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Alien macrocrustaceans in freshwater ecosystems in the eastern part of Flanders (Belgium)

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ABSTRACT. Biological invasions of freshwater macroinvertebrates are gaining more and more interest because the ecological and economical impact of some of these species is high. Since crustacean taxa appear to be successful groups invading new areas, an inventory of the macrocrustaceans in Flanders was made. At least 22 freshwater macrocrustacean species have been reported from Flemish water bodies. A detailed study of six canals, one small artificial watercourse and one natural river in the eastern part of Flanders revealed that invaders such as *Dikerogammarus villosus*, *Gammarus tigrinus* and *Chelicorophium curvispinum* are already quite common. Especially *D. villosus* is currently rapidly expanding and has a serious impact on native and other exotic gammarid species. Based on observations in neighbouring countries, several additional species are expected to arrive in the near future. A follow-up of the alien species together with a monitoring scheme to detect new incoming species is valuable to estimate the size of the problem and to be able to closely follow their ecological and economical impact.

KEY WORDS: *Chelicorophium curvispinum*, *Dikerogammarus villosus*, exotic species, *Gammarus tigrinus*, macroinvertebrates.

INTRODUCTION

During the last century, an increasing number of alien species has been observed in watercourses worldwide. Although migration of species can be considered as a natural process, anthropogenic influences have altered the geographical scale, speed and manner of spread of invaders (ELTON, 1958; CROOKS, 2002). In Europe, different groups of exotic macroinvertebrates are found in freshwater systems, of which the majority belong to the crustaceans and the molluscs originating from the Ponto-Caspian basin (VANDEN BOSSCHE et al., 2001; BIJ DE VAATE et al., 2002; DEVIN et al., 2005b). Their intrinsic characteristics, such as a short generation time, rapid growth with early sexual maturity, high fecundity, euryhaline and omnivorous, make them extremely suitable for rapid expansion and establishment in freshwater ecosystems (BIJ DE VAATE et al., 2002). It is known that alien species can have an impact on both native and exotic biota (KINZELBACH, 1997; DICK & PLATVOET, 2000; SALA et al., 2000; VAN DER VELDE et al., 2000; BIJ DE VAATE et al., 2002; DICK et al., 2002; BOLLACHE et al., 2004; KELLY & DICK, 2005; VAN RIEL et al., 2007); change the functional diversity within macroinvertebrate communities (DEVIN et al., 2005a); cause homogenization of freshwater ecosystems (RAHEL, 2002; BOLLACHE et al., 2004) and facilitate the establishment of other invaders (RICCIARDI, 2001; DEVIN et al., 2003).

Because of the growing number of invaders and the ecological and economical consequences, the invasion issue has received special attention. As a result, the number of publications, workshops, congresses and journals about exotic species has increased substantially (PYSEK et al., 2006). In contrast to other countries and even Wallonia, the southern region of Belgium (VANDEN BOSSCHE et al., 2001; VANDEN BOSSCHE, 2002; JOSENS et al., 2005), Flanders has hardly been examined for the presence and spread of freshwater exotic species. WOUTERS (2002) gave an overview of the alien macrocrustaceans in the whole of Belgium. He stated that at least 13 macrocrustaceans had invaded Belgium. Other studies revealed that exotic molluscs (*Dreissena polymorpha* (Pallas, 1771), *Potamopyrgus antipodarum* (Gray, 1843), *Corbicula fluminea* (Müller, 1774), *C. fluminalis* (Müller, 1774)), annelids (*Hypania invalida* (Grube, 1860)) and flatworms (*Dendrocoelum romanodanubiale* (Codreanu, 1946) and *Girardia tigrina* (Girard, 1850)) have invaded Flemish watercourses (SWINNEN et al., 1998; NGUYEN & DE PAUW, 2002; VERCAUTEREN et al., 2005). For marine and brackish waters in Flanders, an overview of all alien taxa has been presented by KERCKHOF et al. (2007). Also for Cladocera, a group of microcrustaceans, an overview was given of the indigenous as well as non-indigenous species occurring in Flanders (LOUETTE et al., 2007). The proximity of the sea, the interconnection between different waterways, the high degree of canalisation, the boat transport and the presence of harbours make Flemish watercourses susceptible for aquatic invasions (VERCAUTEREN et al., 2005).

MATERIALS AND METHODS

Data and sampling locations

The Flemish Environment Agency (VMM) monitors a large number of sampling sites scattered over the different stagnant and running freshwater systems in Flanders. Annually, almost 1500 biological samples of macroinvertebrates are identified at genus or family level. Consequently, information about alien macrocrustacean species such as *Dikerogammarus villosus* (Sowinsky, 1894) or *Gammarus tigrinus* Sexton, 1939 was not available since both species belong to the same family Gammaridae as the indigenous species *G. pulex* (Linnaeus, 1758). The present study aims to make an inventory of the presence of alien freshwater macrocrustacean species in Flemish watercourses based on the samples of the VMM and the available literature. Three types of data were available.

(1) In total, 292 samples of macrocrustaceans, collected by the VMM in the eastern part of Flanders (Fig. 1) between 1991 and 2005, were identified at species level. The sampling sites were located in six large canals: the Albert canal, the Dessel-Schoten canal, the Bocholt-Herentals canal, the Dessel-Kwaadmechelen canal, the Zuid-Willemsvaart canal and the Briegden-Neerharen canal; one natural watercourse: the Kleine Nete and one small artificial watercourse: the Postelvaartje. The canals were chosen based on previous observations of several alien macrocrustaceans and their connection with the Scheldt as well as the Meuse catchment. The other watercourses were selected because of their connection with one of the canals and for comparing their status of invasion with the canals. The samples were collected at 66 different locations scattered over the different watercourses, however, those stations were not sampled annually. Table 1 gives an overview of the number of samples collected and analysed in the watercourses. For each watercourse, the data of the different localities were combined and the average relative abundance of the crustacean families was calculated (Fig. 2). Macrocrustaceans were identified at species level, based on different identification keys (Gledhill et al., 1993; Eggers & Martens, 2001; Huwae & Rappé, 2003).

(2) In addition to these samples, a macroinvertebrate dataset of the VMM was available. This dataset contains data from families of crustaceans in Flemish watercourses between 1989 and 2005. Since some families are only represented by a single exotic species in these samples (the family Janiridae by *Jaera istri* Veuille, 1979, Cambaridae by *Orconectes limosus* (Rafinesque, 1817), Varunidae by *Eriocheir sinensis* H. Milne Edwards, 1854, Talitridae by *Orchestia cavimana* Heller, 1865 and Atyidae by *Atyaephyra desmaresti* (Millet, 1831)), the distribution of these species in other parts of Flanders could be analysed.

(3) Additional information of exotic macroinvertebrates was available from literature and observations made by colleague zoologists (personal communications).

Sampling methodology

Depending on the depth of the watercourses, macroinvertebrates were sampled by means of a standard handnet or artificial substrates as described by Gabriels et al. (in press). The canals were sampled with artificial substrates; the samples of the Kleine Nete and Postelvaartje were collected with a handnet. The sampling technique affects the catchability and hence the observed proportion of the densities of the different species reflects how often these species were caught and not necessarily their relative abundance in the field

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TABLE 1

Number of sampled localities in the studied watercourses per year
(NA = not available, - = not identified; () = no crustaceans found)

Watercourse	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total (n=292)
Albert canal	1	2	NA	7	8	3	6	6	5	1	4	3	8	5	5	64
Dessel-Schoten canal	2	NA	2	4	4	5	2	2	3	4	2	4	3	2	2	41
Dessel-Kwaad-mechelen canal	1	NA	NA	1	1	1	1	3	1	NA	NA	2	1	2	2	16
Bocholt-Heren-tals canal	5	2	6	5	5	5	4	6	5	4	6	3	6	3	6	71
Zuid-Willems-vaart canal	NA	NA	NA	1	4	2	1	1	1	1	1	2	NA	1	2	17
Briegden-Neer-haren canal	NA	NA	NA	1	NA	NA	1	NA	NA	NA	NA	1	NA	NA	NA	3
Postelvaartje	-	-	-	NA	NA	NA	(1)	NA	2	1	NA	3	NA	5	1	13
Kleine Nete	-	-	-	1	NA	7	9	6	5	7	5	8	5	8	6	67

TABLE 2

Overview of the freshwater macrocrustaceans encountered in Flanders, with indication of their origin, the year of first detection of exotic species in Flanders with reference, the current abundance in Flanders (+ only a few records; ++ rare; +++ common; ++++ very common) and the number of sampling sites in the study area where the species was found. R.B.I.N.S. : Royal Belgian Institute of Natural Sciences.

Order	Family	Species	Origin	First occurrence in Flanders	Reference	Presence in Flanders	Sites in study area (n=66)
Amphipoda	Corophidae	*Chelicorophium curvispinum*	Ponto-Caspian	1990	Vercauteren et al., 2005	+++	40
	Crangonictidae	*Crangonyx pseudogracilis*	North America	1992	Wouters, 2002	+++	3
	Gammaridae	*Dikerogammarus villosus*	Ponto-Caspian	1997	Present study	+++	40
		Echinogammarus berilloni	Iberian Peninsula	1925	Wouters, 2002	+	2
		Gammarus fossarum	Indigenous			+	
		Gammarus pulex	Indigenous			++++	34
		Gammarus roeseli	Southern Europe	1937	Collection R.B.I.N.S.	++	4
		Gammarus tigrinus	North America	1991	Present study	++++	49
	Talitridae	*Orchestia cavimana*	Ponto-Caspian	1927	Wouters, 2002	+++	2
Isopoda	Asellidae	*Asellus aquaticus*	Indigenous			++++	55
		Proasellus coxalis	Southern Europe	1998	Boets et al., unpublished data	++	
		Proasellus meridianus	Southern Europe	1945	Collection R.B.I.N.S.	+++	21
	Janiridae	*Jaera istri*	Ponto-Caspian	2000	Present study	++	10
Mysida	Mysidae	*Hemimysis anomala*	Ponto-Caspian	1999	Verslycke et al., 2000	+	
		Limnomysis benedeni	Ponto-Caspian	2005	Lock et al., 2007	+	
Decapoda	Astacidae	*Astacus astacus*	Indigenous			Extinct	
		Astacus leptodactylus	Eastern Europe	1986	Gerard, 1986	+	
		Pacifastacus leniusculus	North America	1986	Gerard, 1986	+	
	Atyidae	*Athyaephyra desmaresti*	Southern Europe	1895	Wouters, 2002	++	17
	Cambaridae	*Procambarus clarkii*	North America	2008	Boets et al., 2009	+	
		Orconectes limosus	North America	1977	Wouters, 2002	+++	40
	Varunidae	*Eriocheir sinensis*	Southeast Asia	1933	Wouters, 2002	+++	1

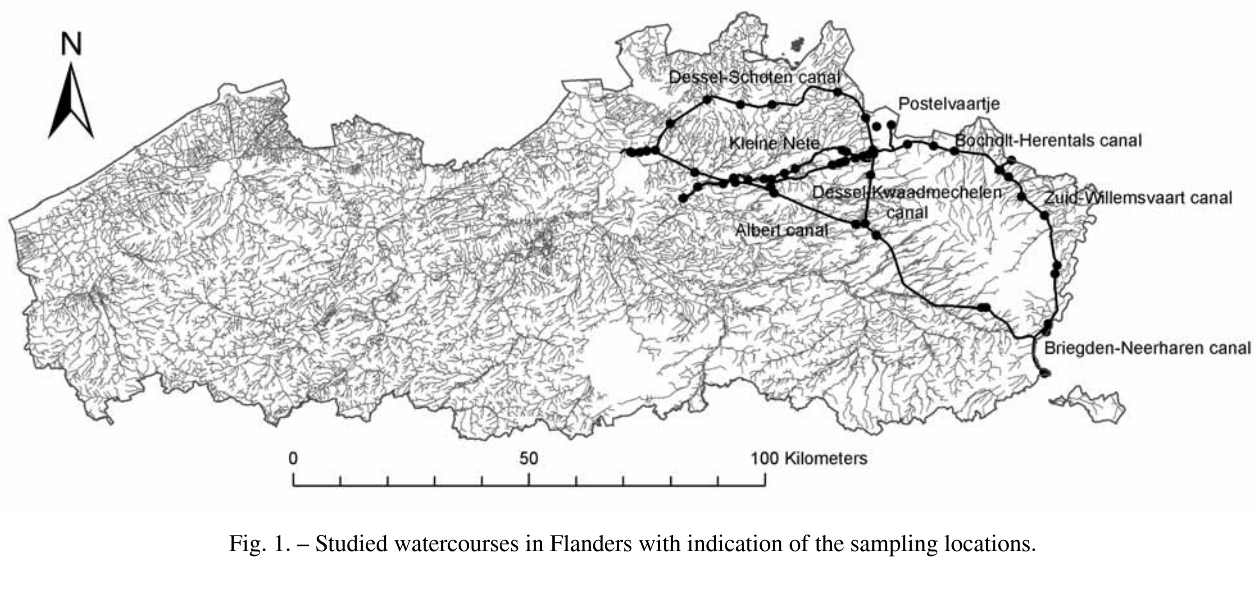

Fig. 1. – Studied watercourses in Flanders with indication of the sampling locations.

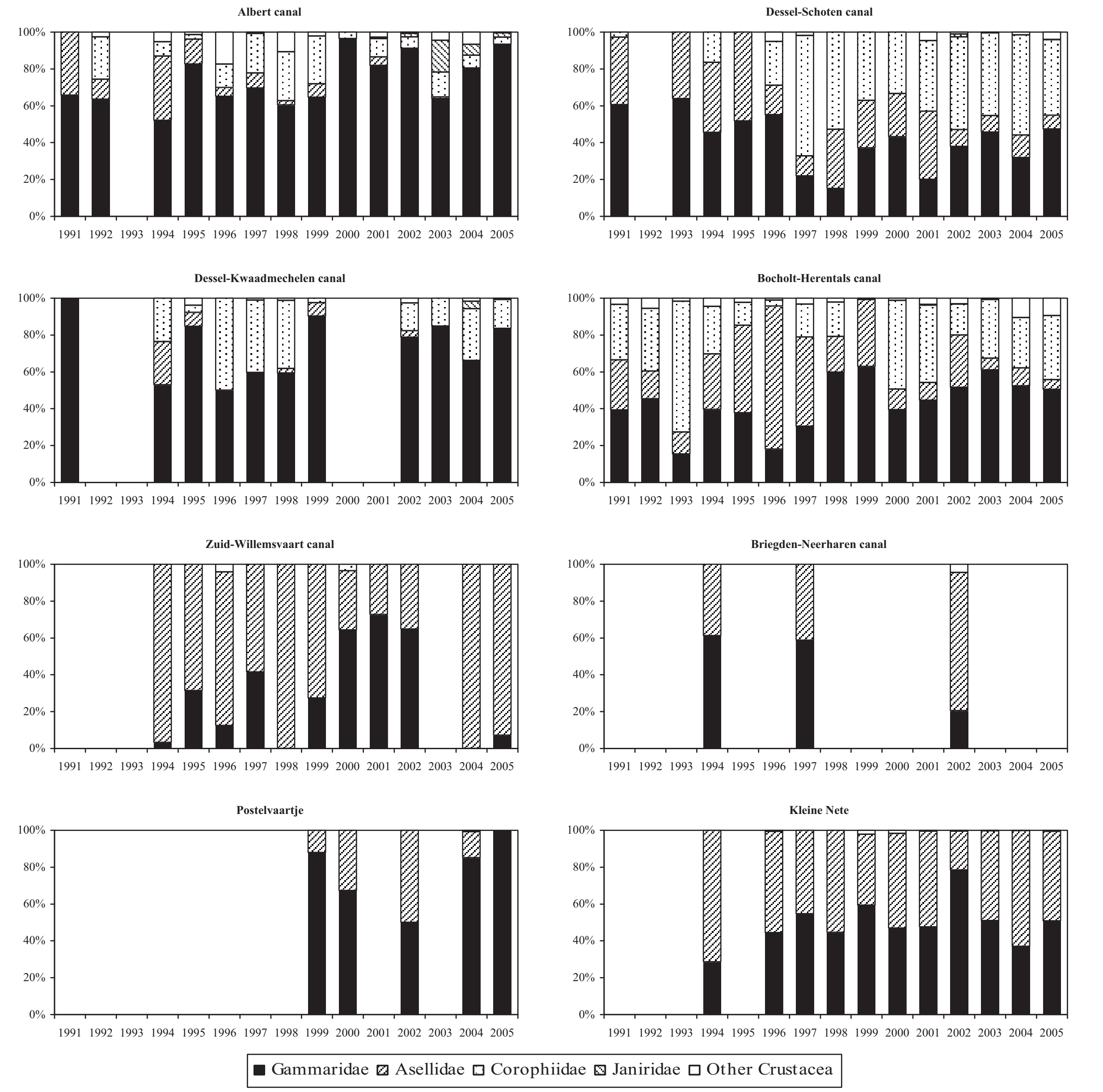

Fig. 2. – Average relative abundance of macrocrustacean families, including alien as well as indigenous species, in the studied watercourses.

RESULTS

An overview of the freshwater macrocrustaceans that have been detected in the study area and in the rest of Flanders is given in Table 2. More detailed results for each family are given below.

Gammaridae

Various gammarid species were found in the analysed samples. Although the earliest report of the exotic *D. villosus* in Flanders dated from 2000 (Vercauteren et al., 2006), analysis of the VMM samples showed that this species was already present in 1997 in the East of Flanders, at least in the Albert canal and the Dessel-Kwaadmechelen canal. More recent samples revealed its expansion into other canals and watercourses in the region. In all the 14 sampling sites containing *G. pulex*, which were invaded by *D. villosus*, *G. pulex* was no longer present during the last sampling campaign. In only four samples, where at most three individuals of *D. villosus* were encountered, both species were found together. In several canals, the appearance of *D. villosus* led to the complete disappearance of *G. pulex* (Fig. 3). In several sites, including those in the Zuid-Willemsvaart canal (Fig. 3), *D. villosus* also replaced *G. tigrinus*, however, in most sites both species still seemed to be able to co-exist. *D. villosus* was recently also found in several other locations in Flanders: in the Charleroi-Brussels canal in Sint-Pieters-Leeuw near Brussels (Vercauteren et al., 2005), in the

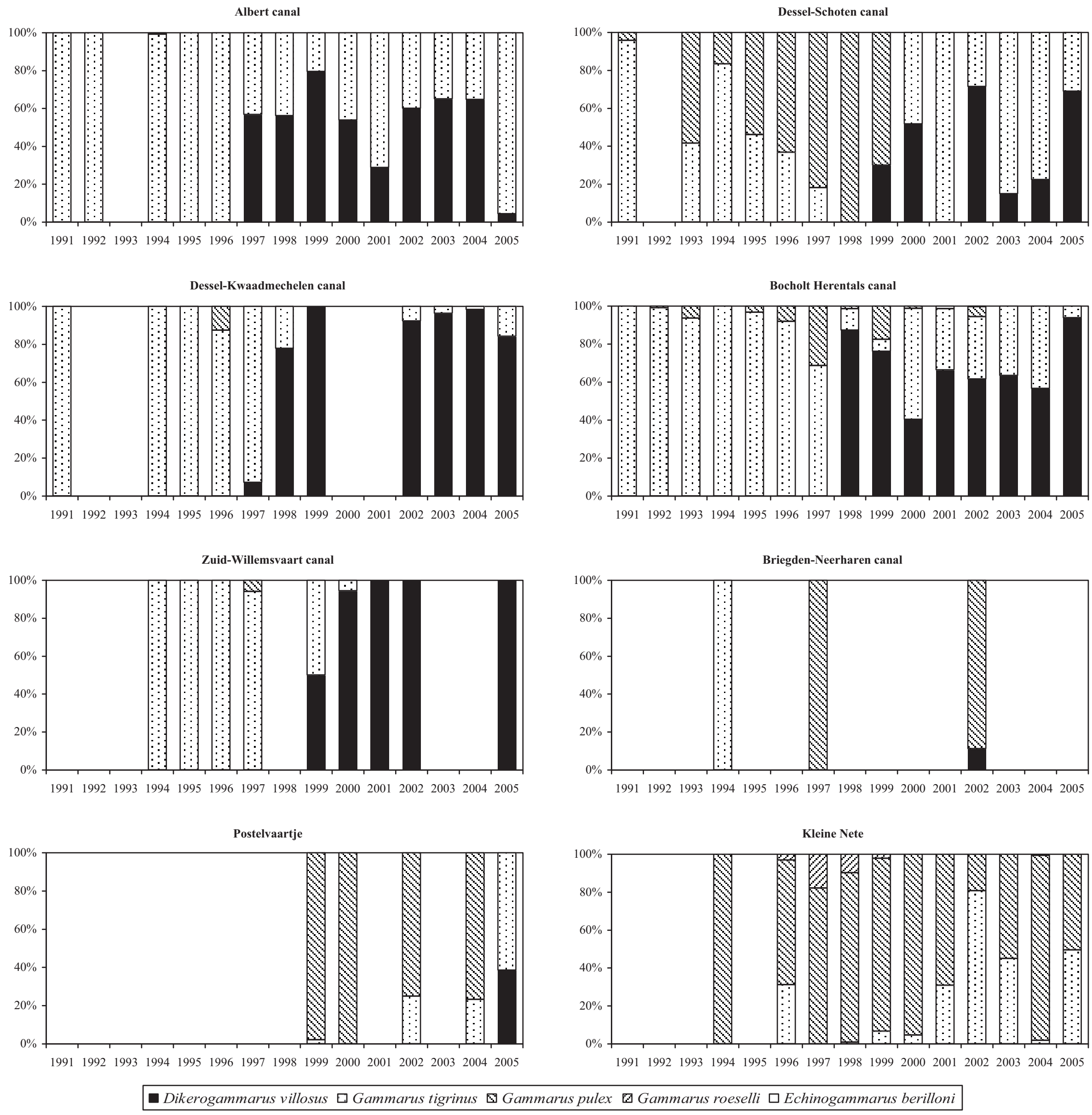

Fig. 3. – Average relative abundance of Gammaridae in the studied watercourses.

Leie-Roeselare canal in Izegem, in a ditch in 'Prinsenpark' near Retie, which is connected with canal Bocholt-Herentals (Vercauteren et al., 2006), in a lake in Harelbeke (Ghyselbrecht, VMM-Ostend), in Kessenich and Heerenlaak, two gravel pits that are connected to the Border Meuse (Lock et al., 2007) and in the canal Ghent-Terneuzen, the canal Ghent-Ostend and the canal Kortrijk-Bossuyt (Boets et al., unpublished data).

G. tigrinus was reported for the first time for Flanders from 1996 (Vercauteren & Wouters, 1999), but it appeared that *G. tigrinus* was already present in the analysed samples of 1991 (Fig. 3). The species has now invaded watercourses all over Flanders (Boets et al., unpublished data).

Both *Echinogammarus berilloni* (Catta, 1878) and *Gammarus roeseli* Gervais, 1835 can be considered as naturalized, as they have already been present in Flanders for a few decades, but were only found in the Dessel-Schoten canal in 1994 and in the Kleine Nete between 1996 and 1999, respectively (Fig. 3).

Corophiidae

The Ponto-Caspian invader *Chelicorophium curvispinum* (Sars, 1895) has been observed in the canals in the eastern part of Flanders since 1990 (Vercauteren et al., 2005). The present study revealed that it also occurred in the Kleine Nete in 2005. This species was also found in the 'Prinsenpark' in Retie (Vercauteren et al., 2006) and the gravel pits Kessenich and Heerenlaak along the Border Meuse (Lock et al., 2007).

Crangonyctidae

Crangonyx pseudogracilis Bousfield, 1958 was first reported for Flanders from 1998 in a ditch near Puurs, probably introduced with *Ludwigia grandiflora*. However, analysis of historical samples in a nearby ditch indicated its presence since 1992 (VERCAUTEREN & WOUTERS, 1999). A few specimens were found in the Dessel-Schoten canal in 1997 and 2005 and in the Bocholt-Herentals canal in 1996 and 1998. This species was also found in the Old Meuse in Stokkem, in two brooks in Genk and Herk-de-Stad (VERCAUTEREN, personal communications) and in a lake in Harelbeke (GHYSELBRECHT, personal communications). Since 2002, a growing number of localities in the western part of Flanders have been invaded by this species (GHYSELBRECHT, personal communication).

Talitridae

O. cavimana was observed for the first time in Flanders in 1927 and was found in the Zuid-Willemsvaart canal and Bocholt-Herentals canal in 1980, in the Dessel-Schoten canal in 1981, in other rivers such as the Leie, Scheldt and Dender (WOUTERS, 2002). More recently, the species was also encountered in the river Yser, in the Stenensluisvaart canal in Woumen and the Zuidervaartje canal in Bruges (GHYSELBRECHT, personal communications). However, in this study, this species was found only twice: in the Dessel-Kwaadmechelen canal in 2001 and 2004.

Asellidae

In the studied area, the family Asellidae was represented by two species: the exotic *Proasellus meridianus* (Racovitza, 1919) and the indigenous *Asellus aquaticus* (Linneaus, 1758). Although JOSENS et al. (2005) consider *P. meridianus* as an exotic species originating from southern Europe, its exotic status can be questioned. According to different authors, this species originates from Western Europe namely Germany and the British isles (GRÜNER, 1965; MOON & HARDING, 1981). Although *A. aquaticus* is by far the most common species in Flanders, *P. meridianus* is widely distributed as well.

Janiridae

J. istri, an isopod originating from the Ponto-Caspian basin, has been present in the studied watercourses since 2000 (Fig. 2). This species has occurred in the Albert canal since 2001 (VERCAUTEREN et al., 2005). It was observed in the Bocholt-Herentals canal in 2001 and in the Dessel-Kwaadmechelen canal in 2004. Analysis of the samples of the VMM showed that one individual was found in 2004 in Mechelen in a tributary of the Dijle.

Cambaridae

Orconectes limosus has been present in Flanders since 1977 (WOUTERS, 2002) and was regularly found in the studied watercourses. Other locations, according to the dataset of the VMM, are the lake Gavers in Harelbeke, the canal Brussels-Charleroi near Sint-Pietersleeuw, the Old Meuse in Stokkem, the river Dender and the Old Scheldt in Oudenaarde. This species was also observed in the 'Prinsenpark' in Retie (VERCAUTEREN et al., 2006), the gravel pits Kessenich and Heerenlaak along the Border Meuse (LOCK et al., 2007).

Atyidae

The arrival time of this species in Flanders is estimated around 1895 (WOUTERS, 2002). The species was regularly found in the studied canals and rivers. *Athyaephyra desmaresti* was found in 100 samples (0.7%) in the dataset of the VMM, including the river Scheldt, the analysed canals and rivers, the Old Meuse, the river Wamp and the Roeselare-Leie canal.

Varunidae

Eriocheir sinensis was observed for the first time in 1933 and is now widely distributed throughout Flanders (WOUTERS, 2002). Based upon the review made by WOUTERS (2002), this species has a wide distribution and occurs both in natural habitats as well as in canalised rivers. However, this species was not frequently found in the dataset of the VMM, probably due to the sampling method.

DISCUSSION

Apart from occasional observations, a large study regarding the occurrence of alien macro-invertebrates in Flanders has not yet been carried out. A detailed study of macrocrustaceans found in six canals, one small artificial watercourse and one natural river in the eastern part of Flanders, which were monitored by the Flemish Environmental Agency, revealed that 14 species of macrocrustaceans were present of which only *G. pulex* and *Asellus aquaticus* can be considered as native (Table 2). However, the exotic status of *Proasellus meridianus* is arguable.

Besides the species that were observed during the present study, several other freshwater macrocrustaceans have been found in Flanders. *Gammarus fossarum* Koch, in Panzer, 1835, is indigenous in small streams in the loamy region. *Proasellus coxalis* (Dollfus, 1892) was first reported from 2005 by VERCAUTEREN & WOUTERS (2008b) in Heist-op-den-Berg. *Hemimysis anomala* (Sars, 1907) was observed for the first time in Flanders in 1999 in a brackish pond 'Galgenweel' (VERSLYCKE et al., 2000). This species mainly occurs in lentic environments and can withstand a wide range of salinities up to 19‰ (BIJ DE VAATE et al., 2002). *H. anomala* was recently also observed in the 'Prinsenpark' in Retie (VERCAUTEREN & WOUTERS, 2008a). *Limnomysis benedeni* Czerniavsky, 1882 was observed in the gravel pits Kessenich (2005-2007) and Heerenlaak (2007) along the Border Meuse (LOCK et al., 2007), in the 'Prinsenpark' in Retie (VERCAUTEREN & WOUTERS, 2008a), in the lake Schulensmeer (LOUETTE et al., 2008) and in the lake Donkmeer (MERTENS, personal communication). *Astacus astacus* (Linneaus, 1758), an indigenous crayfish species, has not been observed recently. This is due to habitat destruction, pollution and the regulation of watercourses. Furthermore, the introduction of *O. limosus* led to the crayfish plague and this disease almost resulted in the disappearance of *Astacus astacus* in the Netherlands (VAN DER

VELDE et al., 2000) and presumably affected the populations in Flanders as well. Apart from *O. limosus*, two other exotic crayfish species have also been present in Flanders for several decades: *Astacus leptodactylus* Eschscholtz, 1823 and *Pacifastacus leniusculus* (Dana, 1852) (GERARD, 1986). In 2008, a fourth exotic crayfish species was observed in Flanders: *Procambarus clarkii* (Girard, 1852) (BOETS et al., 2009).

The sampling method can have an impact on the assessment of the distribution of certain invaders such as *E. sinensis*, *H. anomala*, *L. benedeni* and *Orchestia cavimana*. Based upon the review by WOUTERS (2002), *E. sinensis* is widely distributed in Flanders. This species can have a large impact on their environment due to burrowing activities, predation and competition (HERBORG et al., 2007; OJAVEER et al, 2007). The low occurrence of this species in the dataset of the VMM is probably a consequence of the sampling method. The species is difficult to catch with artificial substrates since the organisms are highly mobile both on land and in the water. Therefore, other sampling techniques, e.g. with nets would give a more accurate picture of its actual distribution. Invaders such as *H. anomala*, *L. benedeni* and *O. cavimana* are not often observed, which is probably also due to the sampling method (artificial substrates and handnet), since *Hemimysis anomala* and *L. benedeni* are fast swimmers, while *O. cavimana* lives along the river banks in fresh and brackish waters (JOSENS et al., 2005). Additional sampling of the river banks and stone sampling might reveal that the latter species is more abundant than the sampling techniques used suggest, while a hyperbenthic sledge would be a good sampling device to sample mysid shrimp.

Although *G. tigrinus* was reported for the first time in Flanders from 1996 in a pond near Antwerp (VERCAUTEREN & WOUTERS, 1999), it was already present in the analysed canals in 1991, which indicates that it arrived earlier in Flanders, probably via the Scheldt-Rhine connection. Via this route, *G. tigrinus* probably invaded the Albert canal and the other canals. Although *G. tigrinus* invaded the part of the Kleine Nete and Postelvaartje closest to the canal, this species was not able to invade these watercourses completely, despite having had the time and the possibility (connections). This is also the case for *Chelicorophium curvispinum*, *Orconectes limosus* and *Athyaephyra desmaresti*, which are mostly found in large river systems, but less in smaller river systems. Probably, smaller rivers and streams do not provide a suitable habitat for these species.

D. villosus was noticed for the first time in the Albert canal in 1997. Its spread was fast and it migrated into the other canals as well. Where it arrived, it always replaced the native *G. pulex* and in some cases the exotic *G. tigrinus* as well. The effect of *D. villosus* on other amphipods could also be observed in neighbouring countries including the Netherlands (VAN DER VELDE et al., 2000; VAN RIEL et al., 2006; 2007) and France (DEVIN et al., 2005a). Therefore, an additional impact assessment of this species on other crustaceans, but also on other macroinvertebrates and fish eggs needs to be performed. Boets et al. (in press) already indicated that in Flanders, this species can especially be found in watercourses with an artificial bank structure with a reasonably good chemical water quality, which is reflected in a conductivity lower than 500µS/cm and an oxygen content higher than 90%.

The Ponto-caspian invader *Jaera istri* has been found in the Netherlands since 1997, in the Rhine, the IJssel and the Waal (KELLEHER et al., 2000). Soon after its arrival in 2001 in the Albert canal, it became locally abundant (SCHÖLL, 2000). *J. istri* thrives well on places with stony substrates and in dammed canals (KELLEHER et al., 2000; VERCAUTEREN et al., 2006; VAN RIEL et al., 2007).

It can be concluded that the canals in the East of Flanders are extremely prone to colonisation by invaders because of their high degree of connectivity and structural characteristics. Invaders can expand their area and migrate to other canals and rivers depending on the structural characteristics and hydrological regimes of the recipient habitats. The increasing pace of arrival of new alien species in Flanders since 1980 is remarkable (WOUTERS, 2002). This may be not only due to the higher degree of connection between important waterways, but possibly also supports the invasion meltdown hypothesis (SIMBERLOFF & VON HOLLE, 1999), which states that similar species may facilitate the invasion process of other species originating from the same region, which may cause homogenization of freshwater systems (RAHEL, 2002). In this respect, additional analysis of changes in bio- and functional diversity needs to be done (DEVIN et al., 2005a). Another reason exotic species are so successful is the improved water quality of formerly degraded systems, which has resulted in new habitats with a lot of vacant niches.

Crustacean invaders such as *Dikerogammarus haemobaphes* (Eichwald, 1841), which has already invaded the Meuse (JOSENS et al., 2005), and *Echinogammarus ischnus* (Stebbing, 1899) (WOUTERS, 2002), *Echinogammarus trichiatus* (Martynov, 1932), *Orconectes immunis* (Hagen, 1870) and *Chelicorophium robustum* (Sars, 1895), which have already invaded the Rhine (BERNAUER & JANSEN, 2006), can be expected to arrive soon in Flanders. Also the Northern crayfish *Orconectes virilis* (Hagen, 1870), the Marbled crayfish *Procambarus* species and the White river crayfish *Procambarus acutus* (Girard, 1852) / *zonangulus* Hobs and Hobs, 1990, which have already been reported in the Netherlands (KOESE, 2008), can be expected. However, their spread will largely depend on their interference with the species that are already present (KLEY & MAIER, 2003; 2006).

Nowadays, different quality assessment methods are based on the presence and diversity of macroinvertebrates in watercourses. Replacement of native taxa by invaders can influence the results of those indices (NGUYEN & DE PAUW, 2002; KELLY et al., 2006). GABRIELS et al. (2005) proposed to use a semi-fixed list so that new taxa can be added. However, additional analysis of the influence of invaders on biological indices should be performed (KELLY et al., 2006). Furthermore, a continuous monitoring of new and formerly established invaders is necessary, in particular regarding their habitat preferences and their effect on native species (DEDECKER et al., 2005), to obtain a better understanding of their impact due to competition and predation. Moreover, migration models (DEDECKER et al., 2006) can be relevant to make better predictions regarding the migration speed of alien macroinvertebrates in rivers.

Alien species are not mentioned specifically in the European water framework directive (WFD; European Community, 2000). However, the precautionary principle in the broad sense could be applicable for the negative effects of exotic species because aquatic ecosystems have to be guarded from decline. Alien species can modify the native biological structure and ecological functioning of aquatic systems and the assessment of alien species as biological pressure should therefore be considered as a part of a catchment management policy together with other pressures. However, effective control measures to eradicate alien aquatic macroinvertebrates are not feasible and at best slow down their dispersal rate. Control measures usually cause more damage (i.e. application of pesticides) or other risks (introduction of natural predator of alien species). The Belgium Forum of Invasive Species proposes a system of lists, which are based on the ability of a species to disperse and its environmental impact. It is suggested that this list can be used to ban import, trade and introduction in the natural environment and for control measures or eradication. In such a system, it is necessary to demonstrate significant damage before a species is listed (now the only macrocrustaceans on the list are *Eriocheir sinensis* and *Pacifastacus leniusculus*, which have already been established in Flanders for several decades). However, by the time damage can be demonstrated, the considered species has usually already invaded the area and nothing can be done to stop its further spread. In our opinion, preventive measures, such as the obligatory treatment of ballast water, are the only possible solution to reduce the influx of alien aquatic macroinvertebrates.

CONCLUSION

This study about freshwater macrocrustaceans revealed that at least 18 non-native species are currently present in Flemish watercourses. The dispersal routes via the river Meuse and the river Scheldt, the high number of canals, the abundant boat traffic and the increased water quality of formerly degraded watercourses make Flanders highly susceptible for invasions. For this reason, more invaders from neighbouring countries are expected. A continuous monitoring of 'new' and previously introduced species is necessary in order to understand the potential consequences on native and established alien species and their dispersal pathways. As it is hardly possible to eradicate exotic species once they are established, more attention should be given to preventive international measures, which reduce the influx of exotic species.

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