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First record of the alien hooked mussel *Ischadium recurvum* (Rafinesque, 1820) (Bivalvia: Mytilidae) in Belgium

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The hooked mussel *Ischadium recurvum* (Rafinesque, 1820) is characterized by a somewhat solid triangular shell, scarcely inflated and obliquely curved. Its surface is ornated with a pattern of fine, elevated lines that often divide towards the posterior end. The external colour of the shell is bluish-black, while the interior is polished, purplish with a white margin. The species can reach a maximum length of 63.5 mm [1][2]. *Ischadium recurvum* is a brackish water epibenthic mussel that is typically found at salinities between 4.5 and 36.0 ‰, yet it needs salinities above 8.0 ‰ to reproduce. It is therefore considered a meso-euhaline species [2][3][4]. *Ischadium recurvum* is found in shallow waters – from the tidal zone to a depth of about 9 m – in moderate to low wave energy environments, attached with byssal threads to hard substrates such as rocks, oyster reefs and boat docks [1][5]. Densities usually vary from 50 to 1900 individuals per m^2, depending on salinity and substrate suitability [6][7][8], but can reach up to 8450 individuals per m^2 on artificial oyster reefs [9]. *Ischadium recurvum* is an important prey item for crustaceans [10] and waterfowl [11]. The species is a filter feeder, feeding mainly upon suspended phytoplankton [12][13], including brown tide (*Aureoumbra lagunensis*) [14]. *Ischadium recurvum* has separate sexes [15], reaches maturity at a shell length of about 25 mm [2] and has a single annual spawning cycle [16]. Spawning starts in spring at a water temperature of 17.7°C and can continue until temperature drops to 11.6°C in autumn [15]. Its larval stage consists of shelled planktotrophic veliger larvae [3][17]. Although *I. recurvum* can tolerate a wide range of water temperatures, from near freezing up to 37°C, the species is most successful in warm temperate and tropical regions [2]. The species is native to the West Atlantic and its native distribution extends from Cape Cod, Massachusetts, U.S.A, to the Gulf of Mexico and the West Indies [1][2]. Outside its native range, an established introduced population is known from Rhode Island (U.S.A.) [2]. Recently, the hooked mussel has also been introduced to the Netherlands [18]. In this paper, we report the first record of *I. recurvum* in Belgian waters.

In 2021, we found 10 live specimens of *I. recurvum* in macroinvertebrate samples collected in the Doel Dock of the Port of Antwerp, Belgium (51°17′07.0″ N, 4°13′35.1″ E) (Figs 1–2), situated along the mesohaline zone of the river Scheldt [19]. Sampling was part of a macroinvertebrate diversity assessment within the harbour waters, as requested by the Port Authority [20]. Such an assessment was required to evaluate the functionality of several restoration measures implemented by the Port of Antwerp with the aim of improving the ecological status of their waters, in accordance with the EU Water Framework Directive (Directive 2000/60/EC) [21]. Eight specimens were found on the 14th of April 2021 in samples retrieved by scraping the concrete quay walls of the dock with a spatula. Two additional specimens were found on the 2nd of June 2021 in samples retrieved from artificial substrate consisting of stone bricks within metal cages (method after GABRIELS *et al*. [22]) that were attached to the quay walls for 49 days. On average, the collected specimens were 10.2 ± 2.6 mm long and 6.4 ± 1.9 mm wide (mean ± SD). The smallest specimen had a length of 6.1 mm and a width of 3.6 mm, while the largest measured 14.3 by 9.7 mm. All specimens are stored in the collection of the University of Antwerp, ECOSPHERE Research Group. *Ischadium recurvum* was found in macroinvertebrate communities largely dominated by the exotic Australian tubeworm *Ficopomatus enigmaticus* (Fauvel, 1923). Other (non-native) macroinvertebrate species found in great abundance in the same samples were the dark false mussel *Mytilopsis leucophaeata* (Conrad, 1831) and the bay barnacle *Amphibalanus improvisus* (Darwin, 1854). At the time of sampling, water temperature was 10.6°C, dissolved oxygen concentration 18.3 mg l^{-1}, pH 8.73, electrical conductivity 11120 µS cm^{-1} and salinity 6.4 ‰.

We hypothesize that the introduction of *I. recurvum* in Belgian waters occurred very recently, since the first European records of the species happened in 2018 in the North Sea Canal in the Netherlands [18]. The species is not included in the extensive alien species checklists of KERCKHOF *et al*. [23] and BOETS *et al*. [24] and it was not found during recent sampling campaigns carried out in 2008 [25], 2015–2016 [26] and 2017 [27] in the Antwerp harbour docks. Also, the small dimensions of our specimens indicate that they were all juveniles, since the species reaches sexual maturity at an approximate length of 25 mm [2]. Based on length-frequency distributions published by LIPCIUS & BURKE [9] we infer that the specimens collected in the Antwerp harbour are less than one year old.

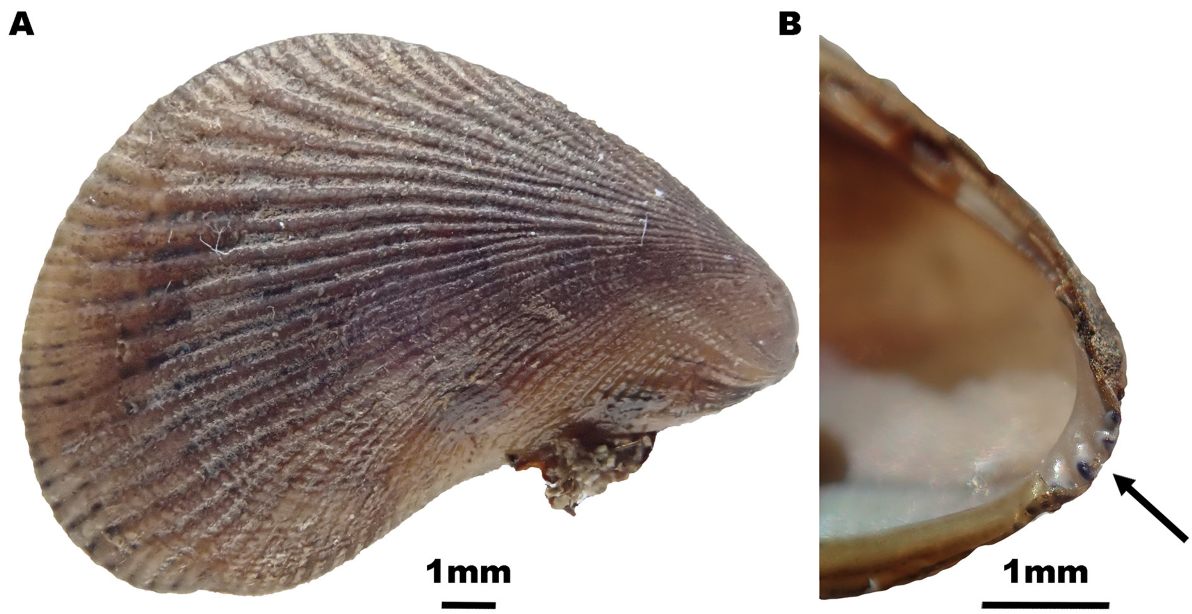

Fig. 1 – (A) One of ten *Ischadium recurvum* found in Doel Dock. (B) Detail of the hinge teeth (indicated by arrow), that allow to separate *I. recurvum* from similar taxa [18].

The introduction source of *I. recurvum* is unknown, but the species most likely reached Europe either through hull fouling or ballast water [18][28]. Shipping is also the most likely means of introduction for *I. recurvum* in the Port of Antwerp, either directly from its native range or from the non-native population in the Netherlands, since harbour areas are especially susceptible to invasion due to high shipping traffic [24]. The possibility can also not be entirely ruled out that veliger larvae from the non-native population in the Netherlands reached the Scheldt estuary without being transported by shipping activities, although the prevailing North Sea currents are directed northward, towards the North Sea Canal and away from the Scheldt [29][30].

Currently, very little is known about prospects for the long-term establishment of *I. recurvum* populations in Belgian waters. The species successfully established a population in the North Sea Canal in the Netherlands, which shows similar environmental characteristics to the Port of Antwerp in terms of salinity (mesohaline), the dominant species within the macroinvertebrate community (*F. enigmaticus*) and habitat characteristics (man-made canals with steep concrete walls) [18][28]. The Doel Dock, the Belgian locality where *I. recurvum* was found, had a salinity of 6.4 ‰ at the time of sampling [20]. This is within the tolerated limits for the species (4.5 to 36.0 ‰), although lower than the minimum of 8 ‰ required for reproduction [1][2]. However, GITTENBERGER *et al.* [27] report salinities of 11 ‰ at the same location during summer, making it at least theoretically possible for this species to reproduce in the Doel Dock. Additionally, brackish waters are usually species-poor environments and thus represent a relatively empty niche, which makes these areas prone to invasion and establishment by exotic species [31]. It is therefore possible that a population of the hooked mussel could become (or already is) established in the Port of Antwerp. The species, however, is unlikely to form large populations beyond the dock area. The Scheldt is a highly dynamic river with substrate that predominantly consists of soft sediments [19], while the species prefers moderate to low wave energy environments and hard surfaces [1][5]. The potential spread of *I. recurvum* may therefore be limited to other docks and canals with brackish water.

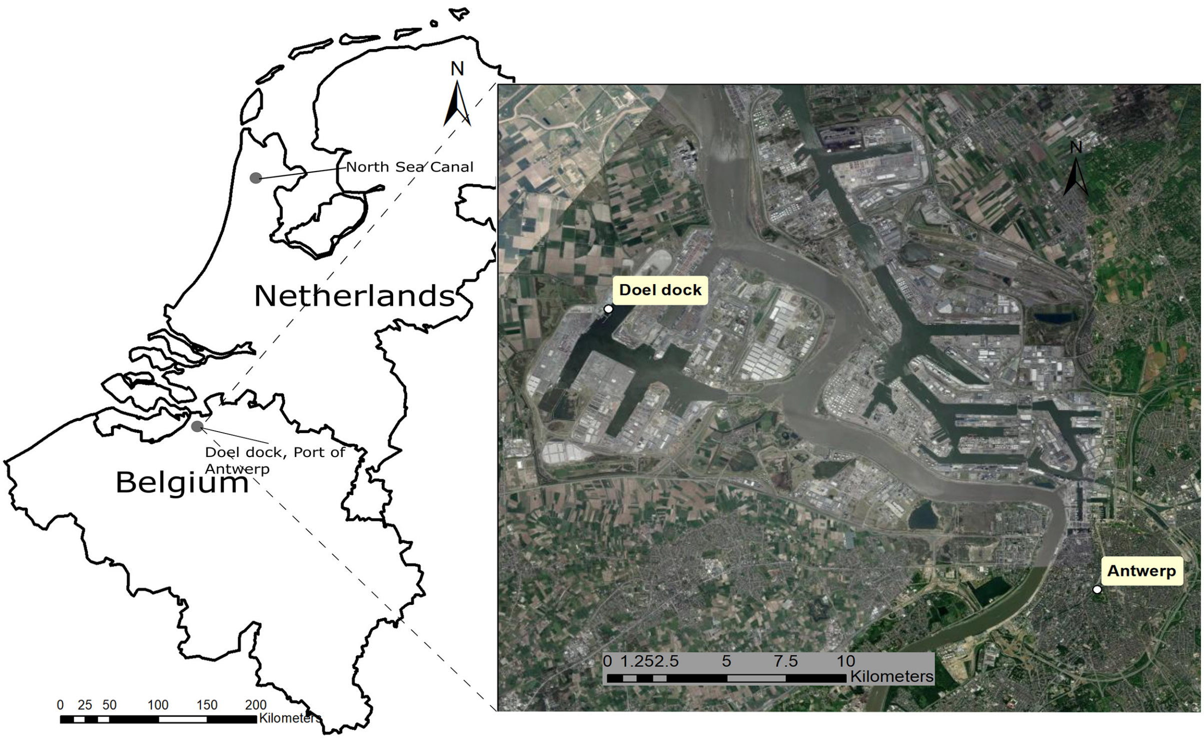

Fig. 2 - Map of Belgium and the Netherlands with the localities where *Ischadium recurvum* was found (left) and detail of the study site (Doel Dock), in the Port of Antwerp, Belgium (right).

Since *I. recurvum* forms strong byssate clumps [5] and considering its rapid establishment on artificial substrates, the species may have biofouling potential in sheltered areas with low wave energy, as was already reported for another alien invasive brackish water bivalve, *Mytilopsis leucophaeata,* in the Port of Antwerp and elsewhere in Europe [32]. It is unknown to what extent an established population of *I. recurvum* could have adverse or beneficial effects on native fauna within the Antwerp harbour docks. In its native range, *I. recurvum* is often the dominant species in brackish estuaries and it is an efficient filter feeder [12]. Consequently, the species may compete with other native and non-native filter feeders in the Port of Antwerp. Additional sampling campaigns in the docks of the Port of Antwerp and in other potentially suitable brackish water bodies connected to the river Scheldt are needed to monitor its further spread and potential ecological effects.

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