Belgian Journal of Zoology
www.belgianjournalzoology.be

ISSN 2295-0451

Short note

https://doi.org/10.26496/bjz.2023.112

Leptocheirus pilosus Zaddach, 1844 (Crustacea: Amphipoda: Corophiidae) expands its range to Belgium

Tom Van den Neucker [1,*], Lucilla Boito [1], Jan Soors [2], Jurgen Dewolf [3], Joost Mertens [3], Dimitri Van Pelt [1], Stefan Van Damme [1] & Jonas Schoelynck [1]

[1]University of Antwerp (UA), Department of Biology, ECOSPHERE, Universiteitsplein 1C, 2160 Wilrijk, Belgium.
[2]Research Institute for Nature and Forest (INBO), Herman Teirlinck Havenlaan 88 bus 73, 1000 Brussels, Belgium.
[3]Flemish Environment Agency (VMM), Raymonde de Larochelaan 1, 9051 Sint-Denijs-Westrem, Belgium.

[*]Corresponding author: tom.vandenneucker@uantwerpen.be

Keywords. *Leptocheirus pilosus*, brackish water, Scheldt, Canal Ghent-Terneuzen, Belgium.

Van den Neucker T., Boito L., Soors J., Dewolf J., Mertens J., Van Pelt D., Van Damme S. & Schoelynck J. (2023). *Leptocheirus pilosus* Zaddach, 1844 (Crustacea: amphipoda: Corophiidae) expands its range to Belgium. *Belgian Journal of Zoology* 153: 125–133. https://doi.org/10.26496/bjz.2023.112

Leptocheirus pilosus is a small amphipod with an adult size that rarely exceeds 4 mm. The dorsal side of living individuals is reddish brown, caused by dark branched pigment cells, whereas ventrally the colour is much paler. The colour fades in preserved specimens, but the branched pigment cells remain visible. Another notable characteristic of *L. pilosus* is the presence of long feathery setae on the second gnathopod. On the anterior face of the basal joint of the second gnathopod there are two rows of long setae and single rows of similar setae are projecting upwards and inwards from the horizontal meral and carpal joints [1,2]. *Leptocheirus pilosus* is a brackish water species, predominantly found within the oligohaline and mesohaline salinity range [1,3–6]. Records exist from waterbodies with strongly fluctuating salinities between 0 and 35 ppt [7,8], but the species does not occur in purely freshwater environments [9,10]. *Leptocheirus pilosus* is recorded at water depths ranging from 0.4 to 9 m [4,6]. It is a tubicolous species (i.e., species living in self-constructed tubes). The tubes are flat, blister-like capsules constructed with mucus, detritus, and sediment particles. These are fixed to clean, smooth surfaces, such as the upper side of rocks and algae thalli [1]. *Leptocheirus pilosus* is a selective deposit feeder. Detritus particles that can serve as food items are grasped with the antennae. Suspended detritus particles can be intercepted with the sieve setae on the second gnathopod. The life-history patterns of *L. pilosus* are understudied, but ovigerous females are known to occur from April till September and carry on average 11 eggs [1]. The native distribution of *L. pilosus* is scattered along the European coasts from the Baltic Sea to the Mediterranean and Black Sea. The species is native to Finland, Sweden, Estonia, Poland, Germany, the British Isles, Ireland, the Netherlands, France, Spain, Portugal, Italy, Greece, Türkiye, Libya and Tunisia [1–8,10–21]. Here, we present an overview of the first Belgian records of *L. pilosus*.

In Belgium, *L. pilosus* was found for the first time on the 17th of September 2020 in the river Scheldt, near Galgeschoor (Antwerp) (Fig. 1; Table 1). Two specimens were found in a box corer sample taken 3.2 m below the mean low water mark. Galgeschoor is situated in the mesohaline zone of the river Scheldt. Salinity was 16.5 ppt at the time of sampling (Table 2) and varied between 1.8 and 16.8 ppt in 2020 [22]. Sampling was carried out by the Research Institute for Nature and Forest (INBO) and is part of an ongoing project aimed at monitoring the ecosystem of the Scheldt estuary.

In April, May and June 2021, a total of 361 specimens of *L. pilosus* were found in macroinvertebrate samples collected in three harbour docks of the Port of Antwerp (Fig. 1; Table 1). On the 14th of April 2021, a single specimen of *L. pilosus* was caught using a hand-held net in the Doel Dock near an artificial foreshore consisting of gabions with rip-rap (i.e., metal mesh baskets with rocks). The hand-net sampling was carried out with a 500 µm mesh net, following the methodology described in GABRIELS *et al*. [23]. The maximum sampling depth at the artificial foreshore was about 1.2 m. On the 15th of April 2021, 166 and 185 specimens of *L. pilosus*, respectively, were found in the Hout Dock (Figs 2–3), in samples retrieved by scraping the concrete quay walls and submerged nylon ropes with a spatula. Seven additional specimens were found in artificial substrate samples from the same dock on the 31st of May 2021. On the 1st and 2nd of June 2021, single specimens of *L. pilosus* were detected in artificial substrate samples from the Kanaal Dock and from the Doel Dock. The artificial substrate used in the Port of Antwerp consisted of stone bricks in 400 × 300 × 150 mm metal cages attached to the quay walls or attached to ropes approximately 3 m below the water surface for six weeks [24]. The harbour docks of the Port of Antwerp are connected to the mesohaline zone of the river Scheldt. However, salinity differed significantly between the harbour docks (Table 2) with a salinity of 1.5 ppt in the Hout Dock and 6.4 ppt in the Doel Dock at the time of sampling in April 2021. Measurements of salinity throughout the year were not available for these two docks. In the Kanaal Dock near the Lillo bridge, salinity measured

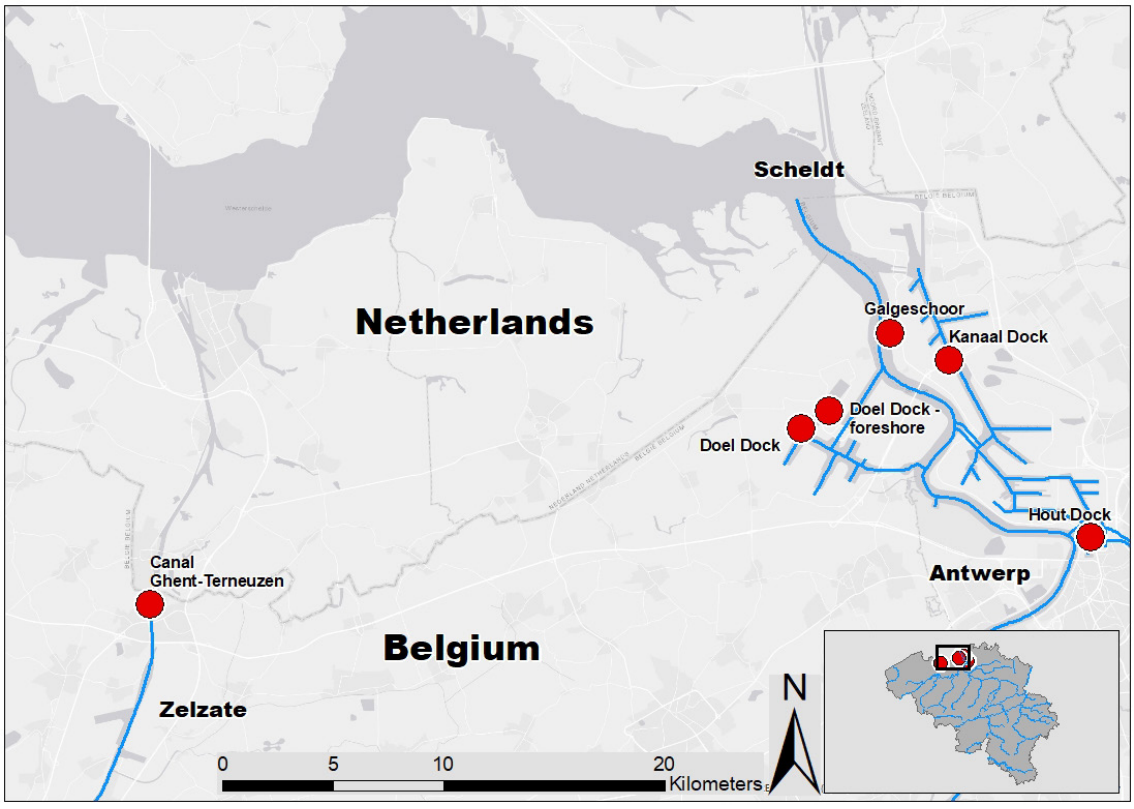

Figure 1 – Recorded distribution of *Leptocheirus pilosus* in Belgium up to the 16th of September 2021.

TABLE 1

The number of *Leptocheirus pilosus* specimens and the three most abundant associated taxa at the sampling locations. The sampling date, method and depth are also given.

Locality	Coordinates	Sampling date	Sampling method	Sampling depth (m)	# *L. pilosus*	Most abundant associated taxa
Antwerp, Galgeschoor, river Scheldt	51°19′9.0″ N; 4°16′45.1″ E	17 September 2020	box corer	3.2	2	*Potamocorbula amurensis* (Schrenck, 1862) *Heteromastus filiformis* (Claparède, 1864) *Boccardiella ligerica* (Ferronnière, 1898)
Antwerp, Doel Dock, artificial foreshore	51°17′15.0″ N; 4°14′25.01″ E	14 April 2021	kick-net	< 1.2	1	*Hediste diversicolor* (O.F. Müller, 1776) *Sinelobus vanhaareni* Bamber, 2014, *Heleobia charruana* (d'Orbigny, 1841)
Antwerp, Hout Dock	51°14′10.8″ N; 4°24′34.1″ E	15 April 2021	scrape sample (nylon ropes)	± 3	185	*Mytilopsis leucophaeata* (Conrad, 1831) *Hediste diversicolor* (O.F. Müller, 1776) *Apocorophium lacustre* (Vanhöffen, 1911)
Antwerp, Hout Dock	51°14′10.8″ N; 4°24′34.1″ E	15 April 2021	scrape sample (concrete quay wall)	± 3	166	*Sinelobus vanhaareni* Bamber, 2014 *Mytilopsis leucophaeata* (Conrad, 1831) *Hediste diversicolor* (O.F. Müller, 1776)
Antwerp, Hout Dock	51°14′10.8″N; 4°24′34.1″E	31 May 2021	artificial substrate (bricks)	± 3	7	*Gammarus tigrinus* Sexton, 1939 *Palaemon macrodactylus* Rathbun, 1902 Chironomidae (larvae)
Antwerp, Kanaal Dock, Lillo bridge	51°18′29.8″ N; 4°19′3.9″ E	1 June 2021	artificial substrate (bricks)	± 3	1	*Heleobia charruana* (d'Orbigny, 1841) Chironomidae (larvae) *Gammarus salinus* Spooner, 1947
Antwerp, Doel Dock	51°16′49.9″ N; 4°13′18.3″ E	2 June 2021	artificial substrate (bricks)	± 3	1	*Ficopomatus enigmaticus* (Fauvel, 1923) *Gammarus salinus* Spooner, 1947 *Alitta succinea* (Leuckart, 1847)
Zelzate, Canal Ghent-Terneuzen	51°12′28.3″ N; 3°48′2.4″ E	16 September 2021	artificial substrate (broken bricks)	± 6	500	*Gammarus tigrinus* Sexton, 1939 *Heleobia charruana* (d'Orbigny, 1841) *Palaemon macrodactylus* Rathbun, 1902

TABLE 2

Key water parameters of the Belgian localities where *Leptocheirus pilosus* was recorded.

Locality	Sampling date	Water temperature (°C)	pH	Dissolved oxygen (mg L^{-1})	Oxygen saturation (%)	Conductivity (µS cm^{-1})	Salinity (ppt)
Antwerp, Galgeschoor, river Scheldt	7 September 2020	20.2	7.9	7.5	82.0	27000	16.5
Antwerp, Doel Dock, artificial foreshore	20 April 2021	10.9	8.3	13.6	123.0	10990	6.2
Antwerp, Hout Dock	20 April 2021	11.4	8.3	11.4	104.3	2860	1.5
Antwerp, Kanaal Dock, Lillo bridge	19 April 2021	10.8	8.0	10.3	95.0	8040	5.0
Antwerp, Doel Dock	20 April 2021	10.6	8.7	18.3	164.4	11120	6.4
Antwerp, Kanaal Dock, Lillo bridge	19 May 2021	14.3	8.2	10.9	111.0	9610	6.1
Zelzate, Canal Ghent-Terneuzen	16 September 2021	20.2	7.9	6.0	80.3	7710	4.3

Figure 2 – A preserved specimen of *Leptocheirus pilosus* from the Hout Dock (Antwerp, Belgium).

5.0 ppt in April 2021 and 6.1 ppt in May 2021 and fluctuated between 4.6 and 8.9 ppt in 2021 [22] (Table 2). The sampling campaigns in the Port of Antwerp were part of a macroinvertebrate diversity study carried out by the University of Antwerp (UA) [24]. All specimens collected in the harbour docks of the Port of Antwerp are stored in the collection of the ECOSPHERE Research Group of the UA.

On the 16th of September 2021, 500 *L. pilosus* were found in an artificial substrate sample from the Canal Ghent-Terneuzen, Zelzate (Fig. 1; Table 1). The artificial substrate of this location was composed of 40 to 80 mm pieces of brick in a plastic mesh bag, with a total volume of approximately 5 L [23]. The substrate was placed on the bottom of the Canal, at a depth of about 6 m, and retrieved after 41 days. The Canal Ghent-Terneuzen connects the Ghent harbour with the polyhaline zone of the Scheldt estuary, but the sampling locality in Zelzate can be considered oligohaline. Salinity was 4.3 ppt when the artificial substrate was retrieved (Table 2) but fluctuated between 1.3 and 4.5 ppt in 2021 [22]. Sampling in the Canal Ghent-Terneuzen was part of a long-term water quality monitoring program carried out by the Flemish Environment Agency (VMM). All *L. pilosus* specimens from the Canal Ghent-Terneuzen are stored in the collection of the Royal Belgian Institute of Natural Sciences (collection number 34293).

No earlier Belgian records of *L. pilosus* prior to those reported here could be found. While it is possible that *L. pilosus* may have been overlooked in previous research, it was not mentioned in the extensive non-native species checklists compiled by Kerckhof *et al*. [25] and Boets *et al*. [26], nor does it occur in the list of Belgian marine amphipods of Cattrijsse *et al*. [27]. Moreover, *L. pilosus* was not mentioned in studies of (hyper)benthic macroinvertebrate communities carried out in the Belgian part of

Figure 3 – A close-up of the long feathery setae on the second gnathopod of a preserved specimen of *Leptocheirus pilosus* from the Hout Dock (Antwerp, Belgium), which are an important diagnostic feature of the species [1,2].

the Scheldt estuary [28–30] and in recent macroinvertebrate surveys performed in the Antwerp harbour docks [31–33]. Consequently, it is reasonable to assume that *L. pilosus* is a fairly recent addition to the Belgian fauna, although its status as a (neo)native or non-native species remains unclear. It is unknown whether its recent range expansion results from natural dispersal or whether it reached Belgian waters via shipping activities or man-made corridors such as canals and culverts. The possibility that *L. pilosus* reached the Scheldt estuary without human intervention cannot be excluded, since these amphipods are efficient swimmers [1] and can survive at least temporarily in marine saline conditions [7,8]. Moreover, the species is considered native to neighbouring countries France and the Netherlands [10,21] and it was recently found in Bath, near the Dutch-Belgian border [10], close to the Port of Antwerp. The species depends on hard substrates for the construction of the blister-like tubes which it inhabits [1]. Hard substrates in the main stem of the river Scheldt consist of man-made structures, rip-rap and shells of predominantly fossil and non-native molluscs, while the river bottom mainly consists of soft sediments [34]. In the Port of Antwerp and in the Canal Ghent-Terneuzen, artificial hard substrates such as concrete quay walls and rip-rap are widely available and provide suitable habitats for *L. pilosus*. This may explain why *L. pilosus* was most abundant in samples from the Antwerp harbour docks and the Canal Ghent-Terneuzen. The most abundant associated taxa (Table 1) differed between sampling locations and methods. Nonetheless, several associated taxa found in our study are also part of macroinvertebrate communities with *L. pilosus* in other countries, including *Ficopomatus enigmaticus*, *Sinelobus vanhaareni*, *Apocorophium lacustre*, *Gammarus salinus* and *G. tigrinus* [5–7,20]. Dense *Ficopomatus enigmaticus* reefs in the Antwerp harbour docks [24], as well as shell clusters of non-native bivalves such as the long established *Mytilopsis leucophaeata* and the recently introduced *Ischadium recurvum* [35] could provide additional suitable substrate for *L. pilosus* in the Port of Antwerp. It is possible that the improving water quality in the Scheldt estuary [36,37] could further facilitate the colonization of hard substrates by *L. pilosus* within the optimal salinity range.

High abundances of *L. pilosus* in scrape samples from the Antwerp harbour and in artificial substrate samples from the Canal Ghent-Terneuzen, as well as its presence in the river Scheldt, suggest that the species could already be firmly established in Belgium. The species may become an important part of the food web in oligohaline and mesohaline waters with hard substrate. Additional sampling campaigns in the harbour docks of the Port of Antwerp and in canals and rivers with brackish water are needed to monitor its range expansion and potential ecological effects.

Acknowledgements

Benthos sampling carried out by the INBO and the crew of the Henry De Vos research vessel was funded by the Vlaamse Waterweg nv (MONEOS; INBOPROJ-502). The research carried out by the UA in the Port of Antwerp was funded by Havenbedrijf Antwerpen-Brugge (project: Ecologisch Potentieel in de dokken van de Antwerpse haven) and the Bijzonder Onderzoeksfonds of the University of Antwerp (Project no. 44158). Robrecht Debbaut (UA) made the distribution map.

References

[1] Goodhart C.B. (1939). Notes on the bionomics of the tube-building amphipod *Leptocheirus pilosus* Zaddach. *Journal of The Marine Biological Association of the United Kingdom* 23: 311–325. https://doi.org/10.1017/S0025315400013916

[2] Hayward P.J. & Ryland J.S. (eds) (2012). *Handbook of the Marine Fauna of North-West Europe*. Oxford University Press. 800 pp.

[3] Boström C. & Bonsdorff E. (1997). Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. *Journal of Sea Research* 37 (1–2): 153–166. https://doi.org/10.1016/S1385-1101(96)00007-X

[4] Zettler M.L. (2001). Some malacostracan crustacean assemblages in the southern and western Baltic Sea. *Rostocker Meeresbiologische Beiträge* 9: 127–143.

[5] Messner U. & Zettler M.L. (2018). The conquest (and avoidance?) of the brackish environment by Ponto-Caspian amphipods: A case study of the German Baltic Sea. *BioInvasions Records* 7 (3): 269–278. https://doi.org/10.3391/bir.2018.7.3.07

[6] Brzana R., Marszewska L., Normant-Saremba M. & Błażewicz M. (2019). Non-indigenous tanaid *Sinelobus vanhaareni* Bamber, 2014 in the Polish coastal waters – an example of a successful invader. *Oceanological and Hydrobiological Studies* 48 (1): 76–84. https://doi.org/10.1515/ohs-2019-0008

[7] Thomas N.S. & Thorp C.H. (1994). Cyclical changes in the fauna associated with tube aggregates of *Ficopomatus enigmaticus* (Fauvel). *Mémoires du Muséum national d'histoire naturelle* 162: 575–584.

[8] Oliver G.A., McGrath D. & Healy B. (2007). The Amphipod *Corophium insidiosum* Crawford in Ireland. *The Irish Naturalists' Journal* 28 (8): 324–326.

[9] Faasse M. & van Moorsel G. (2000). Nieuwe en minder bekende vlokreeftjes van sublitorale harde bodems in het Deltagebied (Crustacea: Amphipoda: Gammaridae). *Nederlandse Faunistische Mededelingen* 11: 19–44.

[10] van Haaren T. (2017). Slijkgarnalen: het genus *Leptocheirus* in Nederland (Amphipoda: Corophiidae). *Zoekbeeld* 7 (2): 19–21.

[11] Sezgin M., Kocataş A. & Katağan T. (2001). Amphipod fauna of the Turkish central Black Sea region. *Turkish Journal of Zoology* 25: 57–61.

[12] Bachelet G., Dauvin J.-C. & Sorbe J. C. (2003). An updated checklist of marine and brackish water Amphipoda (Crustacea: Peracarida) of the southern Bay of Biscay (NE Atlantic). *Cahiers de Biologie Marine* 44 (2): 121–151.

[13] Orav-Kotta H., Kotta J. & Kotta I. (2004). Comparison of macrozoobenthic communities between the 1960s and the 1990s–2000s in the Vainameri, NE Baltic Sea. *Proceedings of the Estonian Academy of Sciences: Biology/Ecology* 53 (4): 283–291.

[14] Jażdżewski K., Konopacka A. & Grabowski M. (2005). Native and alien Malacostracan Crustacea along the Polish Baltic Sea coast in the twentieth century. *Oceanological and Hydrobiological Studies* 24: 195–208.

[15] Carvalho S., Moura A. & Sprung M. (2006). Ecological implications of removing seagrass beds (*Zostera noltii*) for bivalve aquaculture in southern Portugal. *Cahiers de Biologie Marine* 47 (3): 321–329.

[16] Ortiz M. & Petrescu I. (2007). The marine Amphipoda (Crustacea: Gammaridea) of the Republic of Libya, southeastern Mediterranean. *Travaux du Muséum National d'Histoire Naturelle «Grigore Antipa»* L: 11–23.

[17] Belgacem W., Langar H. & Hassine O.K.B. (2011). Depth and temporal distribution of vagile fauna associated with *Posidonia oceanica* meadows in Cap Zebib, north-eastern Tunisian coastline. *African Journal of Ecology* 49: 459–470. https://doi.org/10.1111/j.1365-2028.2011.01278.x

[18] Reichert K. & Beermann J. (2011). First record of the Atlantic gammaridean amphipod *Melita nitida* Smith, 1873 (Crustacea) from German waters (Kiel Canal). *Aquatic Invasions* 6 (1): 103–108. https://doi.org/10.3391/ai.2011.6.1.13

[19] Scipione M.B. (2013). On the presence of the Mediterranean endemic *Microdeutopus sporadhi* Myers, 1969 (Crustacea: Amphipoda: Aoridae) in the Gulf of Naples (Italy) with a review on its distribution and ecology. *Mediterranean Marine Science* 14 (3): 56–63. https://doi.org/10.12681/mms.650

[20] Langbroek W. (2017). *Leptocheirus pilosus* aangetroffen in Amsterdam, een nieuwe vlokreeft voor de Nederlandse binnenwateren. *Macrofaunanieuwsmail* 135: 2–4.

[21] Dauvin J.-C. (2022). An Update of Amphipoda Checklist for the English Channel. *Diversity* 14: 783. https://doi.org/10.3390/d14100783

[22] VMM (2022). Geoloket waterkwaliteit, Flemish Environment Agency. Available from https://www.vmm.be/data/waterkwaliteit [Accessed 21 November 2022].

[23] Gabriels W., Lock K., De Pauw N. & Goethals P.L.M. (2010). Multimetric Macroinvertebrate Index Flanders (MMIF) for biological assessment of rivers and lakes in Flanders (Belgium). *Limnologica* 40 (3): 199–207. https://doi.org/10.1016/j.limno.2009.10.001

[24] Boito L., Van den Neucker T., Van Pelt D., Maris T., Van Damme S. & Schoelynck J. (2022). *Ecologisch Potentieel in de dokken van de Antwerpse haven*. Rapport ECOBE 021-R279, Universiteit Antwerpen, Antwerpen. 46 pp.

[25] Kerckhof F., Haelters J. & Gollasch S. (2007). Alien species in the marine and brackish ecosystem: the situation in Belgian waters. *Aquatic Invasions* 2 (3): 243–257. https://doi.org/10.3391/ai.2007.2.3.9

[26] Boets P., Brosens D., Lock K., Adriaens T., Aelterman B., Mertens J. & Goethals P.L.M. (2016). Alien macroinvertebrates in Flanders (Belgium). *Aquatic Invasions* 11 (2): 131–144. https://doi.org/10.3391/ai.2016.11.2.03

[27] Cattrijsse A., Mees J. & Hamerlynck O. (1993). The hyperbenthic Amphipoda and Isopoda of the Voordelta and the Westerschelde estuary. *Cahiers de Biologie Marine* 34 (2): 187–200.

[28] Ysebaert T., Meire P., Maes D. & Buijs J. (1993). The benthic macrofauna along the estuarine gradient of the Schelde estuary. *Netherland Journal of Aquatic Ecology* 27 (2–4): 327–341. https://doi.org/10.1007/BF02334796

[29] Ysebaert T., De Neve L. & Meire P. (2000). The subtidal macrobenthos in the mesohaline part of the Schelde Estuary (Belgium): Influenced by man? *Journal of the Marine Biological Association of the United Kingdom* 80 (4): 587–597. https://doi.org/10.1017/S002531540000240X

[30] De Neve L., Van Ryckegem G., Vanoverbeke J., Van de Meutter F., Van Braeckel A., Van den Bergh E. & Speybroeck J. (2020). Hyperbenthos in the upper reaches of the Scheldt estuary (Belgium): Spatiotemporal patterns and ecological drivers of a recovered community. *Estuarine, Coastal and Shelf Science* 245: e106967. https://doi.org/10.1016/j.ecss.2020.106967

[31] Pals A. & Vercoutere B. (2008). Bepalen van het Maximaal Ecologisch Potentieel en het Goed Ecologisch Potentieel voor het waterlichaam Antwerpse Havendokken en Schelde-Rijn verbinding K 2086. 17965/R/873173/Mech. 109 pp.

[32] Gittenberger A., Rensing M., Wesdorp K.H. & D'Hont A. (2018). *Monitoring Non-native Species in the Port of Antwerp in 2017 Conform the Joint HELCOM/OSPAR Port Survey Protocol*. GiMaRIS rapport 2018_01. 48 pp.

[33] De Schamphelaere K., Teuchies J., Bervoets L., Ysebaert T., Blust R. & Meire P. (2020). *Opstellen van een triademethode voor de classificatie van waterbodems in brak en zout milieu*. Universiteit Antwerpen, Antwerpen. 217 pp.

[34] Meire P., Ysebaert T., Van Damme S., Van den Bergh E., Maris T. & Struyf E. (2005). The Scheldt estuary: a description of a changing ecosystem. *Hydrobiologia* 540: 1–11. https://doi.org/10.1007/s10750-005-0896-8

[35] Boito L., Van den Neucker T., Van Damme S. & Schoelynck J. (2022). First record of the alien hooked mussel *Ischadium recurvum* (Rafinesque, 1820) (Bivalvia: Mytilidae) in Belgium. *Belgian Journal of Zoology* 152: 157–162. https://doi.org/10.26496/bjz.2022.105

[36] Cox T.J.S., Maris T., Soetaert K., Conley D.J., Van Damme S., Meire P., Middelburg J.J., Vos M. & Struyf E. (2009). A macro-tidal freshwater ecosystem recovering from hypereutrophication: the Schelde case study. *Biogeosciences* 6: 2935–2948. https://doi.org/10.5194/bg-6-2935-2009

[37] Van Damme S., Struyf E., Maris T., Ysebaert T., Dehairs F., Tackx M., Heip C. & Meire P. (2005). Spatial and temporal patterns of water quality along the estuarine salinity gradient of the Scheldt estuary (Belgium and The Netherlands): results of an integrated monitoring approach. *Hydrobiologia* 540: 29–45. https://doi.org/10.1007/s10750-004-7102-2

Manuscript received: 28 March 2023
Manuscript accepted: 10 October 2023
Published on: 27 October 2023
Branch editor: Marleen De Troch