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Citation style: Lewin Iga, Halabowski Dariusz, Rymarski Zbigniew. (2018). The first records of the occurrence of a North American invader Gammarus tigrinus Sexton, 1939 in the tributaries of the upper Vistula River. "Knowledge and Management of Aquatic Ecosystems" (Vol. 419 (2018), s. 31), doi 10.1051/kmae/2018021

Knowl. Manag. Aquat. Ecosyst. 2018, 419, 31
© I. Lewin et al., Published by EDP Sciences 2018
https://doi.org/10.1051/kmae/2018021

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Knowledge & Management of Aquatic Ecosystems
Journal fully supported by Onema

SHORT COMMUNICATION | OPEN ACCESS

The first records of the occurrence of a North American invader *Gammarus tigrinus* Sexton, 1939 in the tributaries of the upper Vistula River

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Abstract – The amphipod species *Gammarus tigrinus*, Sexton 1939 is native to the Atlantic coast of North America. The native range of its occurrence includes oligo- and mesohaline brackish waters with salinity of up to 14‰. Our survey was carried out in the tributaries of the upper Vistula River in Upper Silesia that is the most urbanised and industrialised region in Poland and constitutes one of the largest coal basins in the world. This survey uncovered the first occurrence of *G. tigrinus* with the maximum density of 1040 individuals m^{-2} in the tributaries of the upper Vistula River that have been polluted by coal mine water discharge. The occurrence of the invasive alien gastropod species, *i.e. Potamopyrgus antipodarum* (Gray, 1843) was also recorded in such salinised water. Our results showed that the anthropogenically salinised tributaries of the upper Vistula River constitute new habitats for euryhaline species and create new migration routes for alien and invasive species.

Keywords: alien species / gammarid / river / salinisation

Résumé – Les premiers signalements de l'apparition d'un envahisseur nord-américain *Gammarus tigrinus* Sexton, 1939 dans les affluents de la Vistule supérieure. L'espèce d'amphipode *Gammarus tigrinus*, Sexton 1939 est originaire de la côte atlantique de l'Amérique du Nord. L'aire de répartition de sa présence naturelle comprend les eaux saumâtres oligo- et mésohalines d'une salinité allant jusqu'à 14‰. Notre étude a été réalisée dans les affluents de la haute Vistule en Haute Silésie, la région la plus urbanisée et industrialisée de Pologne et qui constitue l'un des plus grands bassins houillers du monde. Ce relevé a mis en évidence la première occurrence de *G. tigrinus* avec une densité maximale de 1040 individus m^{-2} dans les affluents de la Vistule supérieure qui ont été pollués par les rejets d'eau des mines de charbon. La présence de l'espèce exotique envahissante de gastéropode, à savoir *Potamopyrgus antipodarum* (Gray, 1843) a également été enregistrée dans ces eaux salinisées. Nos résultats ont montré que les affluents anthropogéniquement salinisés de la haute Vistule constituent de nouveaux habitats pour les espèces euryhalines et créent de nouvelles voies de migration pour les espèces exotiques et envahissantes.

Mots-clés : espèces exotiques / gammaridé / rivière / salinisation

The amphipod species *Gammarus tigrinus*, Sexton (1939), which is typical of small and large estuaries or creek mouths, is native to the Atlantic coast of North America. The native range of its occurrence includes oligo- and mesohaline brackish waters with salinity of up to 14‰. Its range includes the estuary of the St. Lawrence River, the Chesapeake Bay, the estuary of the Potomac River and Florida (Bousfield, 1969). *G. tigrinus* colonised the Laurentian Great Lakes at density of 283 individuals m^{-2} during 2001–2004 (Grigorovich *et al.*, 2005). In Europe, it was found in the brackish waters of the Salwarpe River (the Droitwich district, UK) for the first time in 1931 (Sexton, 1939) (Fig. 1). *G. tigrinus* was deliberately introduced into German rivers, which had been heavily polluted by the potash mining industry, *i.e.* the Weser and the Werra in 1957 from England to compensate for a decrease in the native amphipod species (Bäthe and Coring, 2011; Braukmann and Böhme, 2011). This North American species then began to

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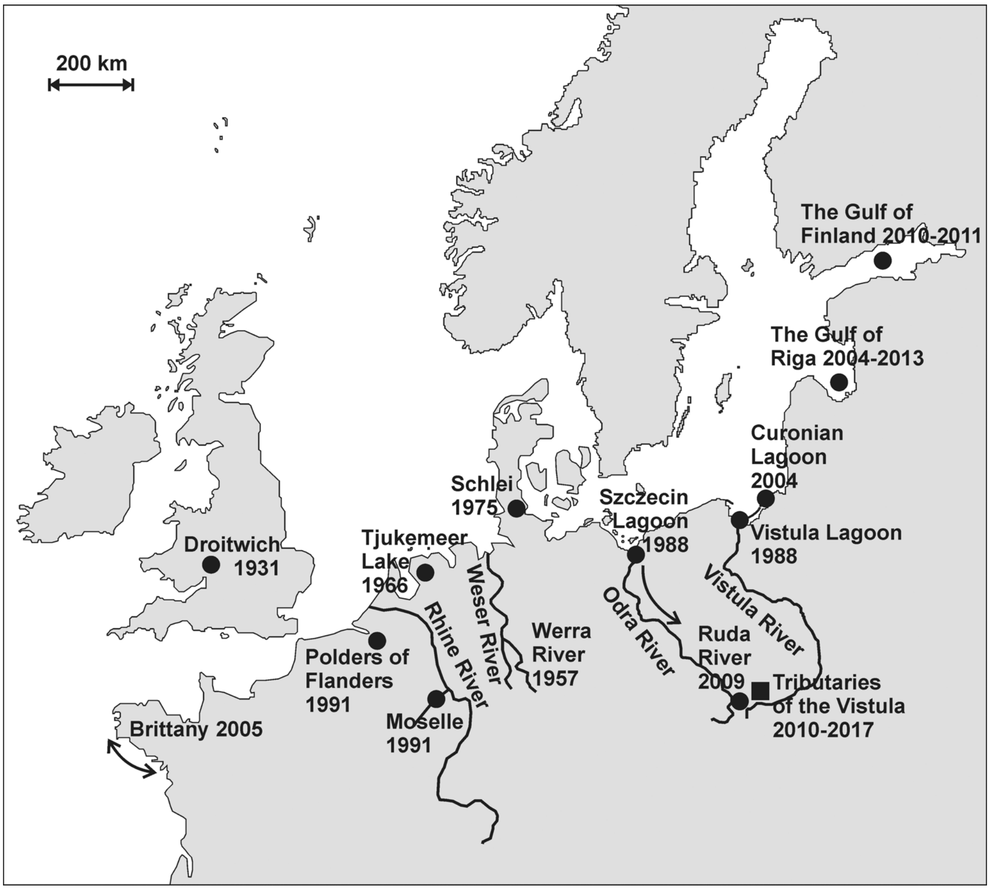

Fig. 1. The distribution and possible migration routes *of Gammarus tigrinus*, Sexton 1939 in Europe (Author: Z. Rymarski).

occur in the inland waters of continental Europe. *G. tigrinus* was recorded in the Netherlands at a density up to 24 000 individuals m^{-2} in 1960 (Chambers, 1977). In 1991, this amphipod was first recorded in the Moselle River, an oligohaline tributary of the Rhine River (north-eastern France) from where it dispersed to the other catchments of the rivers (the Saône, the Rhône, the Loire Rivers) *via* canals. It was first reported along the southern cost of Brittany in 2005 (Piscart *et al.*, 2005; 2008). *G. tigrinus* was first recorded in the Schlei estuary in the Baltic Sea (Germany) in 1975 (Pienimäki *et al.*, 2004). *G. tigrinus* continued its spread to the Szczecin Lagoon (Poland) by 1990 (Gruszka, 1999) and it had reached the Vistula Lagoon by 1998 (Jazdzewski *et al.*, 2004). By 2007, this amphipod species was recorded in the lower and middle courses of the Odra River (Grabowski *et al.*, 2007) and was continuing to spread upstream. Recently, it has been found in the tributaries and catchment of the upper Odra River (Spyra *et al.*, 2015; Sowa *et al.*, 2018). Simultaneously, *G. tigrinus* has successfully continued its spread within the Baltic Sea (Pienimäki *et al.*, 2004; Daunys and Zettler, 2006; Kotta *et al.*, 2013; Strode *et al.*, 2013) (Fig. 1).

Our survey was carried out in the tributaries of the upper Vistula River from 2010 to 2017 (Upper Silesia and adjacent areas, Poland). The Vistula River has a total length of 1047 km and a catchment area of 194 424 km^2 (the longest river in Poland). Upper Silesia is the most urbanised and industrialised region in Poland and constitutes one of the largest coal basins in the world. Three tributaries of the upper Vistula River, *i.e.* the Potok Gromiecki River, the Gostynia River, the Mleczna River as well as the inflow into the Mleczna River from a coal mine dewatering system were investigated. The waters of these tributaries are characterised by high levels of chlorides, sulphates, biogenic elements or conductivity, which is a consequence of the discharge of mine waters from the coal mine dewatering system into the rivers. Samples of the macroinvertebrates were collected according to quantitative methods and the physical and chemical parameters of the water were also analysed (Tab. 1). This survey uncovered the first occurrence of *G. tigrinus* in the tributaries of the upper Vistula River (Fig. 2).

Amphipods were identified to the species level according to Eggers and Martens (2001). The maximum density of *G. tigrinus* was 1040 individuals m^{-2} in the tributaries of the upper Vistula River. The occurrence of the invasive alien gastropod species, *i.e. Potamopyrgus antipodarum* (Gray, 1843) and alien species *Physa acuta* Draparnaud, 1805 were also recorded in such salinised water. The density of *G. tigrinus* decreased to only a few specimens in the Potok Gromiecki River when the conductivity of the water increased to 40 900 ($\mu S\,cm^{-1}$) as a consequence of coal mine water discharge into the river. Our survey showed the first occurrence of *G. tigrinus* in rivers with a relatively high conductivity (salinity) (Tab. 2).

This euryhaline gammarid species tolerates salinity of up to 25 PSU (Pienimäki *et al.*, 2004). According to the surveys of Jazdzewski *et al.* (2004) and Grabowski *et al.* (2009), *G.*

Table 1. Density (individuals m^{-2}) of *Gammarus tigrinus* and *Potamopyrgus antipodarum* in relation to the physical and chemical parameters of the water (ranges) in the tributaries of the upper Vistula River.

Species	The Potok Gromiecki River		The Gostynia River	The Mleczna River	Inflow to the Mleczna River from the coal mine dewatering system
Geographic coordinates	N 50°03.418′ E 19°18.260′		N 50°05.319′ E 18°58.885′	N 50°09.701′ E 19°00.317′	N 50°09.799′ E 19°00.338′
Years of the surveys	2010	2017	2015–2017	2014–2017	2014–2017
Gammarus tigrinus	91	a few specimens	28–261	120–1040	2–176
Potamopyrgus antipodarum	190	0	205–4461	23–62	290–7257
Conductivity ($\mu S\, cm^{-1}$)	9740	40 900	2290–3370	2030–3090	2130–3540
Chlorides (mg Cl^{-} dm^{-3})	2980	28 700	560–590	332–810	388–860
Ammonium (mg NH_4^{+} dm^{-3})	0.89	2.99	0.61–0.97	0.24–0.91	0.16–2.82
Phosphates (mg PO_4^{3-} dm^{-3})	0.26	0.21	0.19–0.24	0.04–0.32	0.01–0.14
Hardness (mg $CaCO_3$ dm^{-3})	495	4498	450–485	480–570	485–645
Salinity (‰)	6.2	25.8	1.1–2.1	1.3–2.0	1.1–2.3

Fig. 2. Male and female *Gammarus tigrinus* Sexton, 1939 in a tributary of the upper Vistula River (The Mleczna River) (Author: D. Halabowski).

tigrinus thrives especially well in oligohaline waters of conductivity ranged from 1000 to 8000 $\mu S\, cm^{-1}$ (0.5–4.0 PSU) and is a very successful invader in the Dead Vistula and in the Vistula Lagoon.

Two different possible patterns of *G. tigrinus* migration to the tributaries of the upper Vistula River can be considered. The first one is the dispersal of *G. tigrinus* from the upper course of the Odra River to the tributaries of the upper Vistula River by the local inland canal-river systems. *G. tigrinus* spreads within the riverine habitats in the Odra River that are well connected to other European waterways (Szlauer-Łukaszewska *et al.*, 2018). *G. tigrinus* is often found in ecosystems disturbed by anthropogenic pollution including salinisation. Such ecosystems are typical of Upper Silesia. It was also shown that specimens of amphipods are able to attach to invertebrates (molluscs, rotifers or infusorians) that can be considered as possible vectors of their accidental introduction (Berezina, 2007). The upstream migration of *G. tigrinus* from the Vistula Lagoon may be considered as the second possible path of the dispersion. However, the result of Grabowski *et al.* (2007) showed that the distribution of *G. tigrinus* was limited exclusively to the brackish parts of the Vistula Lagoon or the Vistula River mouth and that the gammarid had not dispersed upstream. Therefore, the possible migration route of *G. tigrinus* into the tributaries of the upper Vistula River is not known and this requires further research.

According to Grabowski *et al.* (2007), *G. tigrinus* had replaced the native invertebrates, including other gammarid species in most of the colonised habitats. The high degree of invasive potential and its capacity for further expansion is related to its higher fecundity, smaller size at breeding and an earlier start of the breeding season, significant predation pressure as well as its ability to tolerate a broader range of environmental conditions compared to the native gammarids (Jänes *et al.*, 2015). Grabowski *et al.* (2009) revealed that the small, natural tributaries of large rivers (the Odra, the Vistula Rivers) may function as refugia for the native amphipod fauna. In contrast, our results showed that the anthropogenically salinised tributaries (coal mine water discharge) of a large river (the upper Vistula River) constitute new habitats for euryhaline species and create new migration routes for alien and invasive species, *e.g.* for *G. tigrinus* and *P. antipodarum*.

Acknowledgements. The authors are deeply indebted to the Editor-in-Chief and to the anonymous reviewers for their valuable suggestions and comments which significantly improved the quality of this manuscript.

The authors are also grateful to Ms. Michele L. Simmons, B.A., University of Silesia, Faculty of Biology and Environmental Protection, Katowice, Poland, for improving the English style.

Table 2. Examples of the occurrence of *Gammarus tigrinus* in relation to the conductivity, concentration of chlorides in the water and salinity in inland and coastal habitats.

Conductivity ($\mu S\ cm^{-1}$)	Chlorides ($mg\ Cl^{-}\ dm^{-3}$)	Salinity (PSU)	Density (individuals m^{-2})	Area of occurrence, country	References
15 500				Watch Lane Flash (lake) England	Savage (1982)
3422				The Meurthe River, France	Piscart *et al.* (2005)
2800				Bivet, Brittany, France	Piscart *et al.* (2008)
	5860			Brackish polder in Flanders (Belgium)	Boets *et al.* (2011)
8500	2500	4.6	3500	The Werra River (Germany)	Braukmann and Böhme (2011); Bäthe and Coring (2011); Arle and Wagner (2013)
2870				The Odra River (Poland)	Rachalewski *et al.* (2013)
		1.4–3.5	1520	The Vistula Lagoon	Jazdzewski *et al.* (2004); Grabowski *et al.* (2006); Dobrzycka-Krahel *et al.* (2013)
		0.2–4.9	74	The Vistula Delta	Dobrzycka-Krahel *et al.* (2013)
			6399	Puck Bay	Janas and Kedzierska (2014)
		0–10.0	10 767	The Gulf of Finland	Kotta *et al.* (2013)
			1–70	The Latvian waters of the Gulf of Riga	Strode *et al.* (2013)
		4.5–6.0	110–508; maximum 4700	The Gulf of Riga	Reisalu *et al.* (2016)

References

Arle J, Wagner F. 2013. Effects of anthropogenic salinization on the ecological status of macroinvertebrate assemblages in the Werra River (Thuringia, Germany). *Hydrobiologia* 701: 129–148. DOI: 10.1007/s10750-012-1265-z.

Bäthe J, Coring E. 2011. Biological effects of anthropogenic salt-load on the aquatic fauna: a synthesis of 17 years of biological survey on the rivers Werra and Weser. *Limnologica* 41: 125–133. DOI: 10.1016/j.limno.2010.07.005.

Berezina NA. 2007. Invasions of alien amphipods (Amphipoda: Gammaridea) in aquatic ecosystems of North-Western Russia: pathways and consequences. *Hydrobiologia* 590: 15–29. DOI:10.1007/s10750-007-0753-z.

Boets P, Lock K, Goethals PLM. 2011. Shifts in the gammarid (Amphipoda) fauna of brackish polder waters in Flanders (Belgium). *J Crustacean Biol* 31: 270–277. DOI:10.1651/10-3357.1.

Bousfield EL. 1969. New records of Gammarus (Crustacea: Amphipoda) from the middle Atlantic Region. *Chesapeake Sci* 10: 1–17.

Braukmann U, Böhme D. 2011. Salt pollution of the middle and lower sections of the river Werra (Germany) and its impact on benthic macroinvertebrates. *Limnologica* 41: 113–124. DOI:10.1016/j.limno.2010.09.003.

Chambers MR. 1977. The population ecology of *Gammarus tigrinus* (Sexton) in the reed beds of the Tjeukemeer. *Hydrobiologia* 53: 155–164.

Daunys D, Zettler ML. 2006. Invasion of the North American amphipod (*Gammarus tigrinus* Sexton, 1939) into the Curonian Lagoon, south-eastern Baltic Sea. *Acta Zool Litu* 16: 20–26.

Dobrzycka-Krahel A, Tarała A, Chabowska A. 2013. Expansion of alien gammarids in the Vistula Lagoon and the Vistula Delta (Poland). *Environ Monit Assess* 185: 5165–5175. DOI:10.1007/s10661-012-2933-1.

Eggers TO, Martens A. 2001. A key to the freshwater Amphipoda (Crustacea) of Germany. *Lauterbornia* 42: 1–70.

Grabowski M, Konopacka A, Jazdzewski K, Janowska E. 2006. Invasions of alien gammarid species and retreat of natives in the Vistula Lagoon (Baltic Sea, Poland). *Helgol Mar Res* 60: 90–97. DOI: 10.1007/s10152-006-0025-8.

Grabowski M, Jazdzewski K, Konopacka A. 2007. Alien crustacea in Polish waters – Amphipoda. *Aquat Invasions* 2: 25–38. http://dx.doi.org/10.3391/ai.2007.2.1.3.

Grabowski M, Bacela K, Konopacka A, Jazdzewski K. 2009. Salinity-related distribution of alien amphipods in rivers provides refugia for native species. *Biol Invasions* 11: 2107–2117. DOI: 10.1007/s10530-009-9502-8.

Grigorovich IA, Kang M, Ciborowski JJH. 2005. Colonization of the Laurentian Great Lakes by the amphipod *Gammarus tigrinus*, a native of the North American Atlantic Coast. *J Great Lakes Res* 31: 333–342, https://doi.org/10.1016/S0380-1330(05)70264-1.

Gruszka P. 1999. The river Odra estuary as a gateway for alien species immigration to the Baltic Sea basin. *Acta Hydrochim Hydrobiol* 27: 374–382.

Janas U, Kedzierska H. 2014. Benthic non-indigenous species among indigenous species and their habitat preferences in Puck Bay (Southern Baltic Sea). *Oceanologia* 56: 603–628. DOI:10.5697/oc.56-3.603.

Jänes H, Kotta J, Herkül K. 2015. High fecundity and predation pressure of the invasive *Gammarus tigrinus* cause decline of indigenous gammarids. *Estuar Coast Shelf Sci* 165: 185–189, http://dx.doi.org/10.1016/j.ecss.2015.05.014.

Jazdzewski K, Konopacka A, Grabowski M. 2004. Recent drastic changes in the gammarid fauna (Crustacea, Amphipoda) of the Vistula River deltaic system in Poland caused by alien invaders. *Divers Distrib* 10: 81–87.

Kotta J, Pärnoja M, Katajisto T, Lehtiniemi M, Malavin SA, Reisalu G, Panov VE. 2013. Is a rapid expansion of the invasive amphipod *Gammarus tigrinus* Sexton, 1939 associated with its niche selection: a case study in the Gulf of Finland, the Baltic Sea. *Aquat Invasions* 8: 319–332.

Pienimäki M, Helavuori M, Leppäkoski E. 2004. First findings of the North American amphipod *Gammarus tigrinus* Sexton, 1939 along the Finnish coast. *Memo Soc Pro Fauna Flora Fenn* 80: 17–19.

Piscart C, Moreteau J-C, Beisel J-N. 2005. Biodiversity and structure of macroinvertebrate communities along a small permanent salinity gradient (Meurthe River, France). *Hydrobiologia* 551: 227–236. DOI:10.1007/s10750-005-4463-0.

Piscart C, Maazouzi C, Marmonier P. 2008. Range expansion of the North American alien amphipod *Gammarus tigrinus* Sexton, 1939 (Crustacea: Gammaridae) in Brittany, France. *Aquat Invasions* 3: 449–453.

Rachalewski M, Konopacka A, Grabowski M, Bącela-Spychalska K. 2013. *Echinogammarus trichiatus* (Martynov, 1932) – a new Ponto-Caspian amphipod invader in Poland with remarks on other alien amphipods from the Oder River. *Crustaceana* 86: 1224–1233. DOI:10.1163/15685403-00003228.

Reisalu G, Kotta J, Herkül K, Kotta I. 2016. The invasive amphipod *Gammarus tigrinus* Sexton, 1939 displaces native gammarid amphipods from sheltered macrophyte habitats of the Gulf of Riga. *Aquat Invasions* 11: 45–54.

Savage AA. 1982. The survival and growth of *Gammarus tigrinus* Sexton (Crustacea: Amphipoda) in relation to salinity and temperature. *Hydrobiologia* 94: 201–212.

Sexton EW. 1939. On a new species of Gammarus (*G. tigrinus*) from Droitwich district. *J Mar Biol Assoc UK* 23: 543–554.

Sowa A, Krodkiewska M, Halabowski D. 2018. Macroinvertebrate communities on various microhabitats of a saline coal mine settling pond. *Oceanol Hydrobiol Stud* 47: 50–59 https://doi.org/10.1515/ohs-2018-0006.

Spyra A, Kubicka J, Strzelec M. 2015. The influence of the disturbed continuity of the river and the invasive species – *Potamopyrgus antipodarum* (Gray, 1843), *Gammarus tigrinus* (Sexton, 1939) on benthos fauna: a case study on urban area in the River Ruda (Poland). *Environ Manag* 56: 233–244. DOI: 10.1007/s00267-015-0483-3.

Strode E, Berezina NA, Kalnins M, Balode M. 2013. New records of the amphipod *Gammarus tigrinus* Sexton, 1939 and *Pontogammarus robustoides* G.O. Sars, 1894 in Latvian waters of the Baltic Sea. *BioInv Rec* 2: 63–68.

Szlauer-Łukaszewska A, Hupało K, Grabowski M. 2018. Spatial distribution of alien gammarids in a large European river (Oder River, Poland). *Knowl Manag Aquat Ecosyst* (in press).

Cite this article as: Lewin I, Halabowski D, Rymarski Z. 2018. The first records of the occurrence of a North American invader *Gammarus tigrinus* Sexton, 1939 in the tributaries of the upper Vistula River. *Knowl. Manag. Aquat. Ecosyst.*, 419, 31.