# Communications

## Expansion of the North American amphipod *Gammarus tigrinus* Sexton, 1939 to the Neva Estuary (easternmost Baltic Sea)*

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### Abstract

The North American gammaridean amphipod, *Gammarus tigrinus*, was found in the easternmost part of the Baltic Sea (Neva Estuary) near a new oil terminal. This species may well have been transported to the Neva Estuary with ballast waters from the Finnish area of the Gulf of Finland, where it was recorded recently. In 2005, the mid-summer density of *G. tigrinus* was 27 indiv. m$^{-2}$. By 2006 this species had spread 100 km to the east from the first site, colonizing the northern coastal zone of the estuary. Its density reached 99–126 indiv. m$^{-2}$. Fecund females and juveniles contributed about 50% to the entire population density, which testifies to the successful reproduction and establishment of *G. tigrinus* in the Neva Estuary. There is a high risk of further expansions of *G. tigrinus* from the new area to the various lakes of Eastern Europe via inland canal-river systems, which may lead to unforeseeable changes in aquatic communities.

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At present, the number of nonindigenous invertebrates in different parts of the world has increased, resulting in structural and functional changes of aquatic ecosystems (Lozon & MacIsaac 1997, Cohen & Carlton 1998). A wide variety of human-mediated vectors such as deliberate and accidental introductions, natural migration via constructed inland waterways and high rates of spread, survival and reproduction in these species have facilitated the rapid dispersal and successful establishment of new species in Europe (Leppäkoski, Olenin & Gollasch (eds.) 2002). As a rule, the dispersion of euryoecious species of amphipods in diverse directions is a rapid process, owing to the ability of a species to migrate great distances and successfully establish themselves under new conditions (Berezina 2004).

The amphipod *Gammarus tigrinus* Sexton, 1939, a species native to estuaries of the Atlantic seaboard of North America, has an extensive invasion history. It was introduced into Northern Ireland with ballast water transport (Hynes 1955). *G. tigrinus* was first reported in 1931 in England in fresh waters contaminated by natural brine seepage (Sexton & Cooper 1939) and in purely freshwater sites in Northern Ireland (Hynes 1955). The wide spread of *G. tigrinus* in inland European waters began after its intentional introductions to supplement fish feeding: from a brackish lake in England to the salt-polluted River Werra, Germany in 1957 (Schmitz 1960), and from the freshwater Lough Neagh in Northern Ireland to the freshwater Ijsselmeer in the Netherlands in 1960 (Nijssen & Stock 1966, Pinkster et al. 1977).

In the Baltic Sea it was first found in the Schlei Fjord in 1975 (Bulnheim 1976). In 1994 *G. tigrinus* was recorded in the Mecklenburg area (Rudolph 1994) and the Odra Estuary (Gruszka 1999, Jażdżewski & Konopacka 2000). Soon, it spread along the entire Baltic Sea shore of northeastern Germany (Zettler 2001). During the next decade the species reached Puck Bay (Szaniawska et al. 2003) and the Vistula Lagoon (Jażdżewski et al. 2002, Ezhova et al. 2005). In 2002 the Vistula Lagoon was the easternmost point of the range of *G. tigrinus* in the Baltic (Jażdżewski et al. 2002). Nevertheless, already in 2003 it was recorded in the Gulf of Riga (Kotta 2005), off the Finnish coast in the Gulf of Finland (Pienimäki et al. 2004) and later in the Curonian Lagoon (Daunis & Zettler 2006), where it was probably introduced accidentally with the ballast water of ships. The high risk of *G. tigrinus* expanding to the easternmost part of the Baltic Sea, the Neva Estuary, had been predicted earlier (Berezina 2004). From 2004 to 2006 intensive midsummer surveys were carried out in the littoral zone of the eastern Gulf of Finland (Neva Estuary) in order to monitor the invasion of nonindigenous species.

One of the largest estuaries (3600 km$^2$) in the Baltic Sea, the Neva Estuary consists of three main parts: Neva Bay, and the inner and outer estuary. Neva Bay is the freshwater part with a low salt content in the water (42–75 mg dm$^{-3}$); it has been separated from the other parts of the estuary by a storm-surge barrier (dam) since the early 1980s (Fig. 1). The water salinity ranges from 210 to 2500 mg dm$^{-3}$ in the inner estuary and is influenced by mesohaline waters from open part of the Gulf of Finland. The summer daytime temperature varied from 14 to 25°C in 2004 and from 16 to 25°C in 2005 and 2006. The substrate at the locations studied consists of coarse sand, gravel and stones. In different parts of the Neva Estuary, the macroalgal communities growing on hard substrates consist of the green algae *Cladophora glomerata* and *Enteromorpha intestinalis*, the brown algae *Pilayella litoralis* and *Ectocarpus* spp., and the red alga *Ceramium rubrum*. The estuary is impacted by a number of human activities, such as discharges of large amounts of waste waters from St. Petersburg and its hinterland, intensive ship traffic, the development of new ports and oil terminals, commercial and sporting fishery, and recreation.

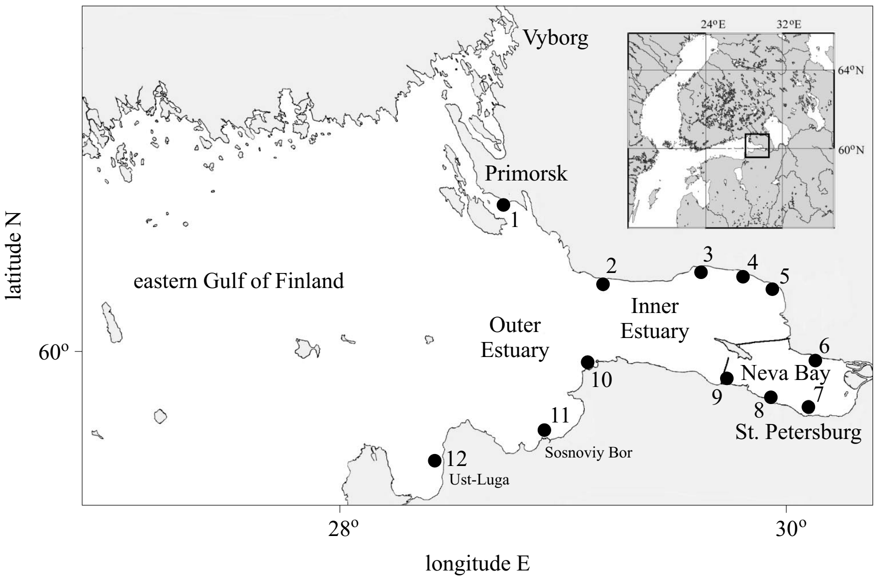


**Fig. 1.** Map of the Neva Estuary showing the sampling sites (1–12)

Littoral communities of macroinvertebrates were monitored at 12 sites in the shallow littoral zone in July 2004–2006 (Fig. 1). The macroinvertebrates were collected with a 0.03 m$^2$ cylindrical metal frame 0.7 m in height, in accordance with a procedure put forward earlier (Berezina et al. 2005). The samples were preserved in 4% formaldehyde and transported to the laboratory in plastic zip-bags.

During the survey in 2004 *G. tigrinus* was not found at all the monitoring sites. The first individuals of this North American amphipod were recorded at only one site in the eastern Gulf of Finland, near a new oil terminal (site 1 – 60°20′27″N, 28°41′54″E; Fig. 1) on July 12, 2005. The density of the newcomer averaged 27 indiv. $m^{-2}$ (± 15 SE). A year later, on July 11, 2006, it was found at two sites (site 1, and site 2 – 60°09′44″N, 29°09′34″E) with respective average densities of 99 (± 50 SE) and 126 indiv. $m^{-2}$ (± 21 SE). In 2006 a total of 39 *G. tigrinus* individuals were found, 36% of them males, 38% female, and the remainder juveniles. The body lengths of males and females were 10–13 and 7–11 mm respectively. 60% of females were fecund with 16–30 eggs of stage 2–3 in their marsupia. Native species of amphipods (*Gammarus zaddachi, G. salinus* and *G. oceanicus*) and isopods (*Jaera albifrons praechirsuta* and *Saduria entomon*), the nemertine *Cyanophthalma obscura*, the mysid *Neomysis integer*, the gastropods *Theodoxus fluviatilis, Bithynia tentaculata* and *Lymnaea ovata*, together with some oligochaete and aquatic insect species (Chironomidae, Ephemeroptera and Trichoptera) were present in the benthic communities at the sites. In 2006 *G. tigrinus* contributed 1.5% (site 1) and 2% (site 2) to the total density of the macroinvertebrate communities.

Past predictions (Bulnheim 1976, Pinkster et al. 1977) on the eventual range of expansion of *G. tigrinus* have come true, owing to the high ecological potency and reproductive capacity of this species. This invader has a high salinity tolerance. Native to the tidal estuaries in the northwest Atlantic Ocean, it is widely distributed from the St. Lawrence River in Quebec to the east coast of Florida, and occurs in salinities of up to 25 PSU (Bousfeld 1973, Kelly et al. 2006). The species is known from German freshwaters with a high ion content. It has been shown experimentally that *G. tigrinus* is able to regulate extracellular $K^+$ in river waters with high potassium concentrations, and to tolerate stress levels ($>$ 380 mmol $dm^{-3}$) of $Na^+$ and $Cl^-$, which makes it more successful in salt-polluted rivers than other amphipods, including its competitor *Gammarus pulex* (Koop & Grieshaber 2000). *G. tigrinus* has become a member of the benthic community in many freshwater systems. Since 2002 *G. tigrinus* has been recorded in samples from the Laurentian Great Lakes, where it has reproduced successfully (Grigorovich et al. 2005, Kelly et al. 2006).

A study of the invasion pathways between the source and introduced populations of the amphipod *G. tigrinus* using a molecular phylogeographical approach has shown that the most divergent clades occurred in the British Isles and mainland Europe and were sourced from the St. Lawrence and Chesapeake/Delaware Bay estuaries. *G. tigrinus* did not occur in freshwater at putative source sites, but colonized both fresh and brackish waters in the British Isles, Western Europe and Eastern Europe. Populations consisting of admixtures of the two invading clades were found principally in recently invaded fresh and brackish water sites in Eastern Europe, and were characterized by a higher genetic diversity than the putative source populations (Kelly et al. 2006).

The Gulf of Finland is a transition zone on waterways from Europe and other continents to the inland waters of Russia. The further dispersal of *G. tigrinus* to the lakes of Eastern Europe via the canal-river systems from the easternmost Baltic area is currently possible, which may result in unforeseeable consequences for ecosystem stability, something that happened in the largest European lake, Lake Ladoga, after the successful establishment there of another successful invader, the Baikalian amphipod *Gmelinoides fasciatus* (Berezina in press). Comprehensive risk assessments of new *G. tigrinus* invasions should be based on possible vector pathways, the invasibility of systems, and the ecological requirements of the new invader, including information on its tolerance to environmental factors, life cycle traits, reproduction rate, food habits, energy requirements, and strength of interactions with other species.

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