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SHORT COMMUNICATION

New sites of the invasive signal crayfish, *Pacifastacus leniusculus* (Dana, 1852), from the Lutynia and Prosna rivers in Poland

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Abstract. This article presents new observations of the invasive signal crayfish, *Pacifastacus leniusculus*, in Poland. The species was detected for the first time in the Lutynia and Prosna rivers in southwest Poland. In total 59 and 50 individuals were captured. The population examined probably came from illegal releases, while the presence of juvenile specimens may suggest that the population is capable of reproduction. This species could continue to spread and expand its range to include additional aquatic ecosystems. Therefore, it is recommended to monitor the environment regularly and take appropriate remedial actions against this population.

Keywords: alien species, control, aquaculture, crustacean, Cambaridae

Introduction

Invasive crayfish are considered to be among the most destructive of invasive species (Galib et al. 2022). They affect directly the biotic elements of water reservoirs, threatening naturally occurring species (Wiśniewski et al. 2020). Many invasive crayfish species can carry crayfish plague caused by *Aphanomyces astaci*, which makes them a particular threat to native crayfish in Europe (Carvalho et al. 2022, Mojžišová et al. 2022). Invasive alien crayfish species enter new environments mostly by escaping from aquaculture or intentional releases (Bohman and Edsman 2013).

One such species is the signal crayfish, *Pacifastacus leniusculus* (Dana). It is a North American species, the native range of which is from the Pacific Ocean to the Rocky Mountains (Kozák et al. 2015). This species is distributed widely in Europe (Kozák et al. 2015, Śmietana et al. 2018). This species was imported to Sweden in 1959 to be cultured for the gastronomy sector (Kozák et al. 2015). At that time, it was not known that this species was also resistant to the crayfish plague and could be its vector (James et al. 2017). In 1971, *P. leniusculus* was brought to Poland as part of a deliberate introduction aimed at economic benefits (Śmietana et al. 2018). Currently, *P. leniusculus* can be observed mainly in the northern regions of Poland (Nędzarek et al. 2020, Protasowicki et al. 2023). The negative impact on the native noble crayfish, *Astacus astacus* (L.), in Poland has been proven (Krzywosz 2006). The impact of *P. leniusculus* on other natural values appears to be

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smaller, but due to its omnivorous nature, it may harm aquatic vegetation and invertebrate communities (Vedia et al. 2016). The species is subject to the provisions of the Polish Alien Species Act due to its negative impact on biodiversity and related ecosystem services. The act defines the legal framework for counteracting the spread of invasive alien species according to Regulation No. 1143/2014 of the European Parliament and of the Council of 22 October 2014 on preventive and remedial actions against the introduction and spread of invasive alien species. The regulation obliges all EU member states to take joint actions to eliminate, control, and isolate invasive alien species, which is possible based on notifications made under the Alien Species Act. This act requires local governments to report the presence of invasive alien species. A directive also intends to ensure proper information is disseminated to the public by creating a Central Data Register on invasive alien species, which collects data on the occurrence of invasive alien species in the environment and remedial actions taken against them. In this paper, we present new locations with confirmed occurrences of *P. leniusculus* in Poland.

Material and methods

Localization

The Lutynia (Fig. 1) is a small lowland river the source of which is located near the village of Korytnica. The river flows into the Warta River which is the third largest river in Poland. The length of the Lutynia is 62.69 km, and its average depth is between 1.0 and 1.5 m. Its depth is regulated by weirs, and this river has a sandy bottom with banks that are covered with lush aquatic plants such as the matting rush, *Schoenoplectus lacustris* L., and the common calamus, *Acorus calmus* L. There are lush clusters of submerged *Ceratophyllum demersum* L. and *Elodea canadensis* M. In turn, tree roots, grasses, and sedges submerged in the water provide excellent shelter for many aquatic animals. Moreover, there are

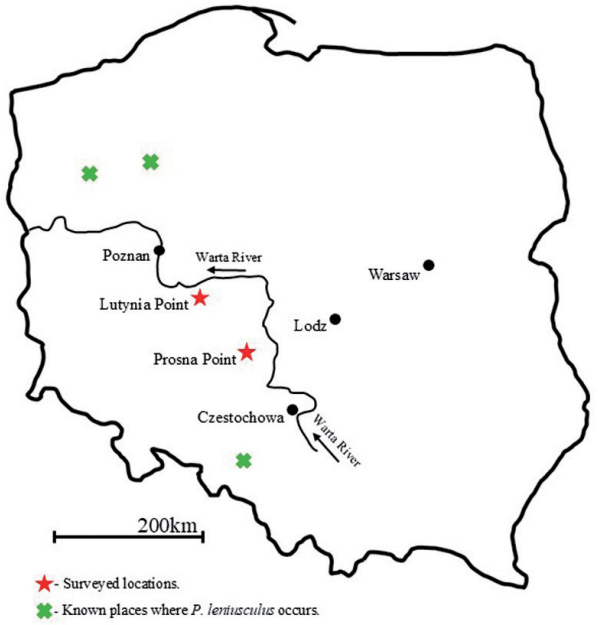

Figure 1. A map showing new locations of *P. leniusculus*. Other locations of this species were identified previously by Śmietana et al. (2018).

embedded plastic mats, ceramics, and plastic PVC pipes underwater.

The river is an attractive one for anglers, particularly the weirs where the depth is greater and therefore larger numbers of fish and crustaceans occur. These deeper areas are inhabited by fishes such as asp, *Leuciscus aspius* (L.), common barbel, *Barbus barbus* (L.), stickleback, *Gasterosteus aculeatus* L., ruffe, *Gymnocephalus cernua* (L.), chub, *Squalius cephalus* (L.), common perch, *Perca fluviatilis* L., pikeperch, *Sander lucioperca* L., northern pike, *Esox lucius* L., and sea trout, *Salmo trutta* L. Species under strict protection also occur, including spined loach, *Cobitis taenia* L., European bitterling, *Rhodeus amarus* (Bloch), and stone loach, *Barbatula barbatula* (L.). The presence of the invasive alien species topmounth gudgeon, *Pseudorasbora parva* (Temminck & Schlegel), Prussian carp, *Carassius gibelio* (Bloch), and spiny cheek crayfish, *Faxonius limosus* (Rafinesque), has also been detected (Golski et al. 2021).

The source of the Prosna River (Fig. 1) is located between the towns of Olesno and Gorzów Śląski in the village of Wolęcin, Radłów commune, Opole Voivodeship. The river flows into the Warta and, like

the Lutynia, is a left tributary. The length of Prosna is 216.8 km and the average depth is two meters. Along the course of the river, there are many hydrotechnical structures, including the power plant in Jastrzębniki and several weirs. The Prosna has a clay bottom, and in some places, the river bank is covered with lush aquatic plants such as *C. demersum*, *E. canadensis*, and common calamus, *A. calmus*. This river is known for its recreational values and is popular among anglers (Wiatkowski 2010). Fish species such as *P. fluviatilis*, *S. lucioperca*, and *E. lucius* live in the river, and they may help reduce the abundance of invasive crayfish. The spined loach, *C. taenia*, which is a protected species in Poland, is also present. Moreover, *F. limosus* is also noted (Kruk et al. 2017). The crayfish that were caught were euthanized and transported to a laboratory (Warsaw University of Life Sciences) for scientific examination to determine if they were infected with parasites. The crayfish were caught in throughout a 2,500 m¸ surface area in each river. The sites where crayfish were caught are presented in Fig. 2.

Figure 2. The Lutynia River (A) and the Prosna River (B).

Detection and identification

The new position on the Lutynia River (52°01’26.9"N 17°32’43.2" E), was 50 km southeast of Poznań. The position on the Prosna River (51°08’07.1"N 18°22’46.8" E) was approximately 40 km northwest of Czestochowa (Fig. 2). Two inspections were conducted in June on the Lutynia River and in September on the Prosna River. In each location, observation time was two hours.

The crayfish were caught in both locations with a 2 mm mesh net or manually with rubber gloves. Potential hiding places such as rocks and aquatic plants were searched for crayfish. Catch methods were the same during all samplings. The crayfish were then transferred to a 10 l bucket (Wróblewski 2023). Each crayfish was identified according to a key (Kozák et al. 2015). The sex was determined, and the total length of each crayfish was measured (Fig. 3).

Results

In total 109 individuals of *P. leniusculus* were caught. Their various body lengths and standard deviation was 64.1±26.1 mm for the population in the Lutynia River and 39.0±16.3 mm in the Prosna River. In total, in all locations 56 males and 53 females of *P. leniusculus* were caught. Additionally, two individuals of *F. limosus* were identified, and both specimens were females.

In the Lutynia River, 59 specimens of *P. leniusculus* and one female of *F. limosus* were caught. The largest number of crayfish were specimens with a total length of ≤ 50 mm, and the smallest number were in the 81–90 mm range (see Table 1). In the Prosna River, 50 specimens of *P. leniusculus* and one

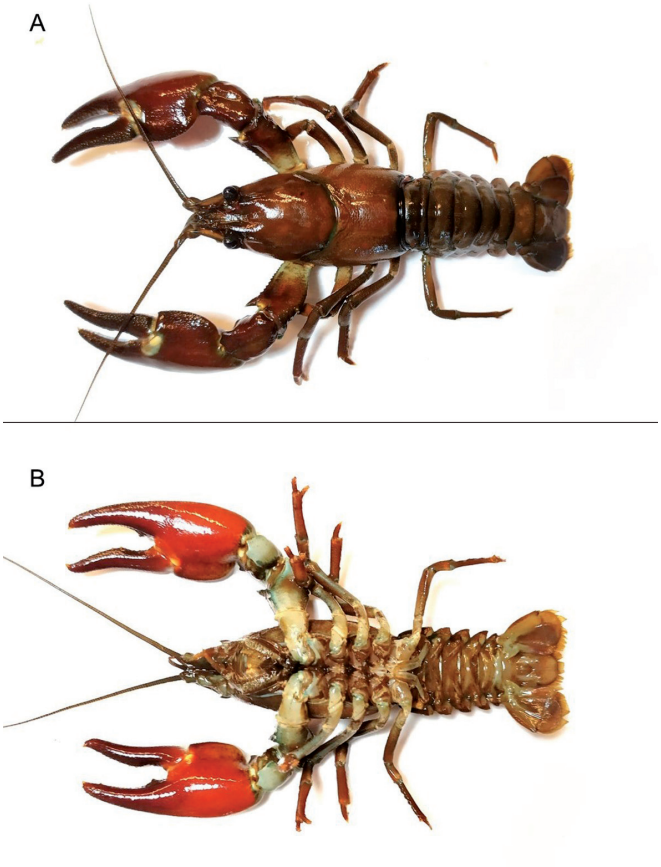

Figure 3. Signal crayfish caught in the Prosna River: dorsal view (A), ventral view (B).

Table 1
Number of signal crayfish (n) caught and their share (%) by total length

	Lutynia		Prosna	
Total lenght (mm)	n	%	n	%
≤ 50	28	47.5	37	74.0
51–60	9	15.2	6	12.0
61–70	2	3.4	4	8.0
71–80	3	5.0	2	4.0
81–90	1	1.7	0	0
91–100	8	13.6	1	2.0
≥100	8	13.6	0	0
Summary	59	100	50	100

female *F. limosus* were caught. The largest number were crayfish with total lengths ≤ 50 mm (Table 1).

The sex ratio of females and males was 50.8% male and 49.2% female *P. leniusculus* in the Lutynia River and 52% male and 48% female *P. leniusculus* in the Prosna River. The crayfish density at the site in Lutynia River was 0.59 specimen per meter of shoreline, and in the Prosna River it was 0.5 specimen per meter of shoreline.

Discussion

We provide new documented data on the occurrence of *P. leniusculus* in rivers in Poland. These are new locations in the Łódź, Opole, and Greater Poland voivodeships, where this species has not previously been registered (Central Data Register on Invasive Alien Species). The very fact that the species was found in new rivers shows that this species may be more widespread. There is also information about the occurrence of this crayfish in the Oder River from 2022 (Barowska et al. 2023).

The individuals caught had sizes of ≤ 50 mm, which suggests that they may have been juveniles. This, in turn, could be proof that the populations studied in the Lutynia and Prosna rivers are breeding. According to Kozák et al. (2015), juveniles at the end of the first season reach 30 mm and in the second year they reach 60 mm, but this can differ among populations and locations where they breed. The same authors point out that *P. leniusculus* reach maturity when they are two to three years old and achieve 70–90 mm total length. The population studied could therefore contain sexually mature individuals.

Many sources confirm the negative impact of this crayfish on native animal species, plants, and whole ecosystems (Elser et al. 1994, Hessen et al. 2004, Dobler and Geist 2022, Mohammed et al. 2023). Their occurrence contributes to the consumption of spawn, eggs, and juvenile stages of amphibians and fishes (Larson et al. 2012, Ludányi et al. 2022).

There is also a risk of the crayfish plague, *Aphanomyces astaci* (Schikora), being transmitted by *P. leniusculus*, which may be confirmed by future research on the individuals caught. The transmission of crayfish plague by *P. leniusculus* in other locations in

Europe is well known (Havlíčková et al. 2013, James et al. 2017). Progressing climate change and anthropogenic changes in aquatic ecosystems favor invasions of *P. leniusculus*. Publications from outside of Poland confirm that this crayfish willingly chooses places transformed by humans (Horvatović et al. 2022, Lovrenčić et al. 2022).

The way these crayfish entered the studied rivers suggests escapes from aquaculture or intentional introductions (Larson et al. 2022). Such human activities concern not only *P. leniusculus* but also many other crayfish considered to be invasive alien species. Examples include the red swamp crayfish, *Procambarus clarkii* (Girard), and the marbled crayfish, *Procambarus virginalis* (Lyko), which were intentionally released into Polish waters from farms (Maciaszek et al. 2022). In turn, the spiny cheek crayfish, *Faxonius limosus* (Rafinesque), escaped from breeding facilities and took over almost all waters in Poland and Europe, similarly to *P. leniusculus* (Huber and Schubart 2005, Grandjean et al. 2017, Bonk and Bobrek 2021, Let et al. 2023, Tarandek et al. 2023). The probable sources of *P. leniusculus* occurrence in the locations studied are fish farms. This may be evidenced by the genesis of the introduction of this species to Polish waters as part of a deliberate introduction aimed at economic benefits (Śmietana et al. 2018).

The research conducted on the Lutynia and Prosna rivers may indicate that the studied ecosystem is suitable for *P. leniusculus* (Ercoli et al. 2021). In the case of invasive alien species recognized as requiring coordinated action at the EU level, remedial actions should also be taken to minimize the threat they pose (Dresser and Swanson 2013, Madzivanzira et al. 2023). Legislation aims to limit the spread of undesirable species into the environment (Peters and Lodge 2009, DiStefano et al. 2023). It is also recommended to implement regular environmental monitoring and control measures in the occupied and surrounding areas, as the presence of *F. limosus* has also been recorded (Wróblewski 2023).

The invasive *P. leniusculus* has adapted well to the conditions typical of human-transformed rivers. The observations made suggest the optimal period for implementing remedial actions aimed at eliminating this species from the natural environment in Poland. It is therefore very important that the population of *P. leniusculus* is regularly monitored to limit the numbers of this crustacean in Polish waters. It is also recommended to introduce remedial measures for the populations studied.

Author contributions. P.W.: conceptualization, methodology, and writing; R.M.: investigation, and supervision; W.Ś.: formal analysis, review of the final draft.

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