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SHORT NOTES

Distribution of crayfish (Decapoda, Astacoidea) in Flanders (Belgium): an update

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There are thought to be approximately 600 crayfish species worldwide, which can be subdivided into two superfamilies: the Astacoidea, of which all species occur in the northern hemisphere, and the Parastacoidea, which have only been recorded in the southern hemisphere (1, 2). The Astacoidea can be subdivided into two families: Astacidae and Cambaridae. Crayfish constitute an important link in the food web since most species are keystone consumers of macroinvertebrates, detritus and macrophytes in lotic and lentic waters, and in turn serve as prey for several species including birds, fish and otter (3). It has been estimated that between one-third and one-half of the world's indigenous crayfish species are threatened with population decline or extinction (4). Non-indigenous crayfish introduced intentionally for astaciculture or unintentionally as unused bait or unwanted aquarium pets constitute the main threats to indigenous crayfish (5, 6, 7). In addition to displacement of indigenous crayfish species by non-indigenous species through competition, the crayfish plague (*Aphanomyces astaci*) has had a devastating effect on indigenous crayfish in Europe (8).

Because of their high commercial value, the cultivation of non-indigenous crayfish species increased enormously during the end of the 20th century in Europe, resulting in numerous introductions in a semi-natural environment (9). The introduction of crayfish in nurseries was very successful and several species were able to build up viable populations (8). This is mainly due to the robust nature of these freshwater crustaceans, coupled with fast individual and population growth, high fecundity and omnivorous behaviour (10). Non-indigenous crayfish can have an ecological as well as economic impact. They have the potential to reduce biodiversity and may also cause direct economic damage by reducing recruitment of commercially valuable fish stocks or by weakening dykes causing flooding danger (3, 7). In addition, non-indigenous crayfish may induce drastic habitat changes, altering the natural habitat and in this way, causing the decline of aquatic populations (11).

In Belgium, five crayfish species have been recorded, the indigenous *Astacus astacus* (LINNAEUS, 1758) and four non-indigenous species: *Astacus leptodactylus* ESCHSCHOLTZ, 1823, *Orconectes limosus* (RAFINESQUE, 1817), *Pacifastacus leniusculus* (DANA, 1852) and *Procambarus clarkii* (GIRARD, 1852) (5, 12, 13). *A. astacus* is threatened in Europe and faces extinction (5). Therefore, this species is classified on the IUCN red list as vulnerable (14). GÉRARD (1986) was the first to give an overview on the distribution of crayfish in Belgium based on a survey that was carried out by the Station

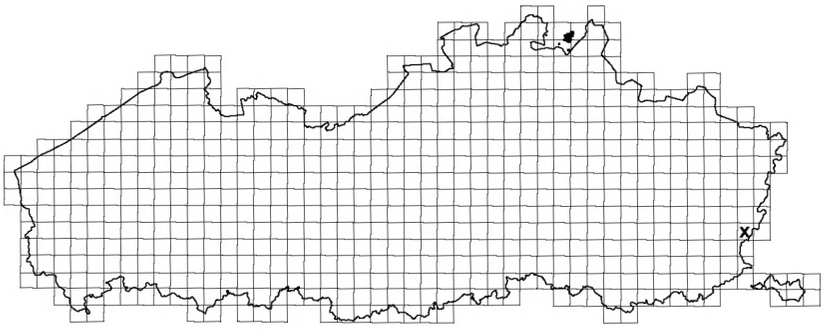
de Recherches Forestières et Hydrobiologiques of Groenendaal between 1982 and 1985 (15). Since then, the Walloon region especially (southern part of Belgium) has been investigated and some research regarding the current distribution of crayfish has been published (8, 16, 17). However, for Flanders (northern part of Belgium), little recent information is available on the presence and distribution of indigenous and non-indigenous crayfish. It is important to know the distribution and gain insight into the ecological effects of non-indigenous crayfish on aquatic communities. Careful mapping revealing patterns in crayfish diversity across regions and habitats is an important first step in this process. In this study, we present an overview of the current distribution of crayfish in Flanders based on existing databases supplemented with intensive field sampling.

Information on the distribution of crayfish in Flanders was retrieved from the database of the Flemish Environment Agency (VMM), which has monitored the water quality in Flanders since 1989. As a consequence, a large collection of more than 10,000 biological samples is currently available. Biological monitoring of macroinvertebrates took place by means of hand netting or use of artificial substrates as described by GABRIELS et al. (2010) (18) and more than 2,500 samples containing Crustacea were identified to species level. Analysis of these samples revealed important information regarding the occurrence of crayfish in Flanders. Additional information was retrieved from the collections of the Royal Belgian Institute of Natural Sciences (RBINS). Field sampling (at predetermined locations as well as casual observations) carried out by the Laboratory of Environmental Toxicology and Aquatic Ecology (Ghent University) and the Research Institute for Nature and Forest (INBO) yielded additional information on the occurrence of the different crayfish species. Recent samplings of crayfish were performed at several locations where crayfish could be expected, from October 2010 to May 2011 by means of single fyke nets (0.25m diameter and a length of 0.50m), specifically designed to catch crayfish. The length (from rostrum to the end of the telson, accuracy=1 mm) and wet weight (Kern 440-53, accuracy=1 g) of all individuals were measured. The numbers of males and females (including gravid females) were recorded when possible.

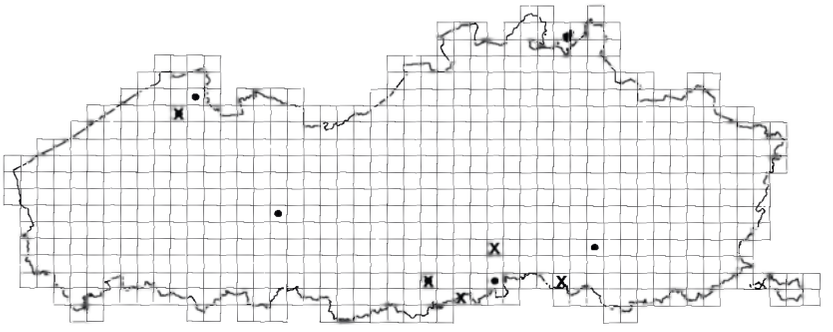
In total, four non-indigenous crayfish species were found during the recent sampling campaign. In Flanders, the only indigenous crayfish, *Astacus astacus*, was recorded for the last time in 1945 in Lanaken (collection RBINS). *A. astacus* is a species that prefers clean running waters or ponds with well-oxygenated water (15). In Wallonia, *A. astacus* is still present in 41 stagnant water sites and six small streams, although its numbers have continued to decline since the 1990s due to the crayfish plague and competition with non-indigenous crayfish species (8). A decrease in water quality and habitat deterioration in combination with the crayfish plague and competition with non-indigenous crayfish species are probably the main causes of the extinction of *A. astacus* in Flanders.

Astacus leptodactylus, originating from East-Europe was introduced for the first time in Belgium in the 1970s and was first recorded in Flanders in 1986 (15). *A. leptodactylus* was originally introduced to replace stocks of indigenous crayfish, but it also seemed to be vulnerable to the crayfish plague and consequently did not fulfil the expected yield (19). Currently, the species occurs at six scattered locations in Flanders (Fig. 1): three ponds, one small stream and two canals. It has habitat preferences similar to *A. astacus* (15), but has a competitive advantage over the indigenous species (20) and is thought to be outcompeting the remaining populations of *A. astacus* in the southern parts of Belgium (8).

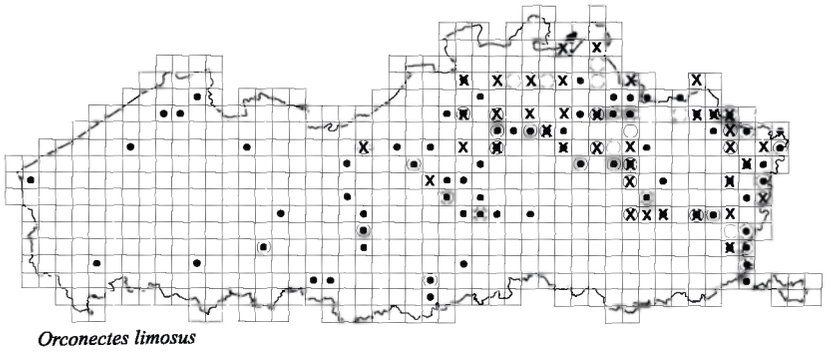
Pacifastacus leniusculus was introduced for the first time into Flanders in 1979 (14) and was recorded at three locations in Flanders before 1990 (Fig. 1). During recent sampling, the species was only found in one pond near Hasselt at low densities. Although this species is known to be successful and widespread throughout Europe



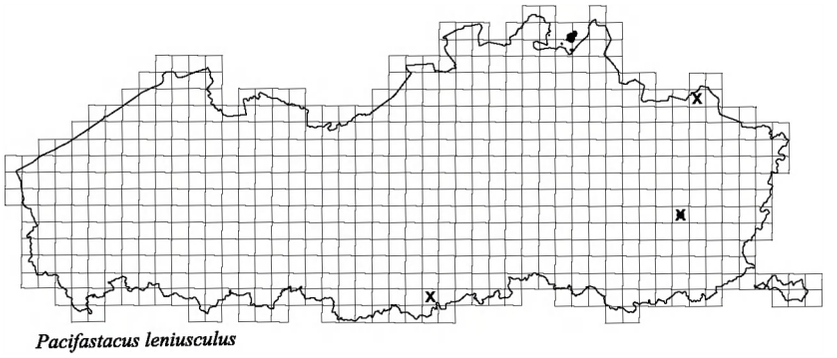
Astacus astacus



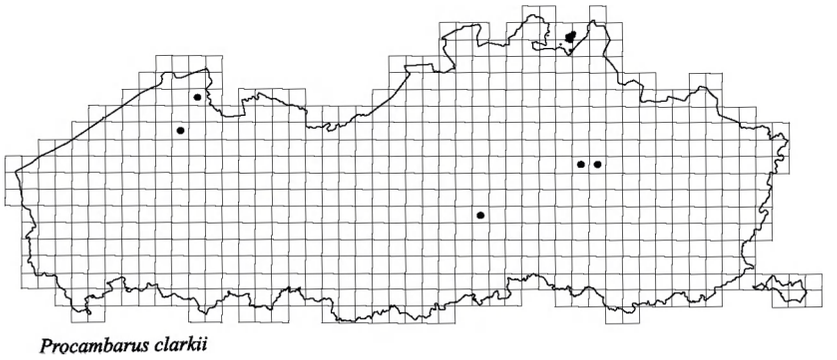
Astacus leptodactylus



Orconectes limosus



Pacifastacus leniusculus



Procambarus clarkii

Fig. 1. – Distribution of the crayfish species in Flanders before 1990 (cross), from 1990 to 1999 (circle) and since 2000 (black dot) on a 5*5 km UTM grid.

(8), it seems to have a restricted distribution in Flanders. *P. leniusculus* also has similar habitat preferences to *A. astacus* (21). Despite the reported co-occurrence (22), *P. leniusculus* is able to outcompete the indigenous species (21). *P. leniusculus* attains a similar size, but grows faster, has earlier sexual maturity, produces larger clutches and is resistant to the crayfish plague (23).

The third non-indigenous species present in Flanders is *Orconectes limosus*, which was found for the first time in Flanders in 1977 (24). This very successful species is widely distributed, occurs in all types of aquatic systems (canals, rivers, brooks and ponds) and is the most common crayfish species in Flanders (Fig. 1). This species started its colonisation in the eastern part of Flanders where it rapidly invaded large watercourses (13). Since the 1990s *O. limosus* has spread to the West of Flanders (Fig. 1) with an average speed of 10 km per year. The average cumulative increase in its distribution area since 1977, measured as the number of 5*5 km UTM grid cells per year, was 12 grid cells per year. *O. limosus* appears not to be as sensitive to land use changes and human activities as the indigenous crayfish species (25). Moreover, it can withstand habitats unfavourable to indigenous species, such as soft substrates, turbid and muddy waters, polluted canals and organically-enriched ponds and lakes (26).

The most recently introduced species, *Procambarus clarkii*, was discovered in a pond near Zammel in 2008 (12). Currently, the species is reported at four other locations: a pond near Laakdal, not far from its first observation, a pond near Mechelen and several canals with slow running water near Bruges (Fig. 1). In one of these canals, the Damse Vaart, there is expected to be a large population of *P. clarkii* since the species is frequently caught and reported by fishermen. This might indicate that the species is in full expansion. Besides dispersal by human activities, rapid, active dispersal of the species may occur because it can spread over land and is thus not dependent on the aquatic environment for its dispersal (12). *P. clarkii* may become the next dominant species of crayfish, since it has been shown to outcompete several other crayfish species (27). It is known to contribute to biodiversity loss and habitat degradation in several freshwater systems of south central Europe (7) and is therefore also expected to have a negative impact on aquatic communities in Flanders.

Comparing the length and weight of the different species, *P. clarkii* is the largest, but individuals of the same size weigh less compared to *A. leptodactylus* (Fig. 2). The latter is often cultured due to its relatively large size, high weight and its high economic value (19). *O. limosus* is the smallest of these crayfish species. No individuals heavier than 60 g were found (Fig. 2). Good correlation between the size and the weight of the different species was observed (Fig. 2). With the exception of *Pacifastacus leniusculus*, we found large populations of all species, containing males, (gravid) females and juveniles (Table 1). During the catch in spring, more than 70% of *O. limosus* females carried eggs, whereas only 30% of *A. leptodactylus* females were gravid (Table 1).

Environmental impact and invasion stage were assessed for each species based on an environmental impact assessment protocol (ISEIA) and the geographic distribution of each species in Flanders (28). *O. limosus* was categorised as A3, indicating that the species has a high environmental impact (black list) and is widespread in Flanders. *Pacifastacus leniusculus* and *Procambarus clarkii* were assessed as species with possible high environmental impacts, but with isolated populations and consequently were categorised as black list species (A1). However, as *Pacifastacus leniusculus* only occurred at one location in Flanders its overall impact can be minimized. *A. leptodactylus* has a medium environmental impact, which is reversible and only some isolated populations occur in Flanders; this species has, therefore, been put on the watch list (B1). Our risk analysis of crayfish species is comparable with previous results of an invasive

species screening tool applied to crayfish in Italy (29). The top three species with the highest impact (*O. limosus*, *P. leniusculus* and *Procambarus clarkii*) were also encountered in Flanders and classified as 'black list species'. More detailed research and monitoring is needed in order to assess their impact on local communities and ecosystem functioning in Flanders.

This update on the current distribution of crayfish in Flanders clearly shows that the indigenous species *A. astacus* is extinct in Flanders and that meanwhile several non-indigenous species have now established good populations. Moreover, we hypothesize that *P. clarkii* has the potential to become the next dominant crayfish species in Flanders since it is rapidly expanding its range. A good overview of the distribution of the various species is vital to conservation efforts. The habitats of remaining indigenous populations in Belgium urgently need protection and appropriate management as sanctuary sites. In addition, our faunistic data can be helpful in identifying regions where *A. astacus* could be reintroduced. In order to reduce propagule pressure as a result of intentional introductions, it is important to build awareness among the public on the dangers related to the introduction of non-indigenous crayfish.

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TABLE 1

Overview of the crayfish species found in Flanders during recent samplings of several locations from October 2010 to May 2011, with indication of the female:male ratio, the percentage of gravid females and the average size with standard deviation.

Species	Origin	female:male	% gravid females	Av. size ± SD (mm)
Astacus leptodactylus (N=58)	East Europe	1:2	30	92±12
Orconectes limosus (N=64)	North America	1.5:1	76	86±10
Pacifastacus leniusculus (N=1)	North America	-	-	104
Procambarus clarkii (N=38)	North America	-	-	111±9

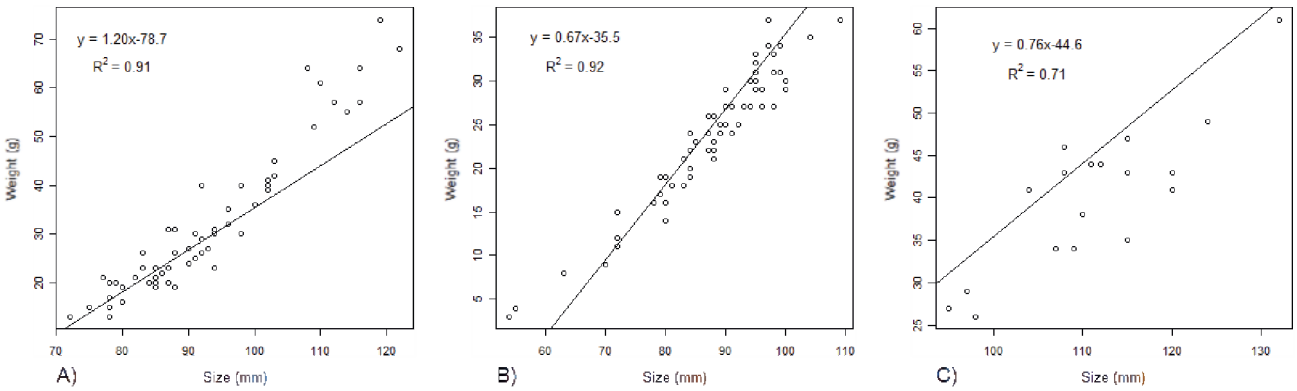

Fig. 2. – Relationship between size and weight of the crayfish species. (A): *Astacus leptodactylus*. (B): *Orconectes limosus*. (C): *Procambarus clarkii*.

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