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New records of the rare glacial relict *Eurytemora lacustris* (Poppe 1887) (Copepoda; Calanoida) in atypical lake habitats of northern Germany

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ABSTRACT

During monitoring investigations of lakes in Schleswig-Holstein (northern Germany) in 2000 and 2008, the calanoid copepod Eurytemora lacustris *(POPPE 1887) was found in three lakes of the Ratzeburger Lake complex: the Kleine Küchensee, the Große Küchensee and the Große Ratzeburger See. The species has a broad geographic distribution but has become rare and endangered by eutrophication and global change. The lakes are mesotrophic (Gr. Ratzeburger See) and eutrophic (Kl. Küchensee, Gr. Küchensee) with cool (<10 °C) hypolimnia; they have surface areas of 12.6, 0.2 and 1.8 km^2 and a maximum depth of 24.4, 12.8 and 14.7 m, respectively. All three lakes are shallower than lakes reported as typical habitats for* E. lacustris*. Oxygen conditions in the hypolimnion were different in the two years of investigation. In 2000, the oxygen concentration in summer (July) was zero from 13 m downwards in the Gr. Ratzeburger See and zero from 7 m downwards in the Kl. and Gr. Küchensee. In the year 2008 the hypolimnia of both lakes were well oxygenated in summer (>1 mg O_2 L^{-1}). Food and physical conditions seem to be favourable enough to permit survival and reproduction of the species at least in spring. It remains unclear, however, whether the populations in the studied lakes are autochthonous.* Eurytemora lacustris *possibly invaded the lakes or was transported via a canal from the Schaalsee upstream, where a viable population exists.*

Key words: calanoid copepod, endangered species, glacial relict, atypical habitat

1. INTRODUCTION

In Germany the genus *Eurytemora* is represented by three species, *E. affinis* (Poppe 1880), *E. lacustris* (Poppe 1887) and *E. velox* (Lilljeborg 1853). Among the three species *E. lacustris* is found exclusively in fresh waters while *E. affinis* and *E. velox* often prefer brackish waters (Kiefer 1978, Einsle 1993). Although *E. lacustris* has a broad geographical distribution, it occurs only in few, generally oligotrophic lakes which show particular morphological, chemical and physical characteristics (Weiler *et al*. 2003; Kasprzak *et al*. 2005, 2006; Arbačiauskas & Kalytytė 2010). Most lakes where *E. lacustris* was observed are deep with a well oxygenated, cold hypolimnion (Pesta 1928). Weiler *et al.* (2003) and Kasprzak *et al*. (2005) concluded that *E. lacustris* is largely restricted to lakes with a maximum depth >30 m where temperature in the hypolimnion does not exceed 10 °C and where oxygen concentration in the hypolimnion is >1 mg L^{-1} during the summer. *Eurytemora lacustris* is a cold stenothermic and perennial species, which is unable to produce resting eggs and which often forms a population maximum in winter (e.g., Kiefer 1978). In summer this species is generally restricted to the cold hypolimnion (Naber 1933; Herbst 1953; Weiler *et al*. 2003).

2. METHODS

During a monitoring program conducted in Schleswig-Holstein (northern Germany) in the years 2000 and 2008 *E. lacustris* was recorded in three connected lakes of the Ratzeburger Lake complex: the Kleine Küchensee, the Große Küchensee and the Große Ratzeburger See (Speth 2001; Arp & Maier 2009). Zooplankton was sampled in monthly intervals by vertical hauls from bottom to surface with a plankton net of 55 µm mesh size. Until now the three lakes were not known as habitats for the species.

3. RESULTS

Eurytemora lacustris can be distinguished from the other two species of the same genus occurring in Germany by e.g. by the lack of "wings" on the 5th thoracic segment and the shape of the fifth leg (P5) of the male and female (Fig. 1). The Kl. Küchensee (which was sampled only in the year 2000) and the Gr. Küchensee have a surface area of 0.2 and 1.8 km^2, a maximum depth of 12.8 and 14.7 m and a mean depth of 8.9 and

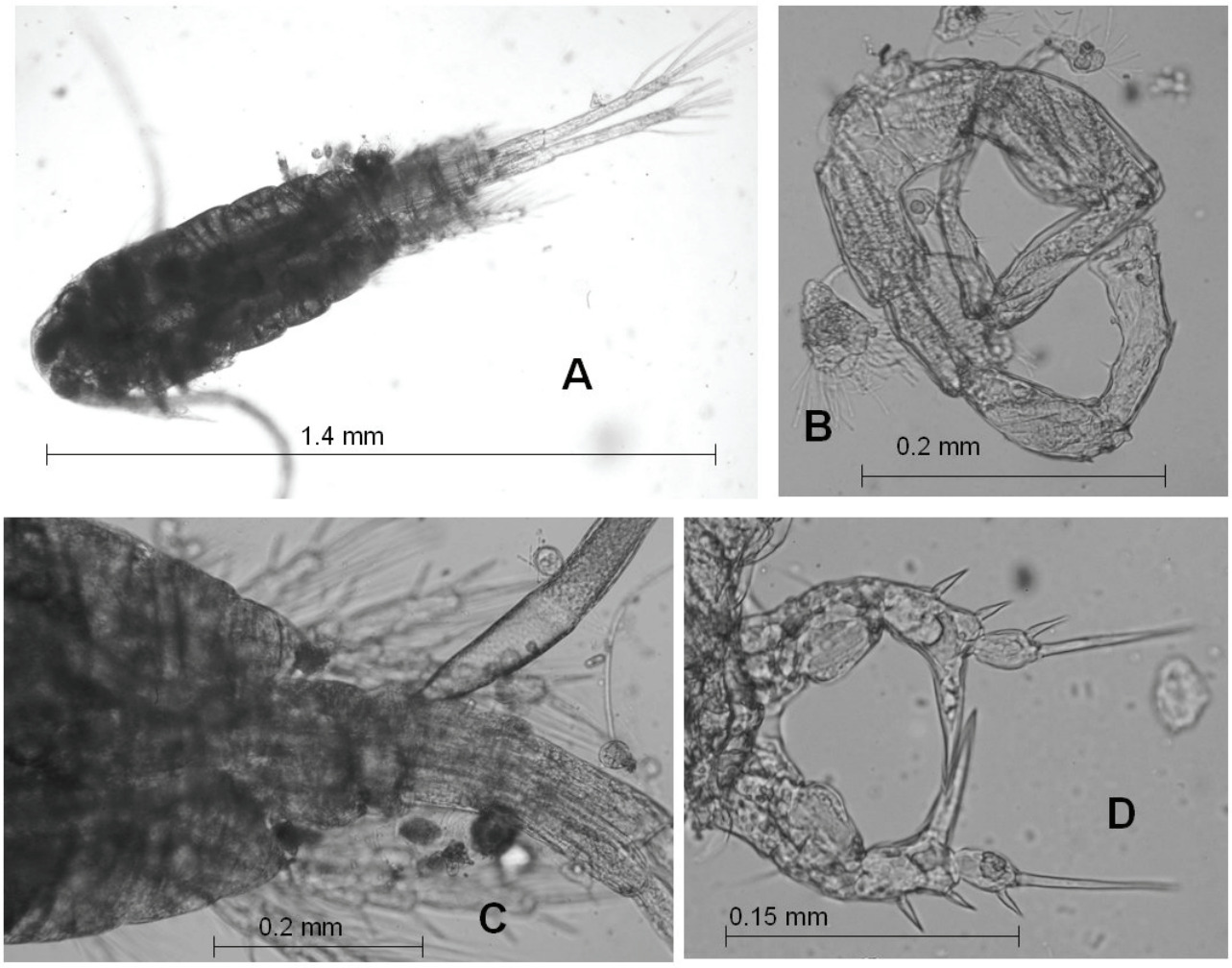

Fig. 1. Photographs of *Eurytemora lacustris* from the Gr. Küchensee viewed under a compound microscope. **A**) Male, habitus. **B**) Fifth pair of legs (P5) of the male. **C**) Female with attached spermatophore; region around the 5th thoracic segment. **D**) Fifth pair of legs (P5) of the female.

8.5 m, respectively. The Gr. Ratzeburger See is larger; it has a surface area of 12.6 km^2, a maximum depth of 24.4 m and a mean depth of 11 m (e.g., Lanu 2002). The lakes are eutrophic (Kl. Küchensee, Gr. Küchensee) to mesotrophic (Ratzeburger See). For example, concentrations of total P (average concentration during the growing season in the 1 m surface layer) are 40 µg L^{-1} in the Gr. Küchensee and 35 µg L^{-1} in the Gr. Ratzeburger See. Oxygen concentrations during summer in the hypolimnion in 2000 were zero from 13 m downwards in the Gr. Ratzeburger See and zero from 7 m downwards in the Kl. and Gr. Küchensee. In 2008, minimum oxygen concentrations in the hypolimnion were >1 mg L^{-1} (>10% saturation) in the Gr. Küchensee and the Gr. Ratzeburger See. No measurements/samples were taken in the Kl. Küchensee in this year. The highest water temperatures in the hypolimnion (April to August 2008) were 8-10 °C (Gr. Küchensee) and 7-10 °C (Gr. Ratzeburger See). Both lakes are connected with the Schaalsee, which is more than 70 m deep, via the Schaalsee canal (Fig. 2).

In the year 2000, *E. lacustris* was found in the Kl. Küchensee in March, in the Gr. Küchensee in March and in February, and in the northern part of the Gr. Ratzeburger See in April and May. Abundance was low in this year (<1 ind L^{-1}). In 2008, the species was present in the Gr. Küchensee for a longer period of time in spring (March to May) and the maximum abundance (copepodids and adults; without nauplii) was higher than in the year 2000 (9.3 ind L^{-1}; Fig. 3). Females carried between 32 and 56 eggs; mean clutch size was 43.9 eggs $female^{-1}$ (n = 7). Males and all copepodid instars were also recorded from March to May. In the Gr. Ratzeburger See, *E. lacustris* was recorded from April to June and in September (Fig. 2). Here the abundance of *E. lacustris* was lower than in the Gr. Küchensee but higher than in 2000. Maximum abundance (copepodids and adults; without nauplii) was 1.8 ind L^{-1} in the northern basin and 0.6 ind L^{-1} in the southern basin of the lake. Only one egg-bearing female, which carried 56 eggs was observed in the northern lake basin. However, males and all copepodid instars were observed in the

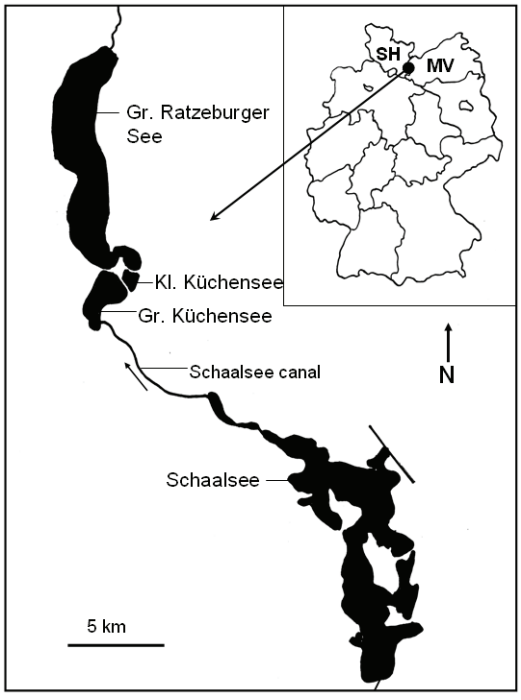

Fig. 2. Map of Germany (upper right corner) showing the position of the new sites of *Eurytemora lacustis* (SH = Schleswig-Holstein; MV = Mecklenburg Vorpommern). The more detailed map depicts the lake complex of Gr. Ratzeburger Lake, Kl. Küchensee and Gr. Küchensee, which are all connected *via* the Schaalsee canal to the Schaalsee upstream.

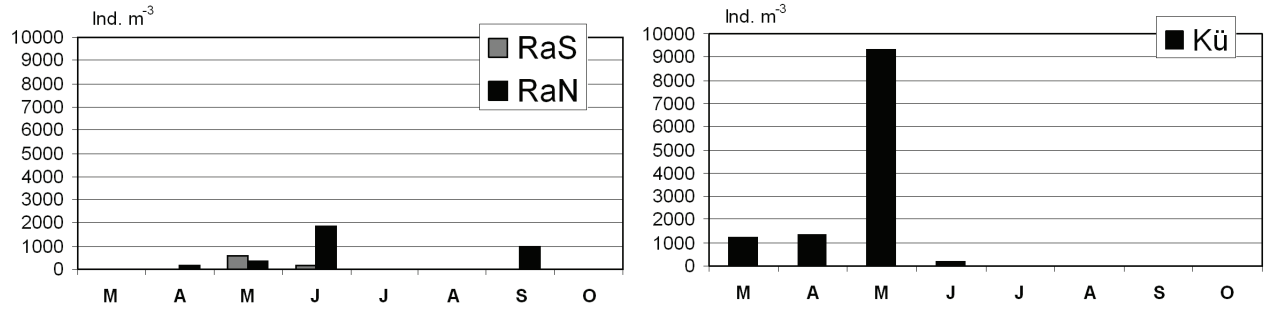

Fig. 3. Abundance of *Eurytemora lacustris* in the Gr. Ratzeburger See (RaN = northern lake basin; RaS = southern lake basin) and in the Gr. Küchensee (Kü) in individuals m^{-3} in 2008.

lake. During the peak abundance of *E. lacustris* in both lakes the phytoplankton was dominated by diatoms (high biovolumes in March) and cryptophytes (dominant in May during the clear water phase). Important species (by biovolume) were *Cyclotella radiosa* (Grunow; Lemmermann 1900) *Stephanodiscus alpinus* (Hustedt 1942) and *Asterionella formosa* (Hassall 1856) accompanied by small cryptophyte flagellates (mainly different *Cryptomonas* and *Rhodomonas* species). The maximum phytoplankton biovolume in March was approximately 14 mm^3 L^{-1} in the Gr. Küchensee and approximately 11 (northern basin) to 16 mm^3 L^{-1} (southern basin) in the Gr. Ratzeburger See. In April the phytoplankton biovolume dropped to approximately 2.5 mm^3 L^{-1} (Gr. Küchensee) and 1 mm^3 L^{-1} (Gr. Ratzeburger See), before decreasing further to 0.3 mm^3 L^{-1} in May in both lakes.

The lakes contain a large number of zooplankton species. Cladocerans were represented by *Bosmina coregoni coregoni* (Baird 1857), *Bosmina coregoni gibbera* (Schoedler 1863), *Bosmina longirostris* (O.F. Müller 1785), *Chydorus sphaericus* (O.F. Müller 1785), *Daphnia cucullata* (Sars 1862), *Daphnia galeata* (Sars 1864), *Daphnia* × *krausi* (Floessner 1993), *Diaphanosoma brachyurum* (Lievin 1848) and *Leptodora kindtii* (Focke 1844). Copepods present (besides *E. lacustris*) were *Eudiaptomus gracilis* (G.O. Sars 1863), *Eudiaptomus graciloides* (Lilljeborg 1888), *Acanthocyclops* sp. group *robustus* (G.O. Sars 1863), *Cyclops abyssorum* (G.O. Sars 1863), *Cyclops kolensis* (Lilljeborg 1901), *Cyclops vicinus* (Uljanin 1875), *Diacyclops bicuspidatus* (Claus 1857), *Mesocyclops leuckarti* (Claus 1857), *Thermocyclops crassus* (Fischer 1853) and *Thermocyclops oithonoides* (G.O. Sars 1863). Dur-

ing the peak abundance of *E. lacustris* in spring, the dominant crustaceans were *B. longirostris*, *D. galeata*, *Eudiaptomus* spp. and *Cyclops* spp. The other species listed above were rare (*D.* × *krausi*, *A.* sp. group *robustus*, *D. bicuspidatus*) or more frequently found during the summer and/or autumn. The average zooplankton biomass (March to October) was approximately 0.4 mg L^{-1} (Gr. Küchensee and Gr. Ratzeburger See N) and 0.25 mg L^{-1} (Gr. Ratzeburger See S) which confirms the eutrophic to mesotrophic condition of the lakes. For more details see Speth (2001) and Arp & Maier (2009).

4. DISCUSSION

Eurytemora lacustris has become rare and endangered in Germany. The species is threatened by eutrophication and global change. The findings in the Gr. Ratzeburger See, the Kl. Küchensee and the Gr. Küchensee are new for Schleswig-Holstein. Formerly, *E. lacustris* was present in several lakes such as the Gr. Plöner See or the Selenter See but the species disappeared from these lakes possibly as a consequence of combined effects of eutrophication and global warming (cf. Weiler *et al*. 2003 and citations therein). The lakes studied here do not show all the characteristics typical for habitats with viable populations of *E. lacustris* as described in Weiler *et al.* (2003) and Kasprzak *et al*. (2005). They are shallower than 30 m, however low temperatures and sufficient food resources seem to permit survival and reproduction at least in spring. The reason why oxygen concentrations in the hypolimnion were unfavourable in 2000 but favourable in the year 2008 cannot be explained at the present stage. Therefore, it remains unclear whether the populations in the studied lakes are autochthonous. It is possible that *E. lacustris* invaded the lakes or was transported via the Schaalsee canal from Schaalsee, which is located upstream and which hosts a viable population (Kasprzak *et al.* 2005). This assumption would support the hypothesis of Weiler *et al*. (2003) and Kasprzak *et al*. (2005) that most shallow lakes where *E. lacustris* is found are connected via canals with deep lakes which contain viable populations of the species. A further argument for the transport/invasion hypothesis is that no specimens of *E. lacustris* were found in summer in the studied lakes. Furthermore, abundance decreased downstream from the "input" of Schaalsee into the Gr. Küchensee to the Gr. Ratzeburger See, which also supports the transport/invasion hypothesis. On the other hand, the fact that E. lacustris was found in both years where the "Ratzeburger Lakes" were studied and the fact that the species was present in spring and autumn in the northern basin of the Gr. Ratzeburger See suggests that the species might be present regularly in these lakes. Since *E. lacustris* is a glacial relict with decreasing populations, further and more intensive studies are necessary to maintain up-to-date knowledge on the status of the species and on the effects of large-scale changes to glacial relicts and other endangered species.

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