https://doi.org/10.35513/21658005.2019.2.4

Zoology and Ecology, 2019, Volume 29, Number 2
Print ISSN: 2165-8005
Online ISSN: 2165-8013

CHANGES IN THE DISTRIBUTION OF AMPHIPODS IN THE DAUGAVA RIVER, LATVIA

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Article history
Received: 18 September 2018; accepted 3 June 2019

Keywords:
Alien amphipods; distribution; Daugava River

Abstract. Scientific information on amphipods and other peracaridan crustaceans in Latvian inland waters is insufficient. Therefore investigations of these animals are indispensable, especially because of the ongoing biological invasions of Ponto-Caspian amphipods causing changes in macroinvertebrate assemblages. Our recent investigation revealed that the alien amphipod *Gammarus varsoviensis* dominates amphipods in the upper courses of the Daugava River, whereas the other alien amphipod *Pontogammarus robustoides* prevails in the lower reaches of the river. Both these Ponto-Caspian amphipods were found co-occurring with the indigenous *Gammarus pulex* in the middle course of the Daugava River upstream from the Pļaviņas Reservoir. We predict that in the future the indigenous *G. pulex* will be fully exterminated by alien amphipods in the Latvian part of the Daugava River.

Freshwater amphipods, both alien and indigenous, have not been sufficiently studied in Latvian waters. This information is important because due to possible invasions of alien peracaridan crustaceans including amphipods, dramatic alterations in macroinvertebrate assemblages and even extinctions of indigenous amphipods can occur. Recently, the Ponto-Caspian amphipod *Dikerogammarus villosus* has been detected in the Riga port (Minchin at al. 2019), and the presence of *Obesogammarus crassus* in the Riga port area has been confirmed (at Voleri, in 2016, pers. unpublished results).

Currently, the Ponto-Caspian *Pontogammarus robustoides* is the dominant alien amphipod in Latvian inland waters, mostly occurring in the Lower Daugava River (Grudule, Parele, and Arbačiauskas 2007; Paidere, Brakovska, and Škute 2016). The species was initially introduced into Latvian waters as valuable fish fodder in the 1960s. It was released into both, Lake Lielais Baltezers, which is nearest to Riga Lake, and the Ķegums Reservoir located on the Lower Daugava River (Kachalova and Lagzdin 1968; Bodniece 1976). The other alien amphipod *Gammarus varsoviensis* was first recorded in the Daugava River in 2006 (Arbačiauskas 2008). This species was first described and separated from the morphologically similar *Gammarus lacustris* in 1975 (Jażdżewski 1975). It used to be considered a native species in Central Europe (Germany, Poland, Lithuania and Belarus), however, the detection of *G. varsoviensis* in the Dnieper River catchment in the Ukraine suggests that the species is not native to Central Europe, but is rather an immigrant species from the Ponto-Caspian region (Grabowski et al. 2012a, b). According to the findings of the haplotype-based genetic analysis, *G. varsoviensis* is grouped into two clades, one of which is distributed in the Lower Dnieper River and the other in the Upper Dnieper River and the Baltic Sea basin (Grabowski et al. 2012b). Consequently, the purpose of this study was to reveal the distribution of *G. varsoviensis* and *P. robustoides* in the Daugava River, and to ascertain whether native amphipod species occur there.

The Daugava River (the Western Dvina) is one of the largest rivers in Eastern Europe. Starting in the Valday Highlands in Russia, the river flows through the East-European Plain and crosses Belarus and Latvia before draining into the Gulf of Riga. The catchment area of the Daugava River is around 87 900 km^2 and its total length is around 1005 km, 342 km of which are within the territory of Latvia. The cascade of three large hydroelectric power plants at Pļaviņas, Ķegums and Riga on the Lower Daugava forms the largest artificial river reservoirs in Latvia (Volchak and Lyakmund 2006).

Sampling of amphipods was carried out within the Pļaviņas Reservoir (site "Gostiņi") and upstream from the Pļaviņas Reservoir, at sites "Veczeļki", "Zeļki", "Jēkabpils" and "Daugavpils", in 2016, 2017 and 2018 (Figure 1). Amphipod samples were obtained seasonally, from May until September/October. Qualitative samples of amphipods were collected at wadeable (up to 0.5 m) depths using a standard hand net with a mouth opening of 25 × 25 cm (500 µm mesh).

Amphipod specimens were identified by morphological characters of adult males (Figure 2) referring to the following literature: Pinkster (1970, 1972), Karaman and Pinkster (1977), Jazdzewski (1975), Eggers and Martens (2001, 2004) and Guide for Identification of the Fauna of the Black and Azov Seas (1969).

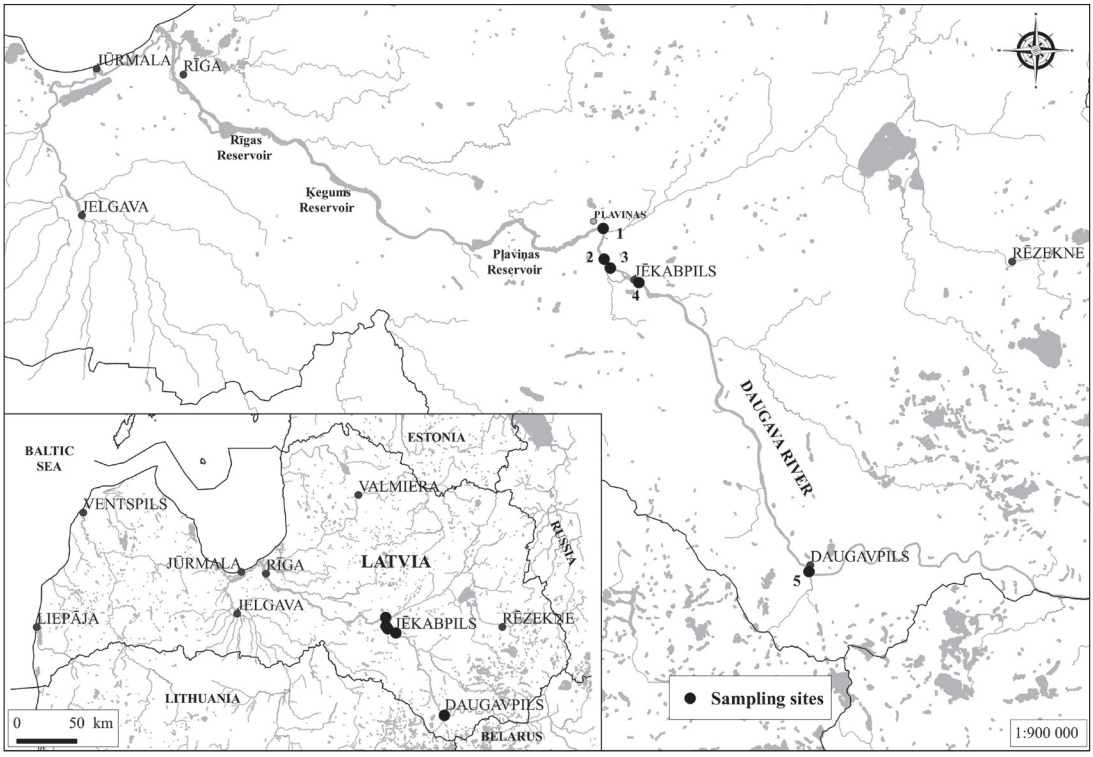

Figure 1. Sampling sites of amphipods along the Daugava River. 1 – Pļaviņas Reservoir (2016, 2017, 2018), 2 – Zeļķi (2016), 3 – Veczeļķi (2016, 2017), 4 – Jēkabpils (2017, 2018), 5 – Daugavpils (2017, 2018). © Paidere, map created with QGIS Essen 2.14 based on the free online database GIS Latvija 10.2 (http://www.envirotech.lv/)

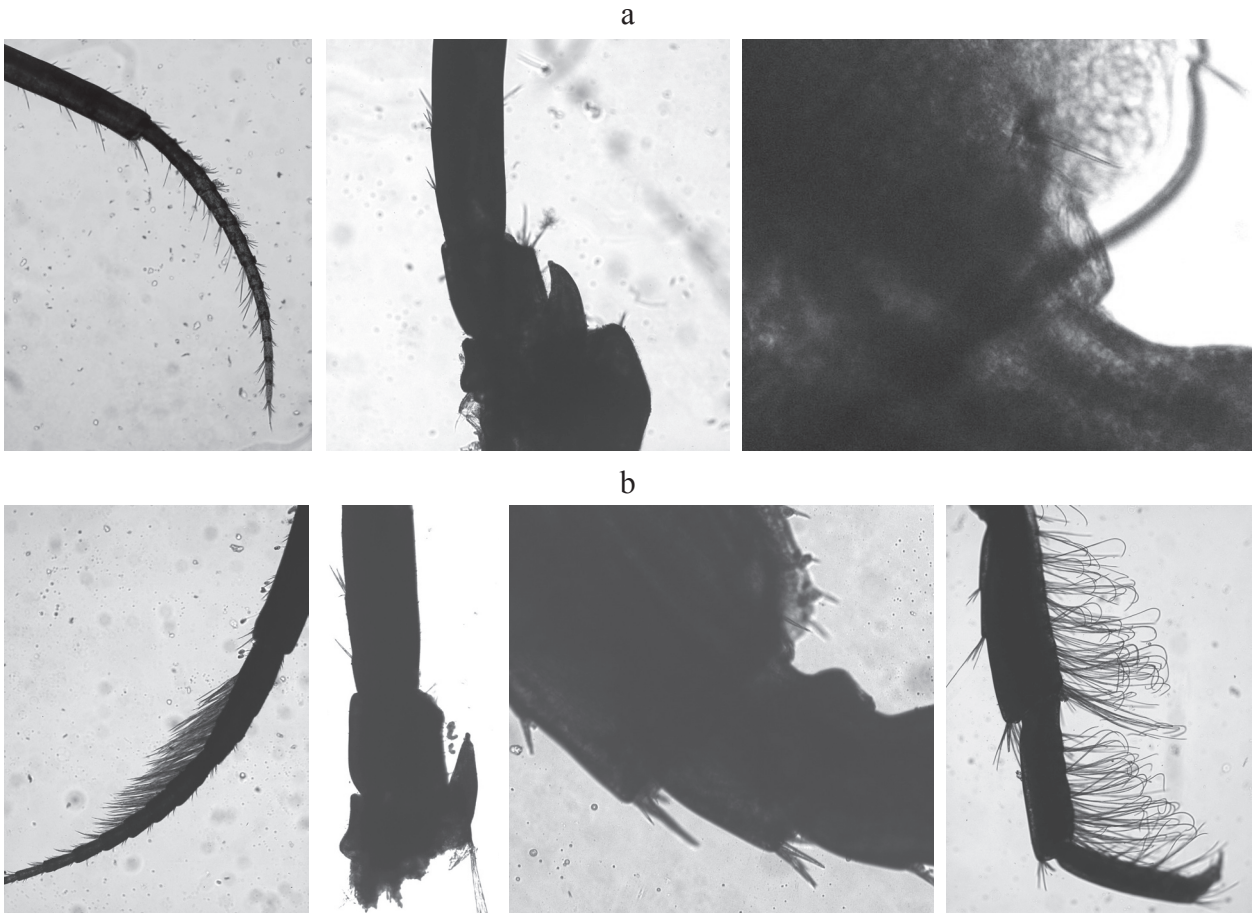

Figure 2. Some morphological characteristics of the specimens *Gammarus varsoviensis* and *Gammarus pulex* from the Daugava River (site "Jēkabpils"); a) *G. varsoviensis*, b) *G. pulex.*

The investigations conducted in 2016, 2017 and 2018 revealed the current distribution of alien amphipods *G. varsoviensis* and *P. robustoides* in the lower/middle course of the Daugava River. *Pontogammarus robustoides*, which was found in the Pļaviņas Reservoir, was the dominant amphipod species during all study years (Figure 3), which is in agreement with the findings of our previous studies (Paidere, Brakovska, and Škute 2016). The amphipod species that were found occurring upstream from the Pļaviņas Reservoir in 2016 differed from those detected in 2017. At sites "Zeļķi" and "Veczeļķi," *P. robustoides* was gradually replaced by *G. varsoviensis*. Although small in numbers, the indigenous amphipod *Gammarus pulex* was also detected there. In 2017 and 2018, the indigenous *G. pulex* and alien *G. varsoviensis* co-occurred at the site "Jēkabpils". In these years, *G. varsoviensis* actually was the only amphipod species found at the site "Daugavpils". Single specimens of *G. pulex* were observed at this site only in May of both years (Figure 3).

According to Grabowski et al. (2012b), *G. varsoviensis*, which has colonised the lowland rivers of the Baltic Sea basin, has immigrated from the Dnieper basin. In Belarus, *G. varsoviensis* is one of the most widespread species in inland waters, occurring not only in the Pripyat River catchment and other tributaries of the Upper Dnieper River, but also in the Upper Daugava River (the Western Dvina) (Makarenko and Vezhnovets 2014). In Lithuania, *G. varsoviensis* inhabits the upper course and some tributaries of the lower course of the Neman River. The species invaded Lithuanian waters at the end of the 18th century via the man-made Oginsky Canal that connected the basins of the Neman and Dnieper rivers, and this happened before the introduction of other Ponto-Caspian amphipods (Arbačiauskas 2008; Arbačiauskas et al. 2017). The distribution of *G. varsoviensis* in the Upper and Middle Daugava River can presumably be explained by artificial connection of the Daugava River and the Upper Dnieper River in 1805 by the so-called "Berezina water system", the Berezina River being the right tributary of the upper Dnieper River. The distribution of the alien mussel *Dreissena polymorpha* in the northern part of Belarus has been also related to this man-made hydrological system (Karataev et al. 2008). Lowland streams and rivers with slow or moderately fast flow velocity are common habitats for *G. varsoviensis* (Jażdżewski 1975; Grabowski et al. 2012a). Currently, the alien *G. varsoviensis* is the dominant amphipod species in the Upper Daugava River; the indigenous amphipod *G. pulex* was recorded only at the mouth of small tributaries of the Upper Daugava River (tributaries upstream and downstream of Daugavpils City were investigated, pers. unpublished results). Possibly, the distribution of the alien *G. varsoviensies* in the Daugava River has been the same as in Lithuanian inland waters, where the species colonized the entire Neman River before the introduction of other Ponto-Caspian peracaridan species in the middle of the 20th century (Arbačiauskas et al. 2017). To affirm it, investigations of *G. varsoviensis* should be continued in tributaries of the Lower Daugava River.

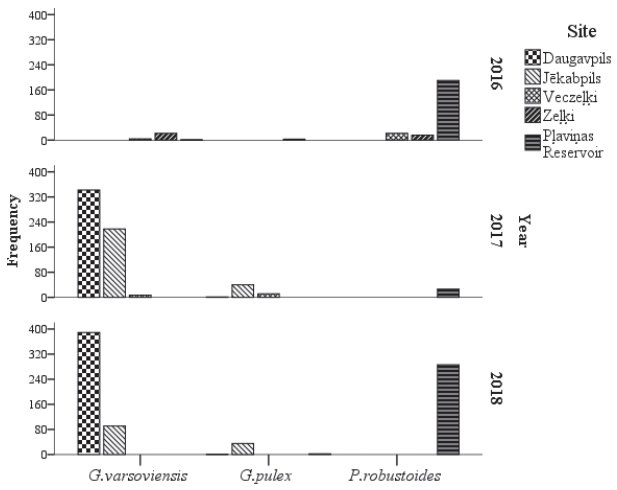

Figure 3. Frequencies of amphipod species in qualitative samples collected from the Pļaviņas Reservoir and the Daugava River in 2016, 2017 and 2018.

The comparison of *P. robustoides* distribution data for 1995–2005, for 2015 (Grudule, Parele, and Arbačiauskas 2007; Paidere, Brakovska, and Škute 2016), and those obtained from the recent study shows that now the alien *P. robustoides* is the dominant amphipod species in reservoirs of the Daugava River. It is obvious that expansion of *P. robustoides* is ongoing and, in the future, the species is going to spread further along the Upper Daugava River.

The indigenous *G. pulex* still occurs in low numbers in some Daugava places. The species also inhabits the middle course of the Lielupe River (at Staļģene, Emburga, observed in 2017, pers. unpublished results), which is not yet invaded by *P. robustoides*. However, in the future, the indigenous *G. pulex* is likely to be fully exterminated by the alien species *G. varsoviensis* and *P. robustoides* in the upper and middle courses of the Daugava River. Apparently, *P. robustoides* has contributed to the elimination of this indigenous amphipod from the Lower Daugava River and its reservoirs, because in the 1960s *G. pulex* was still present in the Lower Daugava River (Kumsare et al. 1967).

FUNDING

This research was supported by the DU Research Project No. 14–95/3 "Research into the factors contributing to biological invasions of alien amphipods (*Pontogammarus robustoides, Gammarus varsoviensis*)".

ACKNOWLEDGEMENT

The authors would like to thank the anonymous reviewers for their insight, helpful and constructive comments that greatly contributed to the improvement of the final version of the paper.

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