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Research Article

**ALIEN CRUSTACEA IN POLISH WATERS - INTRODUCTION  
AND DECAPODA**

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**Abstract**

The paper presents the biogeography, history, and some ecological consequences of the introduction of alien decapod species in Poland, with extensive reference to other European countries. Among some 750 species of Crustacea recorded in Polish waters, 18 representatives of five orders of macrocrustaceans are identified as alien species that either invaded or were introduced to Polish waters in historical times. Of this number, seven species are Decapoda: *Pontastacus leptodactylus*, *Pacifastacus leniusculus*, *Orconectes limosus*, *Atyaephyra desmaresti*, *Palaemon elegans*, *Rhithropanopeus harrisii*, *Eriocheir sinensis*.

One of the species (*P. leptodactylus*) is of Ponto-Caspian origin, and of the remaining six, three (*P. leniusculus*, *O. limosus*, *R. harrisii*) came from North America, one from East Asia (*E. sinensis*), one from southern Europe (*A. desmaresti*), and one entered the Baltic from the North Sea (*P. elegans*). The first part of the paper describes the geographical and ecological aspects of the spread of aquatic fauna in Central Europe and discusses the introduction and range of extension of the seven decapod species in Polish waters.

## INTRODUCTION

One of the most prominent features of the Baltic drainage basin is its young geological age. Including the catchment areas of two major Baltic rivers, the Vistula and Oder, the network was not formed until after the last Würm glaciation in the past 18,000 years. Thus, the freshwater and brackish water fauna of the region is of very recent origin and, in fact, is still undergoing the formation processes, which can be of both natural and anthropogenic character. The natural process includes recolonization of areas released from ice cover, a phenomenon that is commonly observed in Central and Northern Europe. Although fast on the geological time-scale, this can be viewed as long-term change from the human point of view. In contrast, anthropogenic changes are usually rapid, massive, and explosive events, even in comparison with the human life-span. Since the industrial revolution in nineteenth century, human activity has played a major role in shaping the flora and fauna not only in Northern Europe but also in many other regions of the world. In addition to intentional introductions of alien species, the human impact on local fauna includes accidental introductions resulting from the significant development of marine and inland transportation, as well as from the network of artificial waterways connecting previously isolated river catchments. One example is the approximately 1,770 km of inland canals that have been constructed in Germany (Tittizer 1996). Additionally, it has been estimated that an average of three to four thousand species are transported each day in the ballast water tanks of vessels (Gollasch 1996, Carlton and Geller 1993). Another important factor is anthropogenic pressure on the environment through eutrophication, pollution, and the extermination of whole communities of species.

This paper describes the history and current status of Decapoda that have either been introduced to or invaded the inland and offshore waters of Poland. Knowledge of their invasion routes and mechanisms as well as of their biological attributes can be essential to assessing their potential ability to expand and pressure local biotic communities. Although this area has been well studied and some summaries have already been published (Jażdżewski 1980, Jażdżewski and Konopacka 1995, 2000, Jażdżewski *et al.* 2002, Jażdżewski *et al.* 2004, Konopacka 2004), the tempo of the invasion process is incredibly high and successful, new invasions are observed almost every year.

### ***Sources and routes***

In fact, two geographic regions are recognized as the main sources of invaders for the inland waters of Central and Northern Europe. One of them is the Ponto-Caspian basin and the other is the temperate region of North America.

The Ponto-Caspian region is known to be a very important glacial refugium for European terrestrial and aquatic fauna. It serves as a reservoir of species that have been recolonizing the northern part of Europe as the climate has warmed. For example, Warchałowski (1985) estimated that approximately 35% of the European species of Chrysomelidae (Insecta: Coleoptera) are of Ponto-Caspian origin.

The situation of aquatic fauna is different. According to Dumont (1998), the Ponto-Caspian basin, once part of the Ponto-Caspian Sea or the Paratethys, was isolated from the East Mediterranean, the other remnant of the Tethys Ocean, in the Miocene, approximately 7 mya. During that time, the Paratethys evolved into the brackish Sarmatian Lake comprised of the present Black and South Caspian seas. In the Pontian age (late Miocene), a deep tectonic depression formed in the south Caspian Basin collecting water masses and disconnecting it from the Black Sea. Then a period of further tectonic movement was followed by sequential regressions/transgressions, which transformed the two new seas into a number of brackish and freshwater lakes of various sizes. At the beginning of the Pleistocene (approximately 2 mya), rapid climatic changes began, leading again to rapid changes in salinity and sea level, which, linked to glaciation and deglaciation events, reformed the entire water regime throughout the Ponto-Caspian basin. The Caspian Sea still remained isolated, and with time its waters gained a unique salt composition, somewhat similar to freshwater but much more concentrated. The Black Sea, which was a freshwater basin at that time, did not become connected with the Mediterranean until the Holocene (approximately 8,000 years ago). The inflow of Mediterranean Sea waters to the freshwater lake probably caused the widespread extinction of the existing biota, which have survived to the present only in brackish lagoons and river estuaries. This long, complex chain of events that led to the creation of what is now known as the Ponto-Caspian basin created unique fauna and flora, of which about 80% is endemic. It is especially important to stress that until the beginning of the Holocene, evolution of the local biota occurred in total isolation from true marine conditions and fauna. This story of environmental formation may be the background of the comparatively high euryhalinity and physiological ability of Ponto-Caspian species to invade and spread throughout the brackish and fresh waters of Europe.

However, one should remember that the Vistula and Oder catchments belong to the drainage system of the Baltic Sea that was originally isolated from

the Ponto-Caspian basin. Some limited immigration of Ponto-Caspian fauna could have occurred at the very beginning of the Holocene, due to the presence of the wide latitudinal spread of freshwater bodies released from retreating ice cover. This model of postglacial colonization was proposed by Witkowski (1984) as well as by Rolik and Rembiszewski (1987) for several local fish species, but not for invertebrates. In general, the natural migration of freshwater fauna between the two areas was impossible or at least largely suppressed. The route has been open since the connection of these basins in the eighteenth century. The first step was taken with the building of the canal that connects the Bug (Baltic Sea basin) and Pripet (Black Sea basin) rivers in 1784 (Jażdżewski 1980). Further westward expansion of Ponto-Caspian fauna was possible through the canals between the Vistula and Oder rivers, and between the Elbe and Oder Rivers, which were also constructed in the eighteenth century. The Ludwigskanal, a direct, artificial connection between the Danube (Black Sea basin) and the Rhine (North Sea basin), has existed, with some interruptions, since 1845 (Tittizer 1997).

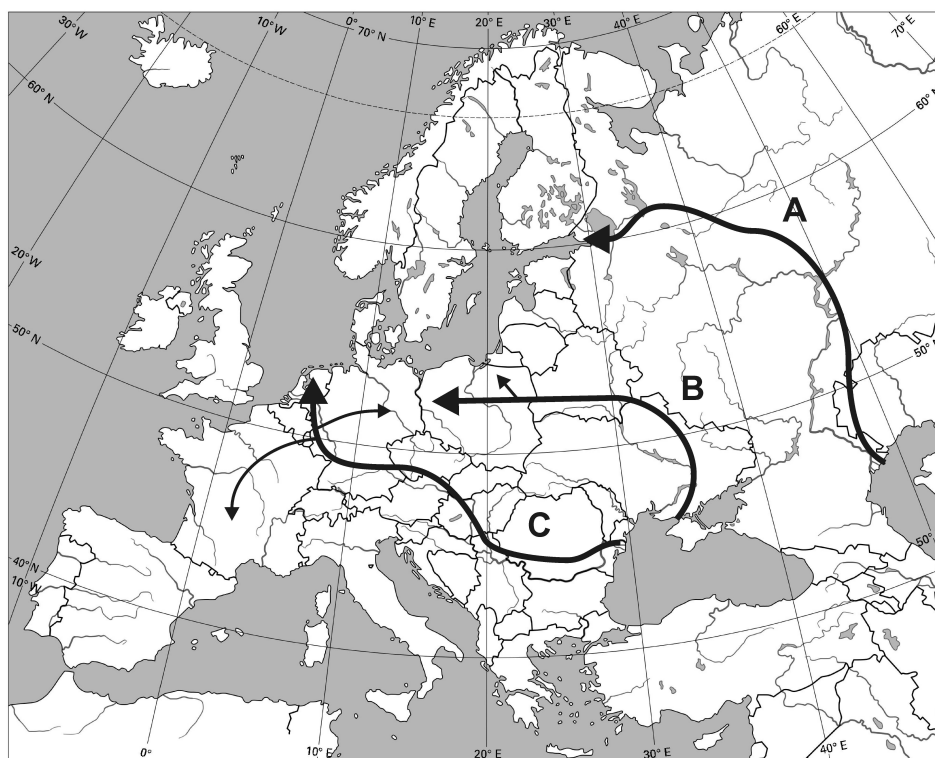
According to Bij de Vaate *et al.* (2002), there are currently three main invasion corridors of Ponto-Caspian species (Fig 1):

- 1) Northern corridor - Volga River → Lake Beloye → Lake Onega → Lake Ladoga → Neva River → Baltic Sea;
- 2) Central corridor - Dnieper River → Vistula River → Noteć River → Oder River → Elbe River → Rhine River → North Sea;
- 3) Southern corridor - Danube River → Rhine River → North Sea.

The northern and central corridors played the main role as invasion routes for Ponto-Caspian species to Polish territory, which belongs almost entirely to the Baltic Sea drainage system.

The North American continent, another important source of invaders, has some special biogeographical relationships with Europe. For many millions of years these continents were connected through the large landmasses of Northern Asia. Although the connection was restricted from the Ice Age, the resemblance of the fauna of the two continents, which evolved together for a long period of time, can still be seen clearly. This is reflected in the zoogeographic division that includes all of the above geographic regions in one superior entity – the Holarctic. A result of this shared geological history is that there are many closely related species inhabiting European and North American terrestrial and freshwater ecosystems. These species not only share a common genealogy but also some adaptations to similar environments, including climate and biotic communities. This is the main reason why North America is such a rich source,

and simultaneously a vulnerable recipient, of potential invaders. The other reason is the development of extensive intercontinental movement. The exchange of fauna between the Old and New Worlds was very much restricted until the fifteenth and sixteenth centuries. Since then, many species from all biota have been either intentionally or more often accidentally introduced to both continents. A great number of these introductions can be attributed to shipping, *i.e.*, the unloading of the ballast water tanks of vessels.



**Fig. 1.** Main invasion corridors used by Ponto-Caspian species in Europe (modified from Bij de Vaate *et al.* 2002): **A** – northern corridor, **B** – central corridor, **C** – southern corridor.

Another possible source of alien species is the Atlantic Ocean. The Baltic Sea is still very young on the geological time-scale, and natural succession has not yet reached a level of “dynamic equilibrium”. There is a constant flow of marine species coming through the Danish Straits. In some cases, species that are euryhaline and euryoecious might establish robust, reproductive populations in the rather poor, brackish environment of the Baltic Sea.

In addition to accidental introductions, the intentional import of alien species is currently one of the most important sources of the large-scale exchange of fauna. This is particularly true for species of economic importance, for example, those that are cultivated as food. Many species of crustaceans, especially decapods, have been transplanted in this way worldwide, including in Polish waters.

**Table 1**

Systematics, origins and ecological preferences of alien Decapoda occurring in Poland.

<b>Subphylum:</b>	Crustacea Pennant, 1777			
<b>Class:</b>	Malacostraca Latreille, 1806			
<b>Order:</b>	Decapoda Latreille, 1803			
<b>Suborder:</b>	Pleocyemata Burkenroad, 1963			
<b>Infraorder:</b>	Astacidea Latreille, 1803			
<b>Family:</b>	Astacidae Latreille, 1803			<b>First record in Poland:</b>
	<i>Pontastacus leptodactylus</i> (Eschscholz, 1823) <sup>1</sup>	PC, NA,	F F	XIX c. ? 1972
	<i>Pacifastacus leniusculus</i> (Dana, 1852)			
<b>Family:</b>	Cambaridae Hoobs, 1942			
	<i>Orconectes limosus</i> (Rafinesque, 1817)	NA, NA,	F F	1890
	<i>Procambarus clarkii</i> (Girard, 1852) <sup>2</sup>			
<b>Infraorder:</b>	Caridea Dana, 1852			
<b>Family:</b>	Atyiidae De Haan, 1849			
	<i>Atyaephyra desmaresti</i> (Millet, 1831)	ME,	F, B	2002
<b>Family :</b>	Palaemonidae Rafinesque, 1815			
	<i>Palaemon elegans</i> Rathke, 1837	AT	B	2000
<b>Infraorder:</b>	Brachyura Latreille, 1803			
<b>Family:</b>	Xanthidae Macleay, 1838			
	<i>Rhithropanopeus harrisi</i> (Maitland, 1874)	NA,	B	1952
<b>Family:</b>	Grapsidae Macleay, 1838			
	<i>Eriocheir sinensis</i> Milne Edwards, 1854		F, B	1928
<b>Symbols used:</b>	Geographic origins: NA – North American, PC – Ponto-Caspian, ME – Mediterranean, FE – Far-Eastern, AT – Atlantic Habitats used in Poland: F – freshwater, B – brackishwater First record in Poland: ? – see explanation in text			

**Annotations by species name:**

<sup>1</sup> In most publications known as *Astacus leptodactylus*. However, **Brodski (1983)** upgraded the old subgeneric name *Pontastacus* Bott, 1950 to generic status to house the species in the Ponto-caspian basin. **Starobogatov (1995)** adopted the system, which after him was introduced to Polish literature by **Mastyński & Andrzejewski (2001)**. More detailed discussion on the subject can be found in **Holdich, ed. (2002)**.

<sup>2</sup> The species has not been recorded in wild environment in Poland yet. Kept in aquaria, it can be potentially released and is able to establish a breeding population in Polish waters.

***Alien Decapoda in Poland***

Among some 750 species of Crustacea recorded in Polish waters, 18 representatives of five orders of macrocrustaceans are identified as alien species that either invaded or were introduced to Polish waters in historical times. Of this number, seven species are from Decapoda: *Pontastacus leptodactylus*, *Pacifastacus leniusculus*, *Orconectes limosus*, *Atyaephyra desmaresti*, *Palaemon elegans*, *Rhithropanopeus harrisi*, *Eriocheir sinensis* (Table 1).

One of the species (*P. leptodactylus*) is of Ponto-Caspian origin, and of the remaining six, three (*P. leniusculus*, *O. limosus*, *R. harrisii*) came from North America, one from East Asia (*E. sinensis*), one from southern Europe (*A. desmaresti*), and one entered the Baltic from the North Sea (*P. elegans*). The first part of the paper describes the geographical and ecological aspects of the spread of aquatic fauna in Central Europe and discusses the introduction and range of extension of the seven decapod species in Polish waters.

### ***Decapoda of Ponto-Caspian origin***

*Pontastacus leptodactylus* (Eschscholz, 1823)

English- narrow-clawed crayfish; Polish - rak błotny, rak stawowy, krawiec.

This species is often recognized as native to Poland; however, it occurred originally in the drainage systems of the Black and Caspian seas (Entz 1912). Although its westward expansion in the eighteenth and nineteenth centuries was partially due to the newly created waterways forming the so called “central corridor”, its spread was most probably also due to intentional introductions (Gajewski and Terlecki 1956). This is why it could be counted among the first successful Ponto-Caspian colonists in Polish waters. It was also the first crayfish species introduced at the end of the nineteenth century in many localities in Central and Western Europe after the unfortunate outbreak of crayfish plague - the North American ascomycete, *Aphanomyces astaci* (Wintersteiger 1985, Pöckl 1999a). The narrow-clawed crayfish established well becoming a common species in Polish waters until the early 1970s (Jażdżewski and Konopacka 1995, Strużyński 2001). By this time, this species had also attained the widest range of all crayfish species in Europe. However, it is not completely resistant to crayfish plague. Another factor that negatively influenced its distribution was water pollution. Due to these factors, this species in Polish waters shared the fate of the noble crayfish and gradually disappeared from most of its former localities. It is now very rare in Poland, and has been displaced by another alien species, *Orconectes limosus*. Some local natural populations still occur mostly in the eastern part of the country (Krzywosz *et al.* 1994, Białokoz *et al.* 1996, Strużyński 1999b), but also in the Brodnickie Lake District (Pyka and Kraśniewski 1997) and Wielkopolska (Andrzejewski *et al.* 1999). Recently, this species has been included in a native crayfish restoration program (Krzywosz 2001, Strużyński 2001). The crayfish was reintroduced into some forest ponds in the Mazovia Lowland region, from where it disappeared in the 1970s (Strużyński and Śmietana 1998). Recent reintroductions have also been made in small rivers and lakes in a number of localities in the Zachodnio-Pomorskie, Pomorskie, Warmińsko-Mazurskie, Podlaskie, Lubelskie, Mazowieckie, Podkarpackie, and Lubuskie districts (Krzywosz, pers. comm.).

The precise locations are kept confidential to avoid illegal fishing or further uncontrolled introductions. To date, it is still not known whether the narrow-clawed crayfish will re-establish itself in these areas.

### **Decapoda of North American origin**

*Orconectes limosus* (Rafinesque, 1817)

English - spiny-cheek crayfish; Polish - rak pręgowany, rak pręgowaty, rak amerykański.

This is the second alien decapod crustacean known to have been introduced intentionally into present-day Polish territory. A native of the eastern part of North America, the spiny-cheek crayfish was introduced for the first time in Europe by Max von dem Borne in 1890 to a small pond in Berneuchen (now Barnówek) in the drainage system of the Mietzel (now Myśla), a tributary of the Oder River, and in Lake Sierosławskie in northwestern Poland – regions that were at the time part of Germany (Holdich 1988, Momot 1988, Jażdżewski and Konopacka 1995). The aim was to use this species to replace the native noble crayfish and the established narrow-clawed crayfish, both of which had been decimated by the crayfish plague. The introduction was extremely successful. *O. limosus*, which is resistant to the *Aphanomyces* (but was also its vector), pollution, and low oxygen concentrations, is also a very efficient breeder. It spawns both in fall, as European crayfish do, and in the spring (May). The species also has a very short egg incubation time (5-6 weeks) compared to that (6-7 months) of the European species (Ulikowski and Borkowska 1999). The spiny-cheek crayfish quickly spread to new territories, and had colonized northern and western Poland by the 1950s. Currently, it occurs in most of the territory where it has replaced the species mentioned above, in all types of fresh waters, even those that are very polluted or in large cities, as well as in brackish, estuarine waters such as the Vistula Lagoon. Generally common and occurring in about three quarters of the country, it is especially abundant in the northern and western regions of Poland (Leńkowska 1962, Jażdżewski and Konopacka 1995, Ďuriš 1999, Strużyński and Śmietana 1999, Strużyński 2001). It has not yet reached the south-eastern provinces, where some natural populations of the noble and narrow-clawed crayfishes have remained safe from crayfish plague (Jażdżewski and Konopacka 1995, Strużyński 1999a).

*Pacifastacus leniusculus* (Dana, 1852)

English - signal crayfish; Polish - rak sygnałowy, rak kalifornijski

This species was also intentionally introduced to Polish waters. It is native to the Columbia River system located between the Rocky Mountains and the Pacific coast of western North America (Lowery and Holdich 1988). As a



species resistant to crayfish plague, it was first introduced in the early 1960s and 1970s to Scandinavia (Fürst 1977), where it was successfully established in aquaculture (Abrahamsson 1972). Subsequently, the species was introduced to many European countries, including Finland, Hungary, England, Ireland, Switzerland, Germany, Austria, Italy, France, Luxembourg, Spain, Denmark, the Netherlands, Yugoslavia, Bulgaria, Cyprus, Lithuania, and the Czech Republic (for references see Krzywosz and Krzywosz 2001). The signal crayfish grows faster and is more fecund than all the other crayfish species occurring in Europe (Krzywosz *et al.* 1995). Several attempts to introduce it to Poland were made in the 1972-1979 period (Kossakowski *et al.* 1978, Krzywosz *et al.* 1995). Although 40,000 individuals were imported from the Swedish farm SIMONTORP AQUACULTURE AB in Blentarp and released into several lakes, ponds, and small rivers in northeastern Poland, the results were poor (Krzywosz and Krzywosz 2001). More successful attempts were made in 1997 at the Inland Fisheries Institute Dgał field station near Giżycko (Krzywosz 2001). To date, of the six introduction sites in northern Poland (Strużyński and Śmietana 1999), at least two are known to still exist (Krzywosz 2001). At the moment, culturing species as well as introductions to open waters are dependent on permission from the Polish Ministry of Environment (Radecki 2000). Just recently, aquaculture experiments with signal crayfish were abandoned as the species can also be a vector for *Aphanomyces*. Instead, an effort is being made to culture and re-establish the native *Astacus astacus* or the previously introduced *Pontastacus leptodactylus* species (Krzywosz 1999, 2001, Pyka 1999, Świerczyński 2000, Mastyński and Andrzejewski 2001, Mastyński *et al.* 2001, Strużyński 2001).

*Rhithropanopeus harrisi* (Maitland, 1874)

English - Harris mud crab; Polish - krabik amerykański

Native to the brackish lagoons and estuaries of the North American east coast, this species occurs from Canada to the Gulf of Mexico in a wide range of salinities. Along with trans-Atlantic transport, the species was first introduced to Zuidersee (Holland) in the early 1900s. It spread from here and in the 1930s it entered the lagoons (limans) of the Black Sea, and the Caspian Sea in the 1940s. In Baltic waters, *R. harrisi* was first noted in the brackish Vistula deltaic system of Poland in 1952 (Birštejn 1952, Demel 1953). Later, it was also recorded in the Pomeranian Bay, the Szczecin Lagoon, and the Gulf of Gdańsk. Its abundance in the Dead Vistula was very high in the 1950s and 1960s when it dominated the local zoobenthos. In the 1970s and 1980s, its abundance suddenly collapsed and only single individuals were recorded locally (Jażdżewski and Konopacka 2000). The population proliferated again in the

1990s, and this species is currently abundant. In 2001-2004, the authors recorded large numbers of young crabs inhabiting aggregations of *Dreissena polymorpha* in the Vistula Lagoon. Colonies of this common Ponto-Caspian bivalve invader apparently serve as a perfect hiding place for these crabs. Evidently, this is the formation of an interesting association between two invaders of different geographic origin.

#### **Other alien decapods**

*Eriocheir sinensis* Milne Edwards, 1854

English - Chinese mitten crab; Polish - krab wełnistorečki, krab wełnistoszczypcy

Currently the largest crustacean in the Baltic Sea, this species was unintentionally brought to European harbors in the ballast water tanks of vessels from southern China (Ingle 1986). It was first recorded in 1912 near Verden, in the Aller River, an affluent of the Weser River (Panning 1939). It spread quickly to the brackish coastal waters of the North Sea and to the Baltic Sea (Hällfors *et al.* 1981). Adult individuals enter large rivers hundreds of kilometers upstream from the sea. Although reproduction takes place in the sea, the young crabs spend their lives migrating upstream en masse. In the 1920s and 1930s, the species became a true pest, burrowing into banks and damaging hydrotechnical facilities. In 1931, local fishermen pulled approximately 125 tons of the crab from the lower Elbe River (Peters 1933). Then, in the late 1930s the size of the population decreased considerably. In the present territory of Poland the species was recorded first by Kulmatycki (1928) in the Szczecin Lagoon, which was then part of Germany. It then spread quickly to the east along the Baltic coast to the Vistula River estuary and the Mazurian Lake District (Kulmatycki 1931, 1932, Demel 1932, Peters 1933, Grabda 1973). During the 1930s, it was noted frequently inland, with the most upstream sightings in the Oder and its tributaries in Lower Silesia in 1929, and in the Vistula near Włocławek, the Warta River, the Drwęca River and Lake Wydminy near Giżycko, the easternmost sighting of this crab in Europe (for a summary see Grabda 1973, Jażdżewski and Konopacka 1995). Until very recently, the most inland sighting in Poland was in the Drwęca River in 1972 (Grabda 1973); however, in the summer of 2002 the crab was observed in the Warta River near Kostrzyń (Ochwat 2002). This was preceded by many reports of it from local fishermen. Since World War II, some single animals have been found each year along the Polish coast. In the past few years, Zettler (1998) has collected Chinese mitten crabs in many new inland localities in Mecklenburg and around the Szczecin Lagoon on the German side. As regards the Polish part of the basin, a very recent communication comes from the morphometric studies

of the crab population in Lake Dąbie by Normant *et al.* (2000). In 2000, Czerniejewski and Filipiak (2001) also reported a large population of mitten crabs from the Szczecin Lagoon, where they are commonly found in fishing nets. *Eriocheir sinensis* does not reproduce locally, and larvae or juveniles are spring immigrants from the western Baltic and the North Sea. Although just recently some ovigerous females were reported in the Gulf of Gdańsk (Normant, pers. comm.), there is still no evidence that the species is able to reproduce successfully in Polish waters. One of the agents for this migration might be the intensive ship traffic between Szczecin and the ports of Western Europe (Gruszka 1999). In recent years mitten crabs have also been observed more frequently in the eastern reaches of the Polish seaside on Lake Łebsko, the Hel Peninsula, the Gulf of Gdańsk, the Puck Bay, and the Vistula Lagoon (Normant *et al.* 2000). Similarly, fishermen have reported finding numerous crabs in nets in other parts of the Vistula Estuary, *e.g.*, the Dead Vistula and the Bold Vistula (Skorkowski, pers. comm.). In light of the preceding information along with the most recent inland sighting of the mitten crab in Polish waters, it can be assumed that the species is possibly beginning another wave of mass invasion towards the eastern parts of the Baltic Sea.

Czerniejewski and Filipiak (2001) also reported some complaints from fishermen concerning the negative influence of the crabs on the local fisheries. Although the mitten crabs feed mostly on aquatic plants, small macroinvertebrates, and only dead fish, they are known for destroying nets, demolishing ditches and banks, as well as for competing for food with fish and foraging in fish spawning grounds.

*Atyaephyra desmaresti* (Millet, 1831)

English - freshwater shrimp; Polish - krewetka nakrapiana (proposed name)

This freshwater shrimp is a recently recorded alien decapod species in Polish waters. Twelve individuals of this species were found by Gruszka (2001) in the western branch of the lower Oder River, near the town of Gryfino. To date, it is the only known record of this species in Poland; however, fast range extension cannot be excluded in the nearest future. Originally, *A. desmaresti* occurred in the fresh and brackish waters of the Mediterranean region (southern Europe and northern Africa). The species spread through Western Europe through the system of artificial waterways and reached the Danube River, Belgium, Holland, and Germany. It was recorded in Flussaue 30 km northwest of Freiburg, in the Rhein, Lippekanal, Leine, and the Mittellandkanal (Weinzierl *et al.* 1997). The species has been recorded in the Elbe drainage system in Mecklenburg since 1959 (Borchert and Jung 1960); from here it could have entered the Oder moving eastwards through the Elbe-Havel and Havel-Oder

canals. This freshwater shrimp reaches a maximum length of 35 mm for females, and 23 mm for males. It has a characteristic transparent body with a number of dark-brown speckles. Usually it occurs in vegetation, where it feeds on detritus, plant fragments, and green algae (Stresemann 1976, Wirtz 1991).

*Palaemon elegans* Rathke, 1837

This euryhaline marine species inhabits vegetated areas (Dalla Via, 1985) and is widely distributed in European coastal waters from the Black and Mediterranean seas to the North Sea and the Atlantic shores of Norway. It was also accidentally introduced to the Aral and Caspian lakes in the 1950s (Zentkevich, 1963). In some publications (e.g., Janas *et al.*, 2004) it was erroneously reported, based on data from Balss (1926), that this species was known from the southern Baltic and had ranged from Kiel to the Gulf of Gdansk since the 1920s. In fact, these data concerned another species – *Palaemon adspersus* Rathke, 1837. In fact, the distribution of *P. elegans* in the Baltic was, until recently, limited to its westernmost part. The species was reported sporadically only from Wismarer Bucht (Köhn and Gosselck, 1989). In the eastern and southern Baltic the species was found first in 2002 in the Arkona Basin (Zettler, 2002) and in Poland in the Gulf of Gdańsk (Janas *et al.*, 2004). However, the authors' unpublished data indicate that *P. elegans* has been present on the Polish Baltic coast at least since 2000 (records from the Martwa Wisła (Dead Vistula)). Currently, the species is the most abundant palaemonid shrimp along the Polish Baltic coast. It also inhabits the Szczecin Lagoon and the Vistula deltaic system including the Vistula Lagoon (authors' unpublished data). In 2003, the species was already found in the Gulf of Finland (Kekkonen, 2003, Lavikainen and Laine 2004). According to the suppositions of Köhn and Gosselck (1989), the larval stages of *P. elegans* were transported occasionally to the Baltic Sea in ballast waters. These authors reported that ovigerous *P. elegans* females did not occur in German Baltic waters and concluded that this species was not reproducing there. However, Zettler (pers. comm.) observed the species breeding in German Baltic waters. The present authors also observed ovigerous females and postlarval stages of all sizes in the Bay of Puck and along the open Baltic coast in Poland. In many places, it replaced completely native *P. adspersus*, while in others it dominated the palaemonid communities (unpublished data). Köhn and Gosselck (1989) hypothesised that *P. elegans* could have been introduced to German waters through shipping (ballast waters); however, there are no data available to either prove or disprove this assumption. Thus, it is still not clear if *Palaemon elegans* should be treated as an introduced, invasive alien species that poses a threat to local biodiversity, or

if it is simply enriching biodiversity through the natural extension of its range from the Atlantic coast.

## CONCLUSIONS

With the exception of one crayfish species that is not yet fully established in Polish waters, most of the other species were once or are at present in the rapid expansion phase. Among the 13 species of Decapoda recorded in Polish waters, seven are past or present invaders of alien origin. Six of these species have appeared in Polish waters during the last 120 years. If two species of marine decapods (*Pagurus bernhardus* - only larvae; *Carcinus maenas*), which are noted only sporadically in the Polish part of the Baltic Sea, are not included, then alien species comprise more than half of the Polish decapod fauna.

Some of the species have quite an important impact on the local fauna. The role of *Orconectes limosus* in the spread of crayfish plague is well documented. This fatal disease caused by the ascomycete fungus *Aphanomyces astaci* (Schikora, 1903) was brought from North America to Italy in the mid 1800s and subsequently spread throughout Europe. It has had a devastating effect on populations of native crayfish (Aldermann 1996). Regional outbreaks of the plague are still observed in Europe (Vogt 1999), and in Poland it affected the abundance of the native noble crayfish *Astacus astacus* and, to some extent, that of *P. leptodactylus*.

Another important but underestimated effect of the invasion is the formation of new biotic communities in local habitats. This has already been observed with regard to the Ponto-Caspian bivalve, the zebra mussel, and the North American *R. harrissi*. As was mentioned above, the zebra mussel colonies seem to create a perfect environment and hiding place for this alien crustacean, thus enhancing its further expansion.

In conclusion, Polish decapod fauna has been changing very dynamically and it is presumed that this will continue in the future. This may also include alteration of the entire benthic and planktonic communities. However, the exact nature of changes especially in biogeographical (*e.g.*, migration routes) and ecological terms (*e.g.*, demography, biology, alien species behavior) remains mostly unknown, and they need to be monitored and studied extensively.

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