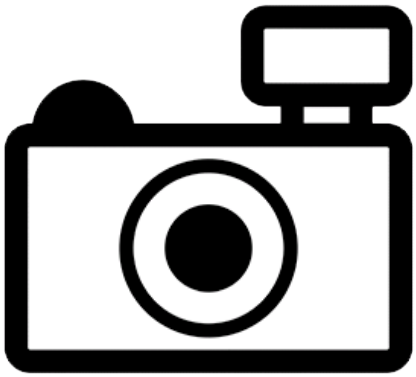
Pontogammarus robustoides (an amphipod, no common name)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, September 2016
Revised, January 2018
Web Version, 5/16/2018



No Photo Available

1 Native Range and Status in the United States

Native Range

From Baker et al. (2015):

"Coastal zones of Black, Caspian, and Azov Seas; lower reaches of large Ponto-Caspian rivers (Volga, Don, Dnieper, Dniester, Danube); and fresh and brackish coastal lakes around the Black Sea (Jazdzewski 1980)."

Status in the United States

From Baker et al. (2015):

"Not established in North America […]"

This species is not in trade in the United States.

Means of Introductions in the United States
From Baker et al. (2015):

"Not established in North America […]"

Remarks
From CABI (2016):

"*P. robustoides* may be confused with other gammarid species. […] The species is difficult to monitor because specialist expertise is needed to identify it."

From Baker et al. (2015):

"Synonyms and Other Names:
Gammarus robustoides Sars 1894 (basionym)"

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing
From CABI (2016):

"Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostraca
Subclass: Eumalacostraca
Order: Amphipoda
Suborder: Gammaridea
Family: Gammaridae
Genus: *Pontogammarus*
Species: *Pontogammarus robustoides*"

From GBIF (2016):

"TAXONOMIC STATUS
Accepted species"

Size, Weight, and Age Range
From Baker et al. (2015):

"Up to 20 mm long; average mature body length: 12 mm (range: 4.5-21 mm); overwintering population: 16-18 mm; ovigerous females: >8.5 mm (Dobson 2012, Grabowski 2011)."

From CABI (2016):

"In its native habitat *P. robustoides* produces no less than two generations per year, and sometimes up to 5-6 generations per year (Mordukhaj-Boltovskoj, 1960). In Central Europe (Bacela and Konopacka, 2005), *P. robustoides* has a multivoltine life cycle, with three generations per year (spring, summer and autumn). […] Spring and summer generations mature in a very short time (4–5 weeks). Females born in May and July start breeding at a body length of 8.5 mm, whereas the length of overwintering females breeding in spring ranges from 11 to 18 mm."

Environment

From CABI (2016):

"In its native regions *P. robustoides* lives in freshwater and oligohaline zones but not in mesohaline waters (Mordukhaj-Boltovskoj, 1960). The osmoregulatory curve of *P. robustoides* ranges from 0 to 23 PSU (Dobrzycka-Krahel and Surowiec, 2011), which allows the species to survive in the wide range of salinities."

"In the Baltic region *P. robustoides* is recorded from brackish waters (Dobrzycka-Krahel and Rzemykowska, 2010), such as Szczecin Lagoon (between Poland and Germany), where the salinity (1-2 PSU) is regulated by the inflow of both seawater and fresh waters and at the Vistula mouth and the Vistula Lagoon (0.3-4 PSU). Investigations have shown that this species can also survive at salinities from 5.8 to 6.1 PSU in the Gulf of Gdansk (Dobrzycka-Krahel and Rzemykowska, 2010)."

"The spread of the species in Europe indicates that it is capable of colonizing waters of ever higher salinities. In 1999, *P. robustoides* was found in Neva Bay (Gulf of Finland) (Berezina and Panov, 2003), where salinity ranges up to 7 PSU. It has been recorded successfully reproducing at 0.2 – 7 PSU in Narva Bay in 2006 (Herkül et al., 2009), and in 2009 in the Gulf of Riga, where the salinity is 7.7 PSU at the bottom of the Irbe Strait in spring and summer (Kalinkina and Berezina, 2010). Laboratory investigations have shown that this species can survive in fully saline sea water (up to 34 PSU) (Santagata et al., 2008)."

"Chekunova (1960) revealed the importance of K and Ca metabolism on the survival of the species."

"Usually occupying shallow waters, *P. robustoides* is characterized as a species of high oxygen demand (Mordukhaj-Boltovskoj, 1960; Arbaciauskas, 2005; Arbaciauskas and Gumuliauskaite, 2007; Gumuliauskaite and Arbaciauskas, 2008). Nevertheless, it has an ability to withstand the lowest oxygen content when compared to other amphipods (Arbaciauskas and Gumuliauskaite, 2007), which allows the species to be successful in stagnant waters. In higher latitudes, however, where stagnant waters may be ice-covered for a part of year, oxygen content may be eliminating factor for the long-term survival of *P. robustoides*."

"Mordukhaj-Boltovskoj (1960) noted that water velocity in typical a river habitat for gammarids is 0.3-0.6 m/sec. Arbaciauskas and Gumuliauskaite (2007) noted that the species tries to avoid lotic waters."

Climate/Range

From CABI (2016):

"Effect of temperature on *P. robustoides* has not yet been studied in detail. In its native habitat water temperature may vary from 0 to 30ºC (Mordukhaj-Boltovskoj, 1960)."

Distribution Outside the United States

Native

From Baker et al. (2015):

"Coastal zones of Black, Caspian, and Azov Seas; lower reaches of large Ponto-Caspian rivers (Volga, Don, Dnieper, Dniester, Danube); and fresh and brackish coastal lakes around the Black Sea (Jazdzewski 1980)."

Introduced

From Grabowski (2011):

"This species is invasive in several Baltic countries. In Latvia, Estonia, and Kaliningrad County (Russia) it is rather local, restricted to coastal areas and few lakes. In Poland, Germany and Lithuania it is spreading along the large rivers (Vistula, Oder, Neman, Elbe) and navigable canals. It is penetrating artificial reservoirs (Wloclawski Reservoir, Zegrzynski Reservoir) as well as lakes (Mecklemburg lakes) (Arbaciauskas 2002, Jazdzewski et al. 2002, Konopacka 2004, Rudolph 1997, Zettler 1998)"

"Since the 1960's *P. robustoides* has been successfully introduced to a number of Ukrainian, Caucasian and Lithuanian artificial dam reservoirs. From the Kaunas Reservoir located on the Neman (Nemunas River) it was transported to several Lithuanian lakes and to the brackish Curonian Lagoon of the Baltic Sea (Gasiūnas 1972, Arbaciauskas 2002), and also to lake Võrtsjärv in Estonia where it did not establish a population (Timm 2005). In 1988, the species was found in the Szczecin Lagoon, which is a part of the Oder River deltaic system, and in the mid-1990's it was recorded from the eastern-most part of the Gulf of Finland (Berezina and Panov 2003), as well as from a number of waterbodies and canals in north-eastern Germany (Rudolph 1997, Zettler 1998, Martens et al. 1999) and in Poland (Vistula River, Vistula Lagoon, Oder River) (Konopacka 1998) [*sic*], Jazdzewski and Konopacka 2000). In 2009 it was found also in the Gulf of Riga in Estonia (Kalinkina and Berezina 2010)."

Means of Introduction Outside the United States

From Grabowski (2011):

"This species was intentionally introduced to several reservoirs in the former Soviet Union (see above). It is likely that it has spread along the inshore Baltic waters and penetrated inland waters

through shipping, probably attached to fouling organisms, as well as by natural migration (Jazdzewski et al. 2002, Grabowski et al. 2003)."

From CABI (2016):

"In addition to the natural ability of *P. robustoides* to extend its distribution, the process was speeded up by intentional transfers of potential fish food gammarids to hydropower reservoirs. *P. robustoides* was among 17 amphipod species that were used in these transfers during 1940–1970 in the Soviet Union (Jazdzewski, 1980)."

"Filinova and Sonina (2012) suggested that in the [Volga River] the spread of gammarids could have been stimulated by intensive macrophyte growth which developed after a number of Volga water reservoirs were created in 1950-60s."

"An expansion rate of the species is considered to be about 2 km per year."

"Arbaciauskas et al. (2011a) presumed that the presence of *P. robustoides* in the mouth of the Šventoji River indicated that their local spread may have been facilitated by marine shipping or that the species may be capable of migration through coastal Baltic waters. The idea that *P. robustoides* dispersed from the Neman drainage system through Baltic waters (Curonian Lagoon) by passive dispersion and/or shipping into other European water systems has been supported by data from many sources (Gasiūnas, 1972; Jazdzewski and Konopacka, 2000; Arbaciauskas 2002; Grabowski, 2011; Kurashov et al., [2012])."

"The initial invasions of *P. robustoides* in central Europe might have been stimulated by the creation of canal networks in the late 18th century, connecting the major eastern and western European river systems."

Short Description

From Baker et al. (2015):

"*Pontogammarus robustoides* has a laterally compressed, curled, semi-transparent body consisting of a head (cephalon), thorax (pereon), and abdomen. Its head bears two pairs of antennae, each short, thick, and similar in length. The first peduncle segment (stalk connected to head) of the first antennae is broadened. The pereon of this amphipod consists of seven segments, and on the seventh segment, the first leg segment (basis) has a broad lobe that reaches no further than the end of the second leg segment (ischium). The posterior distal margin of the basis of this seventh pereon segment, as well as the lower margins of the first four coxal (basal leg segment) plates laterally adjacent to pereon, are covered with numerous, long setae (hairs) along the edge. Setae are straight, with numerous side branches. Additional distinguishing features include armature along its central line of the first urosomal segment (most posterior body region), which varies from a fan of delicate setae to a row of 5-7 spines. The second urosomal segment also bears a cluster of at least two median spines (usually with 4-6). Lastly, the third urosomal segment has a pair of central slender spines located close together and an endopod with three clusters of spines along the outer edge and no spines along its inner edge (Dobson 2012, Grabowski 2011)"

Biology

From Baker et al. (2015):

"Due to its limited ability to swim against currents, it tends to maintain populations in lentic or stagnant water environments, including lagoons, deltas, canals, reservoirs, and lakes (Berezina and Panov 2003, Grabowski and Bacela 2005, Grudule et al. 2007, Jazdzewski et al. 2002, Zettler 2002). This species prefers areas with stony/sandy to muddy bottoms (Carausu et al. 1955), often occupying the roots of terrestrial grasses (Arbaciauskas 2005). Juveniles tend to live associated with fine-leaved plants, while adults exhibit habitat plasticity (Czarnecka et al. 2010). *Pontogammarus robustoides* is most abundant in the upper littoral zone above 3 meters depth (Arbaciauskas 2005); however, when water temperatures drop below 5°C, this species migrates to deeper waters (Berezina et al. 2005)."

"This amphipod uses multiple feeding strategies, alternating among grazing, predation, and collecting-gathering (Berezina et al. 2005). Its diet primarily consists of detritus, sediments, unicellular green algae, and filamentous green algae, with the composition varying with the amphipod's body size. Juveniles (5-7 mm) feed mainly on detritus, while adults (8.0-12.5 mm) rely most heavily on filamentous green algae (1.1 to 3.8 mg algal dry weight/day). The largest adults (>15 mm) act mainly as aggressive predators, feeding on oligochaetes, copepods, and chironomids (Berezina et al. 2005), though such prey have also been consumed by younger individuals (body length: 6-7 mm) (Berezina 2007)."

From CABI (2016):

"The life cycle of *P. robustoides* consists of direct development with no independent larval stage. Females carry their embryos in a brood chamber between the pereopods. When released, the juveniles reach maturity after several molts, without any metamorphosis."

"The fecundity of the species is very high. Berezina and Panov (2003) observed 30 to 106 eggs per female, which resulted in the successful establishment of the species in the eastern Gulf of Finland during a short period. In Lithuaniana (Arbaciauskas and Gumuliauskaite, 2007) the fecundity was estimated at 34 to 167 eggs per female, higher than other amphipods in the region; similar estimates (11 – 185 eggs) have come from Poland (Bacela and Konopacka, 2005)."

"In its native habitat *P. robustoides* produces no less than two generations per year, and sometimes up to 5-6 generations per year (Mordukhaj-Boltovskoj, 1960). In Central Europe (Bacela and Konopacka, 2005), *P. robustoides* has a multivoltine life cycle, with three generations per year (spring, summer and autumn). Reproduction lasts from March/April until October, when the last breeding females are found."

"In its native habitat *P. robustoides* may be characterised by large population size and high densities. For example, in the Don estuary, maximum density was 4280 ind/square meter, and biomass 70.100 g/square meter (Mordukhaj-Boltovskoj, 1960)."

Human Uses

From Grabowski (2011):

"The species provides a food base for many local fish species in large rivers (particularly Vistula River) and their estuaries (Szczecin Lagoon, Vistula Lagoon), where native gammarids disappeared most possibly due to pollution (Grabowska and Grabowski 2005, Kostrzewa and Grabowski 2003, unpublished data)."

From CABI (2016):

"Emelyanova (1994) suggested the species could serve as a pollution indicator, based on its tolerance to different types of contamination, particularly radiation."

Diseases

From CABI (2016):

"Several microparasites of invasive gammarids in Polish waters have been recognized (Ovcharenko et al., 2009; Ovcharenko and Yemeliyanova, 2009). Four species of gregarines (*Uradiophora ramosa*, *U. longissima*, *Cephaloidophora similis*, *C. mucronata*) and five microsporidians (*Nosema dikerogammari*, *N. pontogammari*, *Thelohania* sp. 2, *Thelohania* sp. 5; *Pleistophora muelleri*) were associated with hosts of Ponto-Caspian origins. Infestation rates did not exceed 3%. The authors did not register any transition of parasites of the Ponto-Caspian hosts to the hosts of native fauna."

From Baker et al. (2015):

"*Pontogammarus robustoides* may be a vector of non-native fish parasites (e.g., Trematoda, Acanthocephala) (Sulgostowska and Vojtkova 1992)."

Threat to Humans

From Grabowski (2011):

"The species does not pose any threat to human health since it is not known to be a vector of any human pathogens."

3 Impacts of Introductions

From Baker et al. (2015):

"In habitats across Europe where *P. robustoides* is well established and numerous, significant declines in species richness and diversity, as well as reductions in body length of other macroinvertebrates, have been observed (Arbaciauskas and Gumuliauskaite 2007). In Lithuanian water bodies with abundant populations of *P. robustoides*, competitive exclusion of the native amphipod *Gammarus lacustris* has been observed (Arbaciauskas 2002, 2005). Additionally, asymmetrical intraguild predation may be primarily responsible for the displacement of other

Baltic Sea gammarid species (Arbaciauskas and Gumuliauskaite 2007), including a smaller invasive amphipod, *Gmelinoides fasciatus* in some habitats in the eastern Gulf of Finland (Berezina and Panov 2003), and indigenous *Gammarus duebeni* and *Gammarus zaddachi* in the Vistula Lagoon (Jazdzewski et al. 2004). Large numbers of *P. robustoides* have reduced the densities of benthic detritivores in the stony littoral zone of Neva Bay in the Gulf of Finland (Berezina and Panov 2003). When abundant, this species may also negatively affect populations of the freshwater isopod *Asellus aquaticus* as a result of direct predation (Arbaciauskas 2005). However, in moderate abundances, the negative impacts exerted by *P. robustoides* on species diversity are less severe (Arbaciauskas and Gumuliauskaite 2007)."

"Additionally, *P. robustoides* may affect the composition and abundance of littoral macrophytes through heavy grazing pressure, as seen with the Great Lakes nuisance algae *Cladophora* in the eastern Gulf of Finland (Berezina et al. 2005). Populations in this study were able to consume 4-5 g (dry weight) Cladophora/day."

From CABI (2016):

"*P. robustoides* have been designated as a high-impact species and assigned as a 'blacklist' species for European inland waters (Arbaciauskas and Gumuliauskaite, 2007; Panov et al., 2009; Arbaciauskas, 2011b.) It is forecasted to spread despite any management initiated."

"Berezina and Panov (2003) described the favourable impact of *P. robustoides* on food webs. By intensively consuming plant food, *P. robustiodes* produces abundant faeces which increase organic matter availability for benthic detritovores. In the Gulf of Finland, for example, at gammarid densities of 500-3000 ind/m(-2), the densities of deitritovores [*sic*] were 2-3 times as high. However, such activity also causes severe biocontamination, which was demonstrated by Arbaciauskas et al. (2011b) for Lithuanian rivers."

From Gumuliauskaite and Arbaciauskas (2008):

"In habitats where *P. robustoides* is well established and numerous, it significantly reduces species richness and community diversity. Moderate pontogammarid density in habitats that can sustain the native gammarid *Gammarus lacustris*, however, revealed no negative impact on diversity metrics. Among the lakes studied, the benthic biomass did not differ in invaded and uninvaded habitats. The biomass of indigenous invertebrates (excluding chironomids, which exhibited high lake-specific biomass variation) was lower in the places with well-established *P. robustoides*. A detrimental impact was observed upon the native isopod *Asellus aquaticus* and a negative correlation with most of the higher taxa of native invertebrates. In the invaded lake habitats that favour *P. robustoides*, a change in community structure and a decrease in diversity up to twofold or more are to be expected."

From Orlova et al. (2006):

"On littoral hard bottoms in Neva Bay […], predation by the invasive amphipod *P. robustoides* on other benthic organisms was the main mechanism by which invertebrate density decreased and by which native or earlier established alien species was replaced."

"*G. fasciatus* and *P. robustoides* also play a role in the functioning of littoral communities in EGOF [Eastern Gulf of Finland] through their grazing activities. According to consumption rates of *P. robustoides*, the dense population found in EGOF littoral zone is able to consume up to 1.9–2.4 gCm^{-2} day^{-1} of algae (Berezina et al. 2005). The average biomass of *Cladophora glomerata* was 68±25 gCm^{-2} and primary production 7 gCm^{-2} day^{-1}. Amphipod consumption rates are thus only twofold to threefold lower than *C. glomerata* production and grazing effects will be significant. In locations with high densities of *P. robustoides* and *G. fasciatus*, these amphipods may actually cause a decline in *Cladophora* biomass, alleviating an eutrophication effect."

From Arbaciauskas (2005):

"Of the eight lakes that have been inhabited by the Ponto-Caspian amphipod *P. robustoides* since the 1960s […], the native amphipod species *G. lacustris* was only noted in Lake Plateliai. It was also found in the Antalieptė WR, which was formed after the flooding of a few lakes. In both these water bodies native and non-native amphipods recently co-occurred only in bays where the abundance of *P. robustoides* was low, while the open parts of Lake Plateliai and the Antalieptė WR, which are abundantly populated by alien species, were devoid of *G. lacustris*. A drastic decrease in the abundance of native amphipods following the introduction of Ponto-Caspian amphipods was noted previously in Lake Dusia (Gasiūnas 1975). All of these data definitely suggest the competitive exclusion of the native amphipod *G. lacustris* by the alien species *P. robustoides* in habitats which sustain abundant populations of the newcomers (Arbaciauskas 2002)."

"Prior to the introduction of Ponto-Caspian amphipods, Gasiūnas (1958) wrote that of the fifty commercial lakes of Lithuania known to him, Lake Plateliai harbored the most abundant population of the isopod *A. aquaticus*. He estimated its density in the littoral among macrophytes (*Elodea* sp. and *Fontinalis* sp.) at 1466 ind. m^{-2}. This, however, is not the case today. Native isopods occur in abundance only in the closed bay of Lake Plateliai, where, during 2004, its density in the littoral was at a mean of 792 ind. m^{-2}, although it was absent in quantitative samples from the open part of that lake (Gumuliauskaite, unpubl. data). The specimens of *A. aquaticus*, however, occurred in littoral catches made with drags. In Lake Dusia, *A. aquaticus* was common in the shallow waters of the littoral (Gasiūnas 1957), but about ten years after the introduction of non-native species it was often only in the bay overgrown with macrophytes (Gasiūnas 1975). During 1999-2004, this native isopod was absent in the shallow waters of the littoral, or at least from samples collected in the open part of the lake. It appeared in low numbers only in samples collected with drags from depths of 3 -10 m that usually contained *Chara aspera*. At these depths, the abundance of *P. robustoides* was substantially lower than that from the higher littoral zone. Thus, recent data in comparison to previous observations unambiguously suggest the negative effect the Ponto-Caspian amphipod *P. robustoides* has on the native isopod *A. aquaticus*, which is probably related to direct predation by the former."

4 Global Distribution

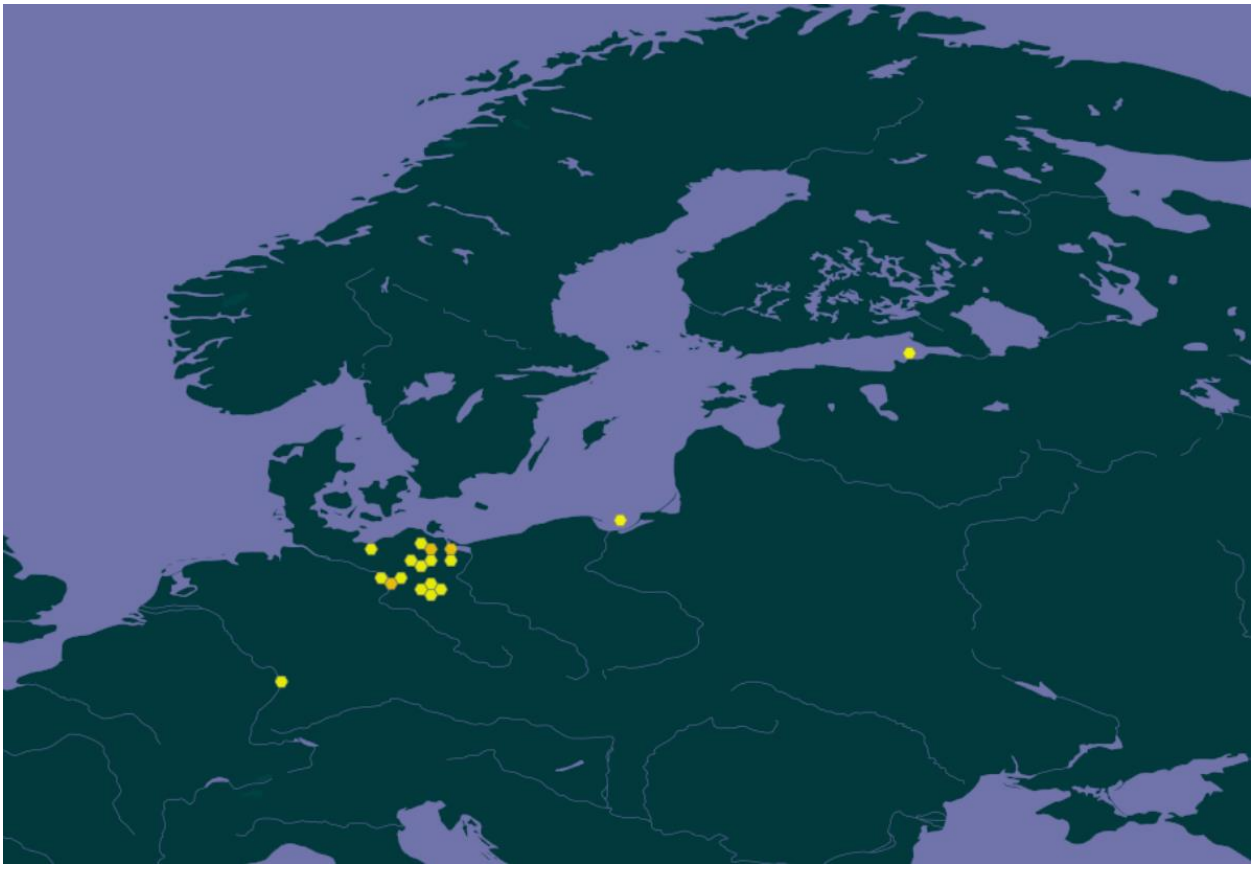


Figure 1. Known global distribution of *Pontogammarus robustoides*, reported from Germany, Poland, and Estonia. Map from GBIF Secretariat (2018). Map does not include georeferenced occurrences for areas around the Black, Caspian, and Azov seas where the species is native (Baker et al. 2015), or for Latvia or Kaliningrad County, Russia, where the species has become established (Grabowski 2011).

5 Distribution Within the United States

From Baker et al. (2015):

"Not established in North America"

6 Climate Matching

Summary of Climate Matching Analysis

Climate 6 score indicated a medium climate match for the contiguous United States. Scores between 0.005 and 0.103 are classified as medium match. The Climate 6 score was 0.083. The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) was high in the vicinity of Lake Michigan. It was medium in the Great Lakes region overall. Climate match was low along the coasts and in the Southeast. Climate match was medium in scattered locations in

the Interior West and across much of the Midwest, Northeast, and Mid-Atlantic regions. The source locations for this climate match included only one source location from the native range of *P. robustoides*. Without more georeferenced occurrences from the native range, this climate matching analysis likely underestimates the true climate match of *P. robustoides* to the contiguous United States.

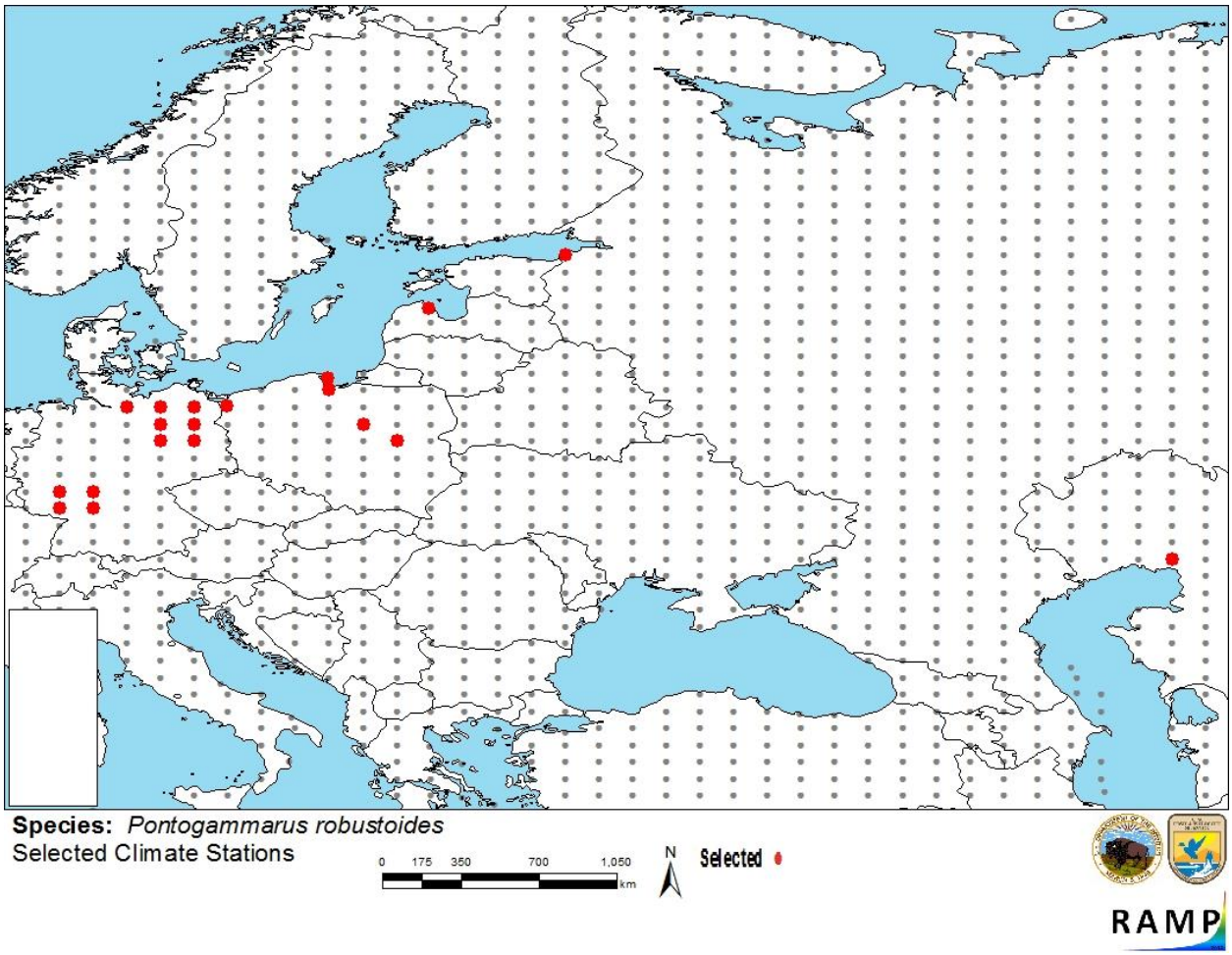


Figure 2. RAMP (Sanders et al. 2014) source map showing weather stations in Europe and western Asia selected as source locations (red; Germany, Poland, Latvia, Estonia, and Kazakhstan) and non-source locations (gray) for *Pontogammarus robustoides* climate matching. Source locations from Grabowski (2011) and GBIF Secretariat (2016).

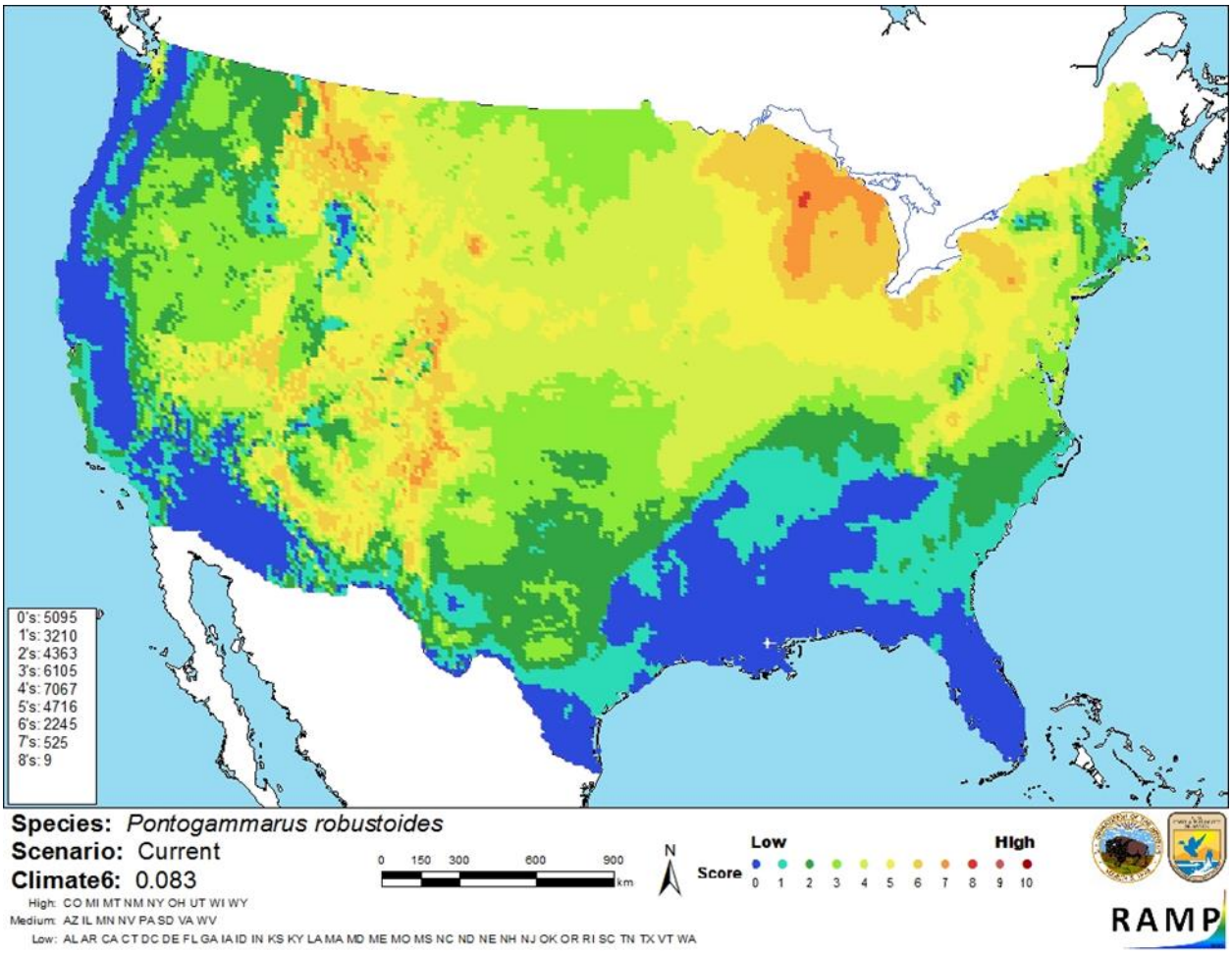


Figure 3. Map of RAMP (Sanders et al. 2014) climate matches for *Pontogammarus robustoides* in the contiguous United States based on source locations reported by Grabowski (2011) and GBIF Secretariat (2016). 0= Lowest match, 10=Highest match. Counts of climate match scores are tabulated on the left.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
$0.000 \leq X \leq 0.005$	Low
$0.005 < X < 0.103$	Medium
≥ 0.103	High

7 Certainty of Assessment

There are multiple peer-reviewed studies on *Pontogammarus robustoides* in ecosystems into which the species has been introduced which provide clear and convincing evidence of impacts. Adequate credible information is available on the range of *P. robustoides* in its introduced range, but georeferenced occurrences are lacking in its native range, introducing some uncertainty to the results of the climate matching analysis. The certainty of this assessment is medium.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Pontogammarus robustoides is an amphipod native to areas around the Black, Caspian, and Azov seas in southeastern Europe and western Asia. *P. robustoides* may provide a food base in polluted waters and may be a vector of fish parasites. Documented impacts of *P. robustoides* invasion in Europe include declines in native amphipods and isopods, significant control of algal growth, and changes in water quality. Although it inhabits freshwater and brackish environments in its native range, it can survive considerably higher salinities and thus is a candidate for transoceanic transport and invasion of North America via ballast water. Climate match to the contiguous U.S. is medium, with highest match in the Great Lakes region. However, only one georeferenced occurrence was available for the native range, so the estimated climate match may be an underestimate. Overall risk posed by this species is high because of the multiple, well-documented impacts it has had where introduced and its medium climate match to the contiguous U.S.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): Medium**
- **Certainty of Assessment (Sec. 7): Medium**
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

Arbaciauskas, K. 2005. The distribution and local dispersal of Ponto-Caspian Peracarida in Lithuanian fresh waters with notes on *Pontogammarus robustoides* population establishment, abundance and impact. Oceanological and Hydrobiological Studies 34(Supplement 1):93-111.

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Gumuliauskaite, S., and K. Arbaciauskas. 2008. The impact of the invasive Ponto-Caspian amphipod *Pontogammarus robustoides* on littoral communities in Lithuanian lakes. Hydrobiologia 599:127-134.

Orlova, M. I., I. V. Telesh, N. A. Berezina, A. E. Antsulevich, A. A. Maximov, and L. F. Litvinchuk. 2006. Effects of nonindigenous species on diversity and community functioning in the eastern Gulf of Finland (Baltic Sea). Helgoland Marine Research 60:98-105.

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10 References Quoted But Not Accessed

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

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