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Aquatic Invasion Records

The copepod invader *Skistodiaptomus pallidus* (Herrick, 1879) (Crustacea, Copepoda, Diaptomidae) from North America in water bodies of Bremen, northern Germany

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Abstract

The paper presents the first European records of the copepod (Crustacea, Calanoida, Diaptomidae) *Skistodiaptomus pallidus* in shallow eutrophic waters indirectly connected with the Weser River, Northern Germany. Its original distribution is in the Mississippi basin of the United States of America. It is probable that this species entered the Weser River via ship ballast.

Key words: Nonindigenous species, Crustacea, Copepoda, Germany, Weser River

Introduction

Copepods are easily transported from one water body to another, either as adults, larvae or in resting stages. In nature passive transport by birds is a strategy to colonize periodic ponds or other water bodies. Long distance dispersal via birds is possible (Green and Figuerola 2005) and has been suggested as a mode of transport of copepods to new regions (Reid and Reed 1994). But human activity is by far the most efficient mechanism to disperse aquatic organisms from one place to another. Long distance displacement through anthropogenic vectors like shipping or aquaculture is a growing problem (Holeck et al. 2004; Bollens et al. 2002). Intercontinental introductions of calanoid copepods were reviewed by Reid and Pinto-Coelho (1994), but only marine or brackish species were recorded. Gollasch and Nehring (2006) offered a checklist for aquatic alien species from coastlines of the North and Baltic Seas and from inland waters within the national borders of Germany. Only the marine calanoid copepod *Acartia tonsa* Dana, 1849 was reported. Some invasive calanoid copepods have spread over continents and within a continent. The euryhaline species *Eurytemora affinis* (Poppe, 1880), native to Ponto-Caspian region, is reported from the western European coast, parts of Asia, and within North America from the Atlantic coast including the Gulf of Mexico to the Pacific coast (Kipp and Benson 2010). Another euryhaline species *Eurytemora velox* (Lilljeborg, 1853) migrated from the estuaries of the North Sea upstream of many rivers (Tollinger 1911) and from the Black Sea upstream in the Danube River (Gaviria and Forró 2000). *Sinodiaptomus valkanovi* Kiefer, 1938, endemic to Japan, where it is found in small ponds and reservoirs, is the only record of a diaptomid introduced from another continent to Europe. It was discovered in an aquarium in the botanical garden of Sofia, Bulgaria (Kiefer 1938) but it is not extant there any more (Ueda and Ohtsuka 1998). Here we present an introduction of a diaptomid copepod from the North American continent to Europe.

Material and methods

Description of the species records

While searching for *Leptodora kindtii* (Focke, 1884) in its type locality in the moat of the former fortifications of the city of Bremen (Dumont and Hollwedel 2009), we found four calanoid copepods, i.e. *Eurytemora velox* (Lilljeborg, 1853), *Eudiaptomus gracilis* (Sars, 1863), *Eudiaptomus graciloides* (Lilljeborg, 1888) and *Skistodiaptomus pallidus* (Herrick, 1879). The latter was a great surprise and difficult to

identify because it is a North American representative of the copepod family of Diaptomidae and was not expected to occur in northern Germany.

The so-called 'Stadtgraben' (Figure 1a) (coordinates 53°04'50.23"N, 08°48'25.97"E), the moat of Bremen, has a typical zigzag shape, a length of about 2,700 meters and covers an area of 9.5 hectares. The depth is about 2-3 m and sometimes dense mats of the coontail *Ceratophyllum demersum* and Nuttall's waterweed *Elodea nuttallii* have been found there. At the south-eastern end 80 liters per second of the Weser River water is pumped continuously into the moat and at the north-western end of the moat excess water flows back to the river. Because of the high conductivity of the Weser water of 1000 to 1400 µS cm^{-1}, the conductivity of the moats shows a similar range, between 1200 and 1400 µS cm^{-1}. During sampling on 17 June 2010 the water temperature was 18.6°C and the conductivity 1251 µS cm^{-1}.

A second population of *S. pallidus* was discovered in a pond on Juliusplate (Figure 1b) (coordinates 53°11'20.68"N, 08°30'58.93"E) a former island in the floodplain of the Weser River. *S. pallidus* was the only calanoid species found. The collection data for these specimens are (4 September 2010: water temperature 17.3°C and conductivity 1260 µS cm^{-1}).

Methods

Qualitative samples were taken from the shore of the moat by casting a plankton-net several times as far as possible and then towing back to the shore. The net had an opening of 20 cm and a mesh size of 56 µm. Samples were immediately preserved in 4% formaldehyde, and specimens identified using standard taxonomic keys (e.g., Kiefer 1978; Einsle 1993; Reid and Williamson 2010).

Results

On the date 17 June 2010 *Skistodiaptomus pallidus* was together with *Eudiaptomus gracilis* very abundant (in numbers: hundreds); *Eurytemora velox* was less abundant (in numbers: tens) and only a few specimens of *Eudiaptomus graciloides* were found. On 20 July 2010 *S. pallidus* was abundant and *E. gracilis* was less abundant.

The *Skistodiaptomus pallidus* specimens found in the Stadtgraben of Bremen had a mean body size (excluding furcal setae) of 1.24 mm (range 1.15 to 1.3; n = 44) for the females and 1.14 mm (range 1.11 to 1.2; n = 68) for males. Few females carried eggs (ca. 15%), mean number carried per female was 16 (range 14 to 20; n = 8). *S. pallidus* is a slender species of medium size.

Here we give a short description of the species with its essential characteristics (Figure 2).

Female:

Wings of the last metasomal segment do not expand laterally, and on each side have some hair-setae and minute sensilla at the tip (Figure 2a). The antennules reach beyond the furcal setae. Fifth legs are symmetrical (Figure 2b), the exopodite segment bears no spine, the basipodite segment is triangular with an outer sensory seta, the first exopodite segment is two times longer than broad, the second exopodite segment bears two unequal spines: one is 1.6 times longer than the other, the end claw slightly curved, there is no third exopodite segment, endopodite exceeds the second exopodite in length and bears two unequal spines at the tip.

Male:

The fourth and fifth metasomal segments are fused and do not expand laterally, each side has some hair-setae and sensilla (Figure 2c). The modified right geniculate antennule bears spines on segments 8, 10, 11, and 13 (Figure 2f); the one on segment 8 is the shortest and nearly triangular; the relations of the length of the spines on segments 10, 11 and 13 is 1:1.25:1.5; the spines on segment 10 and 11 are nearly perpendicular to the segment; the one on segment 13 is nearly parallel. The antepenultimate segment has no projections at the end and no hyaline lamella. The male left fifth leg is shorter than the right, reaching to the end of or slightly past the first segment of the right exopodite (Figure 2d). Coxa of the right fifth leg has a conical process posteriorly, that projects over the basipodite, with a sensilla on the tip. The exopodite is longer than broad. The first exopodite has a rounded sclerotized outgrowth posteriorly on the distal margin, projecting over the second basipodite. The second basipodite is 2.6 times longer than broad with a small triangular process near the middle of the inner border, a lateral spine inserted in the distal third of the segment, and a the claw that is more or

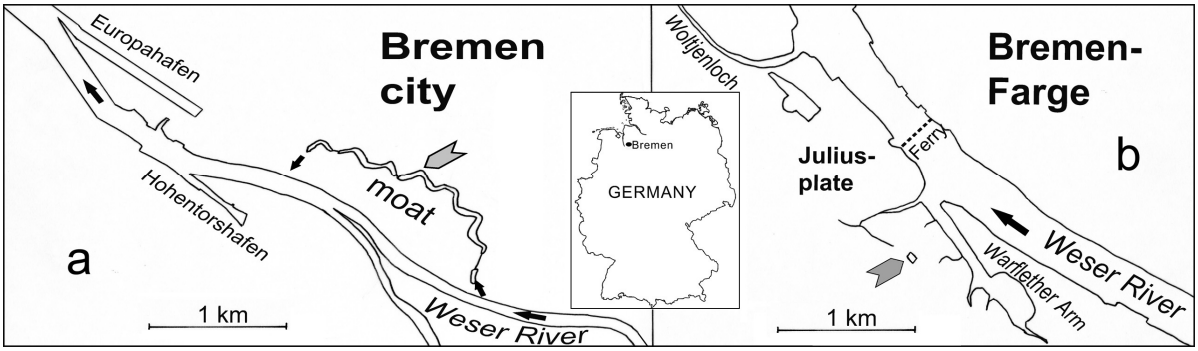

Figure 1. Geographic location of the water bodies in northern Germany where *Skistodiaptomus pallidus* has been found, broad grey arrow indicates sampling site.

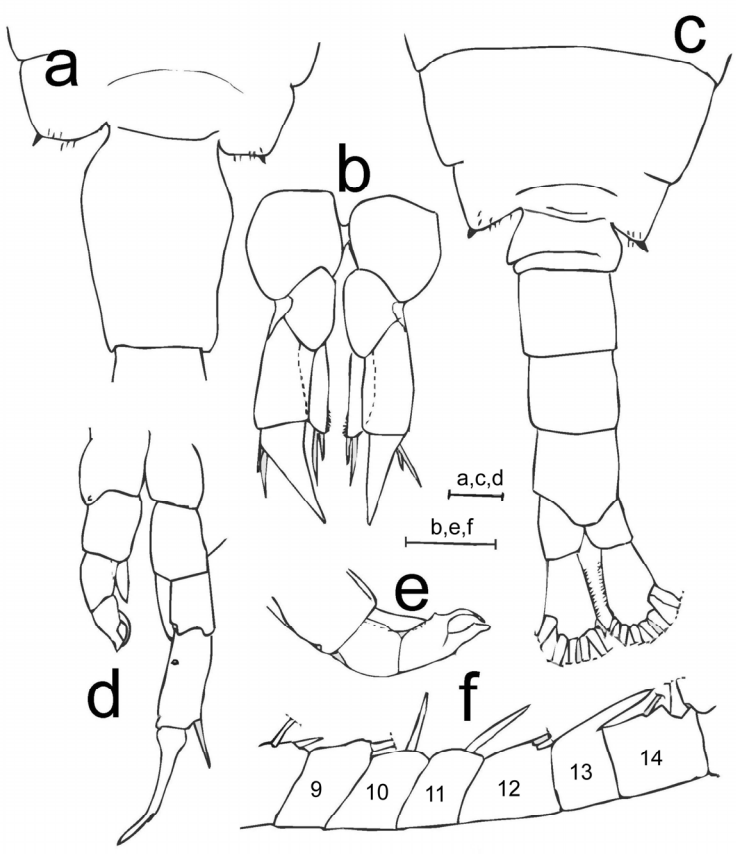

Figure 2. Morphological details of *Skistodiaptomus pallidus* from the moat of Bremen; a Female: fourth and fifth pedigorous somites and genital somite; b Female: fifth leg; c Male: last pedigorous somites and urosome; d Male: fifth leg; e Male: exopodite 1 and 2 of left fifth leg; f Male: segments 9 to 15 of right antennule, scale bars = 50 µm

less evenly curved. The endopodite is slender and reaches past the first exopodite segment. The coxa of the left fifth leg has a small coxal spine posteriorly. The basipodite is nearly quadratic; the exopodite is two-segmented with the first segment subtriangular and the second segment ending in a scythe- or pincer-like process (Figure 2e). The endopodite reaches the middle of the second exopodite.

Further morphological information can be obtained through UNH Center for Freshwater Biology (2009) and Lesko et al. (2003).

Discussion

Skistodiaptomus pallidus has been found in North America in productive lakes, rivers, reservoirs and permanent ponds (Torke 2001). It mainly occurs in beta-mesotrophic to eutrophic habitats with relatively high total phosphorus and total nitrogen. It can also tolerate high suspended solids and greater turbidity. It is typically found in waters with a pH range of 7.5–8.6 and a conductivity range of 77–660 μScm^{-1} (Kipp and Benson 2010). It has also been introduced to New Zealand where it was only found in constructed water bodies, ponds in a botanical garden, and a former quarry (Banks 2007). This corresponds with our findings of this species in man-made shallow eutrophic water bodies with submerse macrophytes. One difference in the environmental conditions in which we found *S. pallidus* was that the conductivity range was higher in the Weser area than in the other areas where it is found.

S. pallidus seems to have built a stable population in the moat of Bremen, where it has been found from June to September 2010. Whether there are other non-indigenous species in other crustacean families there cannot be said at this moment. A more detailed paper dealing also with Cladocera and Ostracoda will be published elsewhere. There is no indication that *S. pallidus* has any effect, positive or negative, upon other species of the moat.

Skistodiaptomus pallidus can produce diapausing eggs (Dowell 1997) which might survive transport by birds or in the ballast water of ships than would other life history stages (Panov et al. 2004). Although long distance dispersal via birds is possible (Green and Figuerola 2005) no bird migrating route exists between North America and Europe. *S. pallidus* probably reached the Weser River via ballast water because during the 20th century the port of Bremen had large shipping traffic navigating to many parts of the world. But other vectors like aquarium products cannot be excluded. The time of arrival may be past 1879/1880 when Poppe (1889) sampled the Stadtgraben and found only *Eurytemora velox* (in the Poppe paper as *Temorella clausii*). Samples from many other water bodies in and around the city of Bremen revealed *Eudiaptomus gracilis* and *Heterocope saliens* (Lilljeborg, 1862) but never any *Skistodiaptomus* (Poppe 1889).

S. pallidus is native to the north central, northeast, and southern United States in the Mississippi River basin (Pennak 1989; Mills et al. 1993; Torke 2001). Some authors consider that this species has been introduced to the Laurentian Great Lakes in North America, but Reid and Hudson (2008) think that The Great Lakes records may be from individuals that are occasionally flushed from the nearby stream-wetland systems into the lakes, where they are unlikely to persist. Therefore they advocate for the removal of *S. pallidus* from the list of accidentally introduced species. In New Zealand the species has been found only on the North Island (Banks 2007), it was perhaps introduced via the dumping of aquarium contents (Duggan et al. 2006). In Germany we have found *S. pallidus* so far in two water bodies indirectly connected to the Weser River. The current distribution in Europe can only be shown by more extensive sampling in the Weser and other water bodies.

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