterosteus aculeatus* L.), Arctic charr (*Salvelinus alpinus* L.), diving ducks, *Hydra* sp. and predaceous oligochaetes (*Chaetogaster* spp.) and chironomids (mainly *Procladius islandicus* (Goetghebuer)) (cf. Einarsson *et al.* 2004).

Lake Mývatn was formed about 2300 years ago following a major volcanic eruption (Thorarinsson 1951, Einarsson 1982, Sæmundsson 1991). The South Basin of the lake lies in a shallow depression in an extensive lava feld produced by the eruption. Another lake existed at the same site before the eruption, but it appears to have been wiped out by the lava. The geology of the area is described by Thorarinsson (1979) and Sæmundsson (1991).

MATERIALS AND METHODS

In the August 2010 sediment core from the Lake Mývatn was drilled by means of Russian corer. During palaeolimno-

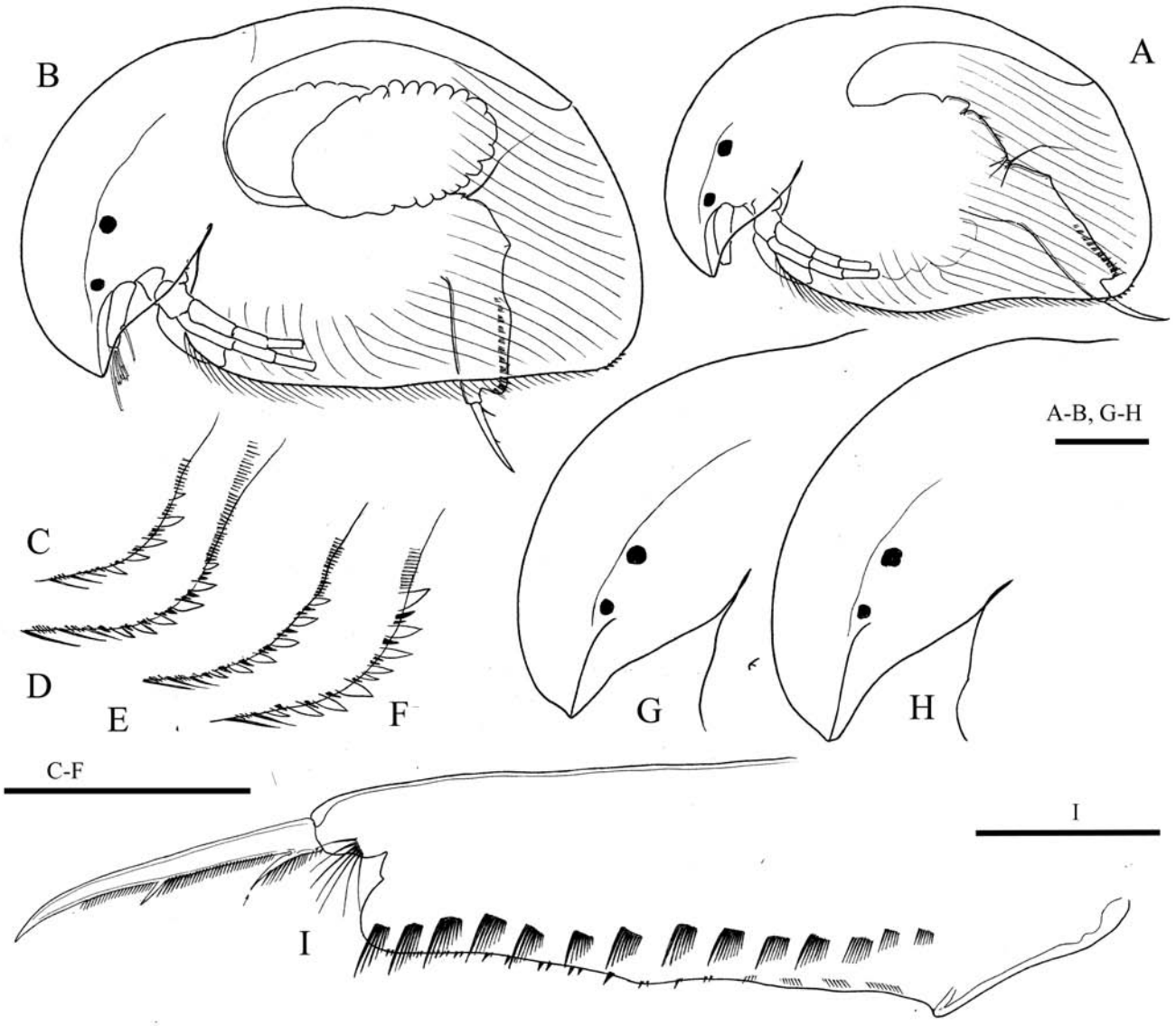

Fig. 2. *Acroperus harpae* f. *multidentata* from Lake Mývatn, Iceland. **A** – juvenile female of instar II, B–I – parthenogenetic females: **B** – lateral view, **C–F** – posteroventral corner of valves (C, D – left and right valves of the same specimen), **G**, **H** – heads of large specimens, *I* – postabdomen. Scale bars: 0.1 mm for A, B, G, H, 0.05 mm for C–F and I.

logical studies unusual remains of *Acroperus* were noted (Fig. 1). These remains were common in the studied sediment core and as well in the historical sediment samples kept in the Institute of Biology, University of Iceland in Reykjavik, Iceland.

The results of palaeolimnological studies inspired the authors to collect zooplankton samples from the current waters of Lake Mývatn. The samples were collected at the beginning of September 2010 by means of plankton net (50 microns) from the littoral zone of the lake. Sampling was done from the lake shore in several sites in the both basins North and South of Lake Mývatn and also from the surrounding small lakes. Immediately after sampling, zooplankton samples were put into plastic jar and were preserved in the pure alcohol. After field work (the same day) samples were moved to laboratory and kept in the fridge in the temperature of +5°C. Over 60 parthenogenetic females of *Acroperus* were found and studied.

Animals were selected from the sample under a binocular stereoscopic microscope, placed on slides (in a drop of glycerol-ethanol mixture) and studied under an optical microscope. Several specimens from each sample were dissected for the analysis of appendages. For SEM examination specimens were dried using critical point drying technology (Anderson 1951), mounted on the aluminum stub, coated with gold-palladium mixture, and examined under a scanning electron microscope (Hitachi S 405-A). Drawings were made by means of camera lucida.

RESULTS

Recovered 60 specimens of *A. harpae* from the current waters of Lake Mývatn and surrounding small lakes represented *Acroperus harpae multidentata*-morphotype. In the sediment and water samples from Lake Mývatn area authors found only this unusual form of *A. harpae*, and no specimens

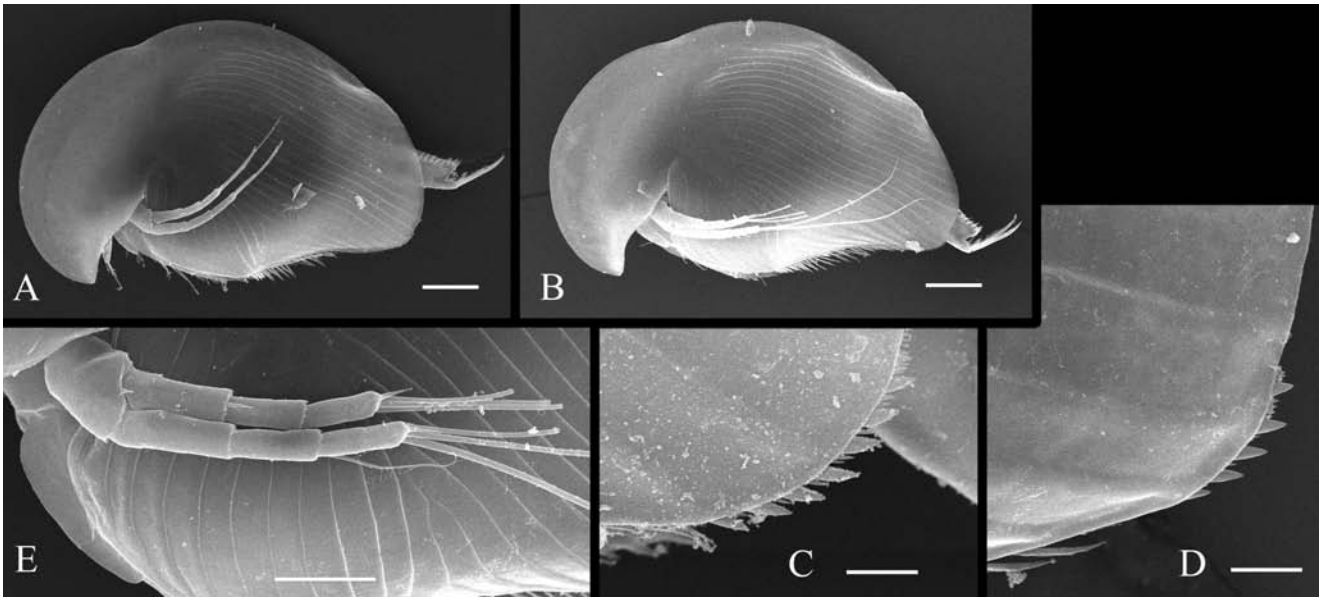

Fig. 3. SEM-photo of *Acroperus harpae* f. *multidentata* from Lake Mývatn, Iceland, parthenogenetic females: **A, B** – lateral view, **C, D** – posteroventral corner of valves, **E** – antenna. Scale bar denote 0.1 mm for A and B, 0.05 mm for E, 0.02 mm for C and D.

of typical *A. harpae*. All examined lakes have the same age and volcanic-dam origin, and very similar ecological conditions to Lake Mývatn.

Acroperus harpae f. *multidentata*

Description. Body moderately high, oval (Figs 2A, B; 3A, B), the maximum height in or before the middle of the body. Maximum length 0.71 mm. Dorsal keel well-developed. Dorsal margin highly arched, with clear depression in distal part of the head, in the region of main head pores. Distal margin convex, posteroventral and posterodorsal angles broadly rounded. Posteroventral angle (Figs 2C–F; 3C, D) with 5–9 denticles and smaller thick setules between them. All denticles are of typical for *Acroperus harpae* morphology – thin, elongated with narrow bases. The setae of ventral margin typical for *A. harpae*. The sculpture of valves typical for *A. harpae*, consisting of diagonal lines.

In lateral view, head more massive than in typical *Acroperus harpae*, with extremely large, broad head keel. Eye and ocellus small. Rostrum broad, in most specimens with angular tip, in larger specimens the shape of rostrum varies from pointed to blunt (Fig. 2G, H). Postabdomen (Fig. 2I) of typical for the species morphology. The morphology of head pores, labrum, antennule, antenna (Fig. 3E) and all thoracic limbs are similar to typical *A. harpae* (for detailed description see Sinev 2009).

Male unknown

Distribution. A. *harpae* f. *multidentata* is presently found in Lake Mývatn, Lake Budlungaflói, and several small lakes in the vicinity of Lake Mývatn. In the sediment core from Lake Mývatn, remains of *A. harpae* f. *multidentatus* were present through all sedimentary sequence.

DISCUSSION

At first glance, the specimens found in Lake Mývatn are very distinctive and can be assigned to separate species or at least subspecies. Still, we found no differences between *A. harpae* f. *multidentata* and "typical" *Acroperus harpae* in any characters used for distinguishing species of *Acroperus*. Antenna, scrapers of limb II, setae of exopodite IV, and shape of exopodite V are exactly the same as described for the European populations of *A. harpae* (Sinev 2009). Shape of body, keel and rostrum varies greatly between populations of the species, and these features cannot be used as species-level characters for Palearctic *Acroperus* (Sinev 2009). Denticles of *A. harpae* f. *multidentata*, while extremely numerous, are of same type as in typical *A. harpae* (see Sinev 2009), small, with narrow bases, protruding from the inner side of valve, with small setules between them. The denticles of posteroventral corner of valves are, in general, a very variable feature within Aloninae. Specimens with and without such denticles coexist within populations of *Alonopsis* and *Alona affinis* (Sinev 1997; Sinev, Atroschenko 2011). A study of valves from previous molts, regained by some specimens of *Alonopsis* revealed that the denticles can be absent in young animal and appear in the following instars (Sinev, Atroschenko 2011). In genera *Camptocercus*, *Karualona* and *Acroperus* (Smirnov 1998, Dumont, Silva-Briano 2000, Sinev 2009) the morphology of denticles is an important diagnostic character. Different species are separated by the shape of denticles, but their number is never stable within the species. Therefore, we chose conservative approach for the moment and treated the studied populations as a morphotype of *A. harpae*. Continuous presence of *A. harpae* f. *multidentata* in Lake Myvath sediment shows this morphotype is stable for a long period of time.

Acknowledgments

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