Research Article

Two new alien crustacean invaders *Grandidierella japonica* (Stephensen, 1938) and *Neomysis americana* (S.I. Smith, 1873) in Belgium

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Abstract

The Japanese aorid amphipod *Grandidierella japonica* (Stephensen, 1938) and the North American opossum shrimp *Neomysis americana* (S.I. Smith, 1873) are reported here for the first time in Belgium. Both *G. japonica* and *N. americana* were found in hyperbenthic samples taken from just above the sediment surface during long-term monitoring of the Schelde estuary. *Grandidierella japonica* was detected for the first time in 2018 and has since appeared regularly in low numbers. *Neomysis americana* has probably been overlooked for some time and was found in high numbers (n = 155/40 m^3) for the first time in July 2012. Since *N. americana* has been found with regular occurrence and in fairly high numbers (n = 0–3530/40 m^3), a well-established population is assumed. The arrival of *N. americana* probably went unnoticed for some time due to confusion with the native species *Neomysis integer*.

Key words: alien species, Crustacea, Mysida, Amphipoda, Schelde estuary

Introduction

Alien species diversity in the Schelde estuary, Belgium is high and keeps increasing at a high rate (Boets et al. 2016; van Haaren and Soors 2009, 2013; Soors et al. 2010, 2020, 2021). This high invasion rate is attributed to the presence of the port of Antwerp, along the river Schelde, which ranks as the 15th largest in the world with more than 13,500 seagoing ships docking yearly (STATISTA 2021). Commercial boat traffic is regarded as a prime pathway for the spread of marine and estuarine alien species (via ballast water and fouling), but leisure sailing, the creation of new corridor pathways such as canals, contaminants on animals and escapes from aquaculture also contribute to the increased spread of non-native species (European Environment Agency 2019; Hulme 2009; Katsanevakis et al. 2013). In this note, we report the discovery and current status of two new non-native crustacean species in the Belgian section of the Schelde estuary.

Grandidierella japonica (Stephensen, 1938) is an estuarine gammarid amphipod from the North-West Pacific that was first reported outside its natural range in 1966 in the San Francisco Bay (Chapman and Dorman

1975). It has since been found in intertidal and subtidal sediments of bays and estuaries of the entire Pacific Ocean region (Chapman and Dorman 1975; Marchini et al. 2016). In Europe, *G. japonica* has been found over the past decades in the Netherlands (van Haaren and de Bruyne 2018), United Kingdom (Ashelby 2006; Smith et al. 1999), France (Droual et al. 2017; Jourde et al. 2013; Lavesque et al. 2014), Sweden (Berggren 2015) and Italy (Marchini et al. 2016). The suspected introduction pathways are diverse and include ballast water, hitchhikers on animals, oyster spat and leisure sailing vessels. In the Netherlands, *G. japonica* was first found in 2017 in the brackish canal Noordzeekanaal, which connects Amsterdam with the North Sea (van Haaren and de Bruyne 2018). We report in this contribution the first observations for this species in Belgium, in the upstream mesohaline section of the Schelde estuary, some 100 km south of the known Dutch population.

The North American mysid shrimp *Neomysis americana* (S.I. Smith, 1873) was reported for the first time in Europe in 2010 in the Dutch Wadden Sea (Wittmann et al. 2012). In 2017, the species was very common in the Seine estuary in France (Masse et al. 2018; Pezy et al. 2019). Transport along with ballast water is assumed to be the most probable way of introduction for this species (Carlton and Geller 1993). We observed *N. americana* for the first time in the Schelde estuary (Belgium) when it already was an abundant and—probably—established member of the mysid community for some time. It has been recorded frequently hitherto.

Materials and methods

The river Schelde is 355 km long, originating on the plateau of Saint-Quentin in France and ending in the North Sea in the Netherlands near Vlissingen. The Schelde estuary is approximately 160 km long and has a complete salinity gradient from polyhaline to a tidal freshwater zone, including extensive freshwater, brackish and saline tidal mudflats and marshes. It is a well-mixed estuary characterized by strong currents, high turbidity and large tidal amplitude (up to 6 m) (Meire et al. 2005).

The hyperbenthic community (i.e., in the water column just above the sediment surface) of the Sea Schelde, the section of the estuary from the Belgian-Dutch border to its upstream end near Melle, has been monitored since 2010. Monitoring occurs at six fixed stations: five stations along the Schelde and one along its major (tidal) tributary – the Rupel (Figure 1, Table 1). Other locations are only sporadically sampled. For regular monitoring, two people pull a Bongo net (diameter 50 cm, mesh 1 mm, 40 m^3 water) by foot along the shoreline for 100 m back and forth (total distance 200 m) at 0.5 m water depth. In the framework of several short projects, additional hyperbenthic samplings have occurred mainly using the Bongo net and occasionally a benthic sledge (width 1 m, height 50 cm, mesh 2 mm). All sample methods were suitable for monitoring, but the benthic sledge

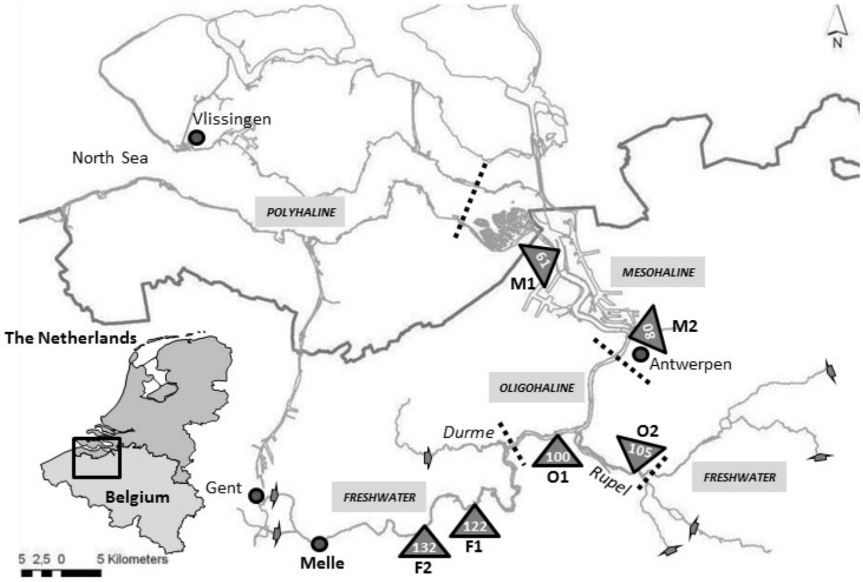

Figure 1. Map of the Schelde estuary, Belgium with the six different sample locations indicated by triangles*, marked up with their distance, in km, from Vlissingen (mouth of the estuary). Dotted lines indicate the borders between salinity zones. Grey arrows indicate the end of tidal influence in the Schelde and its tributaries. Labels are explained in Table 1.

Table 1. Sample location names, coordinates and salinity zone.

Label	Location	Latitude	Longitude	Salinity zone
M1	Paardenschor	51.334722	4.260556	Mesohaline
M2	St-Anna	51.233056	4.396944	Mesohaline
O1	Ballooi	51.103889	4.249167	Oligohaline
O2	Rupel	51.075556	4.398611	Oligohaline
F1	Dendermonde	51.0375	4.1125	Freshwater
F2	Brede Schoren	51.021667	4.040278	Freshwater

proved to be unwieldy and too susceptible for contamination: it was unable to be properly cleaned between samples. Therefore, from 2013 onward, only the Bongo net was used. The sampling frequency varied in the first years due to different research and monitoring programmes. In 2013, monthly sampling was conducted from July till October; in 2014, sampling occurred every fortnight from May to November, with one additional sampling during April and December. From January 2015 until October 2018, the six locations were sampled monthly (De Neve et al. 2020). In 2019 and 2020, the six locations were sampled each month from April until October. Samples were taken along the low water line at low tide, with the exception of a series of Bongo net samples at four of the six stations in 2012 and 2013 (Doel, St.-Anna, Ballooi and Dendermonde), which were taken from a boat near the water surface in the navigation channel. Samples were fully sorted, and all species were identified to the lowest level possible. Very large samples (1000s of specimens) were subsampled (usually 1/8).

Results

Grandidierella japonica was found regularly between 2018 and 2020, but in low numbers, at only the most downstream (i.e, highest salinity) station of

Table 2. Total number of *Grandidierella japonica* collected from the hyperbenthic samples of the Schelde estuary between 2010 and 2020 (N = number of individuals in the Bongo sample i.e. 40m³ water).

Date	N	Location
18 April 2018	5	Paardenschor, Doel
10 April 2019	12	Paardenschor, Doel
8 May 2019	2	Paardenschor, Doel
6 June 2019	8	Paardenschor, Doel
7 July 2019	1	Paardenschor, Doel
2 October 2019	1	Paardenschor, Doel
24 April 2020	2	Paardenschor, Doel
21 August 2020	1	Paardenschor, Doel

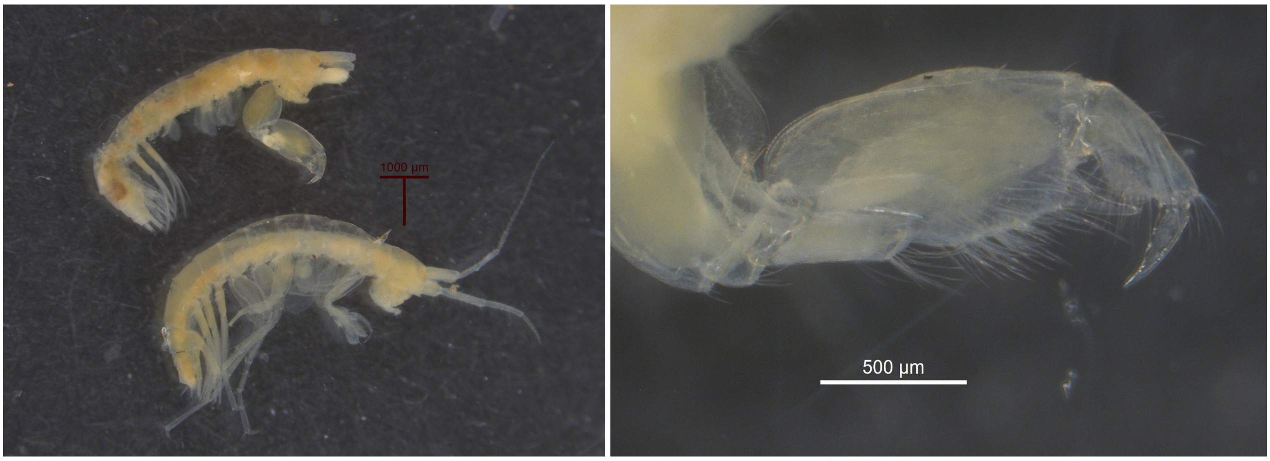

Figure 2. *Grandidierella japonica* (18 April 2018 from the sampling station Doel) male and female habitus (left plate) and detail of the carpochelate gnathopods 1 of the male (right plate).

Doel near the Dutch border (Table 2). The specimens were often damaged, but they could be identified by key morphometric characters, including the following: the length of the uniramous uropod 3 is more than twice the length of the peduncle, a short but wide telson, and the appearance of stridulating ridges on the exterior side of the anterior margin of the carpus from the carpochelate gnathopods 1 of the male (Figure 2). The recently described and similar species *G. japonicoides* (Ariyama, 2020 could be excluded based on the absence of posteromedial projections on the male coxa 2 in our material. Additionally, the proximal part of the basis of male gnathopod 2 is dark brown in *G. japonica* but whitish in *G. japonicoides*.

Grandidierella japonica was accompanied in the samples by native amphipods such as *Corophium volutator* (Pallas, 1766), *Apocorophium lacustre* (Vanhöffen, 1911), *Bathyporeia pilosa* (Lindström, 1855) and the established non-native American species *Melita nitida* (S.I. Smith in Verrill, 1873) and *Gammarus tigrinus* (Sexton, 1939). All of these species were present in some of the samples and in small numbers, probably because they are benthic species that are only sporadically caught in a Bongo net. Other alien crustacean species in these samples were the mysids *Neomysis americana* and *Limnomysis benedeni* (Czerniavsky, 1882) and the isopod *Synidotea laticauda* (Benedict, 1897).

Figure 3. Detail of the telson of a *Neomysis americana* caught on 1 July 2012, Doel.

Neomysis americana was first detected (N = 28) in a sample taken on 1 July 2012 at the mesohaline station of Paardenschor (Doel). This was shortly after the species was reported for the first time in Europe in 2010 (Wittmann et al. 2012). *Neomysis americana* was readily found in the first sample of the Sea Schelde estuary and identified with Wittmann et al. (2012). Older samples (i.e., pre-2012) were not retained, so earlier records could not be detected. The individuals were identified based on the number and shape of the spines on the lateral margins of the telson. *Neomysis americana* has 20–43 spines arranged in series of larger spines with smaller spines in between whereas the very abundant native *N. integer* has 16–24 subequal spines (Wittmann et al. 2012) (Figure 3).

In subsequent samplings at the station of Paardenschor, *N. americana* was frequently present, sometimes in large numbers with an overall maximum of 3520 specimens (30 April 2014). In much lower numbers and also less frequently it was also found at the 19 km more upstream sampling station of Antwerp (St. Anna) where it reached a maximum of 128 specimens (14 July 2015) The species was only occasionally found further upstream, reaching Ballooi only on two occasions (Table 3). In the most upstream stations (i.e., least salty), *N. americana* was not found at all. At the station of Paardenschor, it was found year-round, with highest abundances in April and May, so it differs in phenology from its congener, *N. integer*, which is most abundant in winter (Figure 4). Throughout the

Table 3. Total number of *N. americana* collected from the hyperbenthic samples of the Schelde estuary between 2010 and 2020 (N = number of individuals in the Bongo sample i.e. 40m³ water). The species was not present in the three upstream stations where the same amount and frequency of sampling was done.

	Paardenschor	St-Anna	Ballooi		Paardenschor	St-Anna	Ballooi
Jul.-12	28	0	0	Aug.-16	1	0	0
Aug.-12	115	155	3	Sep.-16	0	0	0
Sep.-12	0	1	0	Oct.-16	0	0	0
Oct.-12	0	4	7	Nov.-16	0	0	0
May-13	2	0	0	Dec.-16	0	14	0
Jun.-13	64	0	0	Jan.-17	0	8	0
Jul.-13	1	0	0	Feb.-17	0	0	0
Aug.-13	32	10	0	Mrt.-17	1	0	0
Sep.-13	0	0	0	Apr.-17	102	0	0
Oct.-13	2	1	0	May-17	144	0	0
Apr.-14	3520	1	0	Jun.-17	1	0	0
May-14	160	2	0	Jul.-17	0	2	0
May-14	56	1	0	Aug.-17	0	1	0
Jun.-14	16	0	0	Sep.-17	0	2	0
Jun.-14	0	2	0	Oct.-17	0	5	0
Jul.-14	64	5	0	Nov.-17	0	0	0
Jul.-14	8	0	0	Dec.-17	15	26	0
Aug.-14	0	0	0	Jan.-18	0	0	0
Aug.-14	2	0	0	Feb.-18	0	0	0
Sep.-14	0	0	0	Mrt.-18	1	0	0
Sep.-14	0	3	0	Apr.-18	20	0	0
Oct.-14	5	2	0	May-18	0	0	0
Oct.-14	82	2	0	Jun.-18	0	0	0
Nov.-14	5	0	0	Jul.-18	0	0	0
Nov.-14	0	0	0	Aug.-18	0	0	0
Dec.-14	0	0	0	Sep.-18	0	0	0
Apr.-15	224	0	0	Oct.-18	9	0	0
May-15	160	0	0	Apr.-19	6	0	0
Jun.-15	33	0	0	May-19	7	0	0
Jul.-15	34	128	0	Jun.-19	24	0	0
Aug.-15	1	1	0	Jul.-19	0	0	0
Sep.-15	0	0	0	Aug.-19	3	0	0
Oct.-15	0	0	0	Sep.-19	0	0	0
Nov.-15	30	0	0	Oct.-19	0	0	0
Dec.-15	1	0	0	Apr.-20	9	0	0
Jan.-16	0	0	0	May-20	2	9	0
Feb.-16	0	0	0	Jun.-20	0	0	0
Mrt.-16	56	0	0	Jul.-20	40	0	0
Apr.-16	1	0	0	Aug.-20	0	0	0
May-16	4	0	0	Sep.-20	0	0	0
Jun.-16	0	0	0	Oct.-20	1	0	0
Jul.-16	6	0	0				

investigated period (2012–2020), *N. americana* remained, on average a less abundant species in the mysids community from the mesohaline station Paardenschor, which is dominated by *Mesopodopsis slabberi* (Van Beneden, 1861) and *N. integer* (Leach, 1814) (Figure 4). Other opossum shrimps that were collected less frequently at these stations were the alien species with a Ponto-caspian origin *Limnomysis benedeni* and *Hemimysis anomala* (Sars, 1907) and marine organisms such as *Schistomysis spiritus* (Norman, 1860), *Praunus flexuosus* (Müller, 1776) and *Gastrosaccus spinifer* (Goës, 1864).

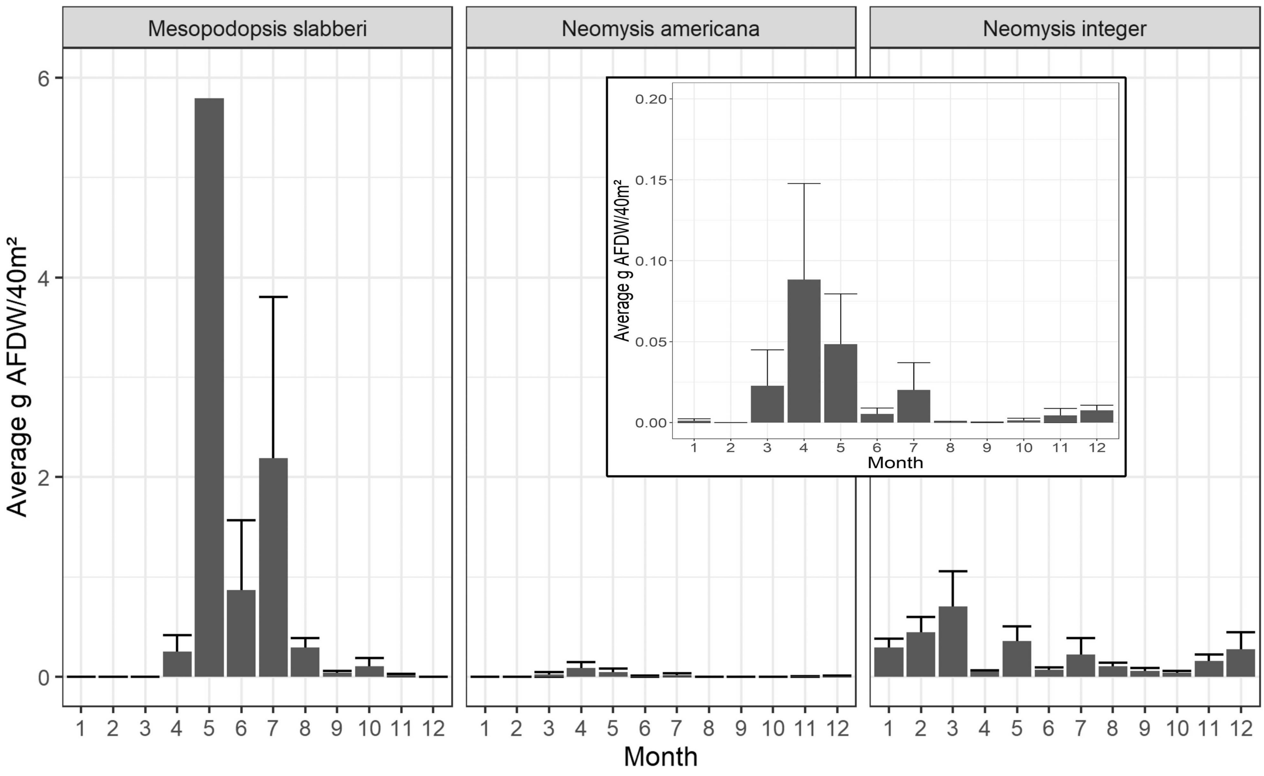

Figure 4. Monthly average (± standard error) of three mysid species (invasive species *Neomysis americana* and two native species *Mesopodopsis slabberi* and *Neomysis integer*) collected from Paardenschor (Doel, Belgium) between 2010 and 2020. Inset: Rescaled detail of the figure for *N. americana*. The peak value for *M. slabberi* (May) has a standard error of 4.7 (not shown).

Discussion

The Belgian section of the Schelde estuary is populated by an increasingly diverse community of alien species. So far 21 alien crustacean species have been reported for this area, and the current note increases this number to 23 (Soors et al. 2021). In the case of *Grandidierella japonica*, the most likely vector of introduction in Europe seems to be the commercial transplant of *Crassostrea gigas* oyster spat from Japan (Chapman and Dorman 1975; Jourde et al. 2013). Present in the UK since 1997 (Smith et al. 1999), first seen on the European continent in 2010 (Jourde et al. 2013), and reported from the Netherlands in 2017 (van Haaren and de Bruyne 2018), it was anticipated that *G. japonica* would arrive soon in the Schelde estuary (2018). In 2020 the species was found in the Dutch part of the Schelde estuary which is called the Westerschelde (Lauren Wiesebron, NIOZ, WMR, *pers. comm.*). It is not known how the species is spreading throughout Europe, but Antwerp, as well as Amsterdam, has a large harbour so shipping (ballast water or fouling) seems the most plausible vector.

Neomysis americana was probably introduced directly via ballast water in Europe, given its pelagic ecology (Carlton and Geller 1993). The first confirmed records for Europe came from the Dutch Wadden Sea in 2010 (Wittmann et al. 2012), and two years later we found it in the Belgian section of the Schelde estuary. An important note is that we probably overlooked the species in previous years of the survey and that it was most likely already present in high numbers. Currently, *N. americana* is an established member of the mysid community of the Belgian Schelde estuary yet remains less abundant than the indigenous, dominant mysids *N. integer* and *M. slabberi* (Figure 4). However, in addition to being caught close to the low water line, *N. americana* has been retrieved several times from a Bongo net operated from a boat in the navigation channel of the river and is the only way we caught this species at the upstream Ballooi station. *Neomysis americana* is almost exclusively confined to mesohaline reaches, with low numbers intruding into the oligohaline reaches of the estuary, while *N. integer* is present throughout the salinity range. We have also noted that the abundance and frequency of *N. americana* in the samples seems to have decreased since 2018 (Table 3). Whether this is a long-term trends remains to be investigated.

Grandidierella japonica makes burrows in muddy bottoms of bays and estuaries where they build U-shaped tubes. Because this species is mainly benthic, our sampling method with the Bongo net underestimates its presence and density. However, because we have continued to sample this species repeatedly and we did not detect it in previous years, the Bongo net is reasonably reliable for detecting *G. japonica*. This may be because males frequently leave their burrows (Chapman and Dorman 1975) or because specimens are flushed from the sediment by the sampling event. Outside its native range, it has established and quickly spread (Jourde et al. 2013; Smith et al. 1999; Trott et al. 2020). *Grandidierella japonica* is a eurytopic species physiologically adapted to tolerate a wide range of salinities (Kikuchi and Matsumata 1997) occurring from coastal saline waters to the brackish zone in estuaries (Trott et al. 2020). A single study from China reports *G. japonica* from inland freshwater lakes, which so far has not been observed anywhere else and may require genetic confirmation, especially since cryptic taxa may be involved (Pilgrim et al. 2013). The mesohaline station at Doel (salinity seasonally ranging between 5–18 in PSU) near the Dutch border is at the most downstream part of a section with a steep salinity gradient, and probably is near the lower boundary of the salinity niche of this species. It is likely that *G. japonica* is more widespread and abundant in the Dutch part of the estuary, which better fits its salinity niche.

Neomysis americana is found together with and is easily confused with the very similar looking and very abundant native mysid *Neomysis integer*. Because of this, *N. americana* was probably overlooked in samples taken before July 2012. After its presence in Europe and the Schelde estuary was revealed (Wittmann et al. 2012), we found *N. americana* in high numbers, and it has been found consistently since. In the Belgian section of the Schelde estuary, *N. americana* currently is most numerous in the brackish (mesohaline) section near the Dutch border, with numbers rapidly decreasing further upstream. It is still outnumbered by the native mysids *N. integer* and *M. slabberi*, and in the eight years since its discovery, it has not increased in abundance or density. It displays a different phenology from its congener *N. integer,* with numbers that peak in early spring for *N. americana*, while *N. integer* reaches its maximum abundance in late winter, preceding the large peak abundance of *Mesopodopsis slabberi* in late spring and summer. *Neomysis americana* also spatially segregates from *N. integer*, whose population is largely found more upstream in oligohaline and freshwater reaches during the summer and autumn while *N. americana* remains downstream from Antwerp. As *N. americana* and other *Neomysis* populations associate closely with maximum turbidity zones (MTZ, Schiariti et al. 2006), it is tempting to hypothesize that during summer and autumn, *N. integer* associates with the upstream MTZ (MTZ 2 sensu Cox et al. 2019) while *N. americana* associates with the more downstream and more brackish MTZ (MTZ1). Indeed, the Schelde river displays two MTZ, one in the freshwater zone and one in the brackish zone, that seasonally vary in magnitude (Cox et al. 2019). Further research is needed to confirm this hypothesis.

In the Seine estuary, *Neomysis americana* became the dominant *Neomysis* mysid species within two years of its arrival in 2017 (Pezy et al. 2019). This is very different from the Schelde, where *N. americana* appears to have settled as an accessory member of the mysid community. The proliferation and subsequent dominance of *N. americana* in the Seine was reached after a strong decrease in the population of the native *N. integer* for unknown reasons (Pezy et al. 2018). Several estuarine communities in Europe have undergone drastic changes over the last decades (Chaalali et al. 2013; Mialet et al. 2011; De Neve et al. 2020). In the Sea Schelde, the hyperbenthos was poorly represented until recently because large sections of the freshwater zone and to a lesser extent the brackish estuary were recurrently hypoxic (Cox et al. 2009; De Neve et al. 2020) but in other estuaries, changes may be climate driven (Chaalali et al. 2013). Adding new alien species to these shifting communities adds another unknown factor that may lead to unforeseen and possibly context-dependent changes to the communities and ecosystems. Continued monitoring of the hyperbenthos in the Sea Schelde will hopefully add new and improved knowledge and understanding on the future behaviour of our estuarine communities.

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Authors' contribution

J. Speybroeck: research conceptualization; J. Soors, J. Speybroeck: sample design and methodology; J. Soors, J. de Beukelaer, O. Bezdenjesnji, D. Buerms, C. Lefranc, F. Van de Meutter: investigation and data collection; F. Van de Meutter, J. Soors: data analysis and interpretation; J. Soors, F. Van de Meutter roles/writing – original draft; writing – review and editing.

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