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Non-indigenous tanaid *Sinelobus vanhaareni* Bamber, 2014 in the Polish coastal waters – an example of a successful invader

by

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Abstract

The paper reports on the first record of *Sinelobus vanhaareni*, a non-native tanaid, in the Polish coastal waters (Gulf of Gdańsk, southern Baltic Sea). The species was found in the port of Gdynia in 2014, while in 2015–2017 it already colonized the western part of the Gulf of Gdańsk, inhabiting mainly hard substrates, including both natural (e.g. boulders) and anthropogenic ones (e.g. vertical concrete piles or walls of offshore structures and breakwaters, horizontal PVC plates and oyster shells used as filling in habitat collectors). During the survey period, *S. vanhaareni* was found in different seasons of the year (from winter and early spring to autumn), which, combined with the presence of ovigerous females as well as high abundance (up to tens of thousands of individuals per square meter), allows us to assume that the species has already established a population in the Gulf of Gdańsk.

Key words: *Sinelobus vanhaareni*, non-native species, introduced species, alien species, tanaids, Tanaidacea, Gulf of Gdańsk, southern Baltic Sea

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Introduction

Coastal seas and estuaries are believed to be particularly vulnerable to biological invasions (Wolff 1999; Leppäkoski & Olenin 2000; Preisler et al. 2009), which are regarded as one of the major threats to marine biodiversity (Bax et. al 2003; Chandra & Gerhardt 2008). The Baltic Sea, with its estuarine character and over 130 non-indigenous species reported to date, seems to follow this rule (Leppäkoski et al. 2002; AquaNIS 2015). Among the introduced species, the most numerous are benthic invertebrates, with crustaceans as a dominant group (AquaNIS 2015; Ojaveer et al. 2017). It includes mainly amphipods, decapods, isopods, mysids and, most recently, also a tanaid, *Sinelobus vanhaareni* Bamber, 2014 (Lackschewitz et al. 2014; AquaNIS 2015; Ojaveer et al. 2017). This species, originally misidentified as *Sinelobus stanfordi* (Richardson, 1901), was found for the first time in Europe in 2006, in Dutch and Belgian waters (van Haaren & Soors 2009; Bamber 2014). In 2009, *S. vanhaareni* appeared in the Elbe Estuary, on the east coast of the North Sea and in 2012 – in Greifswald Bay, on the German coast of the southern Baltic Sea (Lackschewitz et al. 2014). This study is the first ever report on the presence of this tanaid in the Polish coastal waters (Gulf of Gdańsk, southern Baltic Sea) and its spatial and seasonal distribution as well as abundance, dominant associated taxa and key environmental parameters (type of substrate, depth, temperature and salinity). We also point out the key morphological features that can be used to distinguish this species from *Heterotanais oerstedii* (Krøyer, 1842), the only indigenous tanaid in the Baltic Proper.

Materials and methods

Macrobenthic samples were collected at eight sites in the western part of the Gulf of Gdańsk and at one site on the Słupsk Bank (Fig. 1). Sampling was carried out in different months of the years 2014–2018 (Table 1). Water temperature and salinity were measured with a Multi 340i meter (WTW, Germany). As the samples were collected for various purposes, several different methods were used: (1) artificial habitat collectors consisting of 22 × 16 × 18.5 cm plastic crates with 2 kg weights on top, filled with oyster shells, which were deployed in the water for a period of 4 weeks to enable colonization by mobile fauna (Roche et al. 2008; Fowler et al. 2013; Normant-Saremba et al. 2017), (2) sets of three settlement plates (PVC, 15 × 15 cm), which were placed horizontally on a weighted rope at depths of 1, 3 and 7 m, deployed for 6 weeks (HELCOM/OSPAR, 2013), (3) 0.1 m^2 Van Veen grabs and (4) Kautsky samplers with a 0.04 m^2 catch area and a 500 µm mesh (Andrulewicz et al. 2004) (Table 1). At each site, three to four replicate samples were collected at different depths (1–14 m) and substrate types, i.e. soft and hard. In the latter case, both natural (e.g. boulders) as well as artificial substrates (e.g. PVC plates, oyster shells, offshore structures, shipwrecks and breakwaters) were found (Table 1). Except for samples from the Port of Gdynia and the Port of Hel, sampling was carried out by a scientific SCUBA diver. The collected material was preserved in a 4% formaldehyde solution and then analyzed to identify *S. vanhaareni* (van Haaren & Soors 2009; Bamber 2014) as well as the main associated taxa to the lowest possible taxonomic level. Only *S. vanhaareni* individuals were counted.

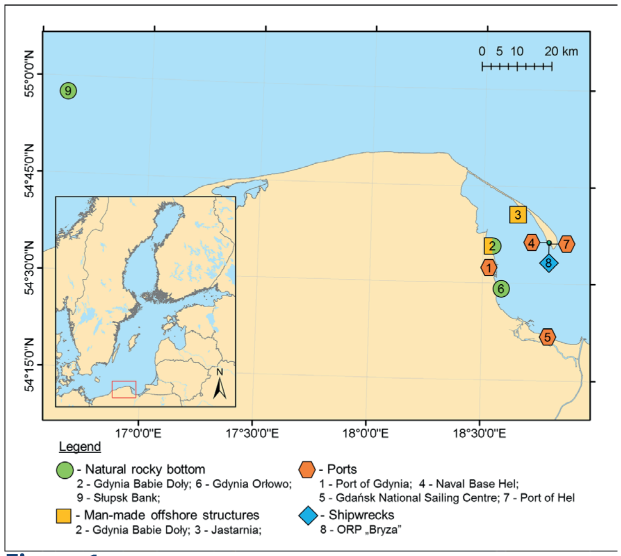

Figure 1

Locations of the sampling sites. GIS layers used for drawing the map were obtained from the GIS Centre of the University of Gdańsk.

Results

Temperature at the sampling sites ranged from 1.7°C in winter and early spring to 22.0°C in summer. Salinity ranged between 4.9 PSU at the Gdańsk National Sailing Centre, located in the mouth of the Dead Vistula River, and 7.3 PSU in the Port of Gdynia and on the Słupsk Bank at a depth of 14 m (Table 1). *S. vanhaareni* was present at 7 of the 9 studied sites. It was absent only in samples collected from the natural rocky bottom at the Słupsk Bank and from ORP "Bryza", i.e. a wreck that rests near Hel. The species was present in samples collected in different seasons of each year (Table 1), from late winter/early summer

Table 1

Abundance of *Sinelobus vanhaareni*, information on the main associated taxa and key environmental parameters at the study sites in Polish coastal waters. Numbers in brackets before sites' names in the first column refer to those given in Fig. 1 (T – temperature, S – salinity).

Site	Sampling date	Abundance (max)	T (°C)	S (PSU)	Depth (m)	Substrate/sampling method	Main associated taxa
(1) Port of Gdynia	July 2014 (first record)	3530 ind. m^{-2}	22.0	6.9	1–3	Horizontal artificial hard bottom (settlement plates)	*Amphibalanus improvisus* *Gonothyraea loveni* *Cordylophora caspia*
	Sept. 2014	47 400 ind. m^{-2}	19.0	7.0	1–7	Horizontal artificial hard bottom (settlement plates)	*Amphibalanus improvisus* *Gonothyraea loveni* *Einhornia crustulenta*
	Oct. 2014	37 000 ind. m^{-2}	16.3	7.1	1–7	Horizontal artificial hard bottom (settlement plates)	*Amphibalanus improvisus* *Gonothyraea loveni* *Einhornia crustulenta*
	Oct. 2014	100 per trap	16.1	7.1	9	Artificial habitat collector	*Leptocheirus pilosus* *Melita nitida* *Apocorophium lacustre*
	July 2015	500 per trap	No data	6.9	9	Artificial habitat collector	*Mytilus trossulus* *Leptocheirus pilosus* *Melita nitida*
	Jan. 2016	100 ind. m^{-2}	1.7	7.3	14	Soft sediment (Van Veen grab)	Oligochaeta Polychaeta *Limecola balthica* *Cerastoderma glaucum*
	June 2016	1 per trap	19.2	6.9	9	Artificial habitat collector	Oligochaeta Polychaeta Amphipoda *Jaera* spp.
	Aug. 2016	10 ind. m^{-2}	21.1	7.1	14	Soft sediment (Van Veen grab)	Oligochaeta Polychaeta *Amphibalanus improvisus* *Limecola balthica* *Mytilus trossulus*
(2) Gdynia Babie Doły	July 2015	3825 ind. m^{-2}	18.6	6.4	2–8	Vertical concrete walls of a man-made offshore structure (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda
	July 2015	358 ind. m^{-2}	18.6	6.4	8	Natural boulders up to 1 m diameter (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* *Leptocheirus pilosus*
(3) Jastarnia	March 2016	1133 ind. m^{-2}	4.0	6.7	2–4	Vertical concrete walls of a man-made offshore structure (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda
(4) Naval Base in Hel	April 2016	No data	4.2	6.5	2–5	Vertical concrete walls of a breakwater (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* *Gammarus* spp.
(5) Gdańsk National Sailing Centre	May 2016	No data	19	4.9	2–4	Vertical man-made concrete piles (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus*
(6) Gdynia Orłowo	June 2016	1791 ind. m^{-2}	6.1	6.5	5	Natural boulders up to 1 m diameter (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* *Heterotanais oerstedii*
(7) Port of Hel	Sept. 2017	60 per trap	18.1	7.2	2	Artificial habitat collectors	Hydrobiidae *Jaera* spp. *Mytilus trossulus* *Heterotanais oerstedii*
(8) ORP "Bryza" Shipwreck	Jan. 2016	Not present	4.0	7.2	12	Steel plating of a shipwreck (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda *Jaera* spp.
	April 2018	Not present	3.9	7.2	12–16	Steel plating of a shipwreck (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda *Jaera* spp.
(9) Słupsk Bank	Jan. 2018	Not present	3.6	7.3	14	Natural boulders up to 2 m diameter (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda *Jaera* spp.
	March 2018	Not present	4.0	7.3	14	Natural boulders up to 2 m diameter (Kautsky sampler)	*Mytilus trossulus* *Amphibalanus improvisus* Amphipoda *Jaera* spp.

(i.e. March–April 2016) to autumn (i.e. September 2014 and 2016 and October 2014). Both ovigerous females and juveniles were found among the analyzed specimens.

S. vanhaareni was present in all habitat types, including soft and hard substrates, both natural and artificial ones. The minimum and maximum depth at which the species was found was 1 m (settlement plate) and 14 m (soft sediment), respectively. The density of *S. vanhaareni* reached up to 100 ind. m^{-2} on soft sediments, 1791 ind. m^{-2} on natural hard substrates, 3825 ind. m^{-2} on permanently submerged, vertical, artificial, hard substrates and nearly 50 000 ind. m^{-2} on temporarily submerged horizontal settlement plates (Table 1). The species was accompanied by taxa typical of hard substrates in the Gulf of Gdańsk: sessile filter-feeders (e.g. *Amphibalanus improvisus, Mytilus trossulus*), predatory hydroids (e.g. *Gonothyraea loveni*, *Cordylophora caspia*) and mobile epifauna, such as amphipods (e.g. *Melita nitida, Gammarus* spp., *Leptocheirus pilosus*). Polychaetes (e.g. *Hediste diversicolor*, *Marenzelleria* spp.) were also present in the samples. At several sites, *S. vanhaareni* co-occurred with a native tanaid, *H. oerstedii* (Table 1).

Discussion

Ways of dispersal

Since its first arrival in Europe in 2006 (van Haaren & Soors 2009; Bamber 2014), *S. vanhaareni* has colonized many new regions on the continent (AquaNIS 2015; Lackschewitz et al. 2014). It has been found in Estonia (2010), Germany (2012), Finland (2016) and probably also in Latvia (2015) and France (2016), where it may have been misidentified as *S. stanfordi* (AquaNIS 2015).

The occurrence of non-indigenous species in the Baltic Sea that had previously been found in the North Sea is a common phenomenon associated with shipping and natural spread (Normant-Saremba et al. 2017; Ojaveer at al. 2017). The earliest record of *S. vanhaareni* from Polish waters comes from 2014, from the port of Gdynia, which may also indicate the role of shipping in the introduction of this species. However, as with other tanaids, *S. vanhaareni* lacks a planktonic larval stage, so it is unlikely to have been introduced with ballast water (Błażewicz-Paszkowycz et al. 2012). It seems more likely that the introduction vector was a ship's hull (van Haaren & Soors 2009; Rander et al. 2009; Błażewicz-Paszkowycz et al. 2012).

On the other hand, the secondary spread of this species, i.e. outside the port area and within the Gulf of Gdańsk, could take place with the aid of small passenger ships and leisure boats. The fact that *S. vanhaareni* was first found in Estonia, before it arrived in Poland and Germany (Lackschewitz et al. 2014; AquaNIS 2015), is somewhat interesting. It is possible that, like in the case of another non-native species, the bivalve *Rangia cuneata*, *S. vanhaareni* could have been introduced into the Baltic Sea by Belgian dredgers that came from the North Sea to deepen Kaliningrad port's waterway in 2008 (AquaNIS 2015). It is also possible that *S. vanhaareni* was introduced into Polish waters before 2014, but was misidentified as the native species *H. oerstedii* during earlier research. Although these two species belong to separate superfamilies, their small body size (< 3 mm), compared to other macrofaunal species of the region, may cause them to appear very similar to an unexperienced and unaware observer.

Since 2014, *S. vanhaareni* has become a widespread species in the western part of the Gulf of Gdańsk, where it inhabits various substrates, mainly hard surfaces. Several members of the family Tanaididae are associated with hard substrates covered with algal mats (Bamber 2008; Bamber et al. 2009; Bamber 2012; Rishworth et al. 2018), underwater meadows (Gardiner 1975) and floating brown algae (e.g. *Zeuxo exsargasso* Sieg, 1980 in Bamber 2012), or they can get onto the hulls of yachts (*Hexapleomera wombat* Bamber, 2012). Some other tanaids are epibionts on turtles or manatees (García-Madrigal et al. 2004; Edgar 2008; Morales-Vela et al. 2008). *Protanais birsteini* (Kudinova-Pasternak, 1970), a species from deep-sea wood-falls, is believed to have entered deep-water areas through a shallow-water accessor associated with certain terrestrial plants or macrophytes (Błażewicz et al. 2015). The capabilities and distribution mechanisms of Tanaidacea are barely known, but the presence of these crustaceans on floating or moving objects and on living organisms demonstrates that at least some tanaids have the ability to disperse passively.

In the material we studied, the abundance of *S. vanhaareni* reached tens of thousands of individuals per square meter (Table 1). The large densities recorded in different seasons over the last four years, as well as the presence of juveniles and ovigerous females demonstrate that there is an established population of *S. vanhaareni* in the Gulf of Gdańsk.

Diversity

Seven native species of the order Tanaidacea occur in the Baltic Sea (Błażewicz-Paszkowycz et al. 2012; HELCOM 2012). Six of them, *Akanthophoreus gracilis* (Krøyer, 1842), *Apseudes spinosus* (M. Sars, 1858), *Araphura brevimanus* (Lilljeborg, 1864), *Leptognathia breviremis* (Lilljeborg, 1864), *Tanaissus lilljeborgi* (Stebbing, 1891) and *Typhlotanais aequiremis* (Lilljeborg, 1864) are exclusively marine species, with type localities in the North Sea. Thus, their zoogeographical ranges do not extend beyond the Danish Straits. *Heterotanais oerstedii* (Kroyer, 1842), on the other hand, is a brackish species, which is considered to be indigenous in Polish coastal waters

(Żmudziński 1982; Szaniawska 2018; WoRMS Editorial Board 2018).

H. oerstedii and *S. vanhaareni* are currently the only representatives of the Tanaidacea in the Baltic Proper. They both belong to the suborder Tanaidomorpha, which is characterized by a simplified body sculpture and/or pereopod setation, uniramous antennules and various details of the mouthparts. They can be immediately distinguished by the number of pleonites (four in *S. vanhaareni* versus five in *H. oerstedii*) and by the rows of dorsal setae on pleonites 1 and 2 in *S. vanhaareni*, which are absent in *H. oerstedii*. Finally, *S. vanhaareni*, as many other members of the family Tanaididae, has black mottling on the carapace, which is absent in *H. oerstedii*. This dark pattern (melanin), which persists after preservation, is an important distinguishing character of *Sinelobus* species (Table 2).

Both *H. oerstedii* and *S. vanhaareni* (Fig. 2) show strong sexual dimorphism, with a narrower anterior of the cephalothorax, numerous aesthetascs on the antennule and larger chelipeds in males (Żmudziński 1974; Bamber 2014; Błażewicz-Paszkowycz et al. 2014; Szaniawska 2018).

Environmental preferences

Based on our limited number of samples, we conclude that *S. vanhaareni* prefers hard substrates, both natural boulders and anthropogenic offshore structures and breakwaters in the form of vertical concrete piles or walls. It also settles on artificial substrates (horizontal PVC plates, oyster shells used as filling in habitat collectors) employed to monitor fouling organisms and mobile fauna in Baltic and north-east Atlantic ports in order to detect non-indigenous species (HELCOM/OSPAR 2013). Large-scale colonization of a new hard substrate by *S. vanhaareni* took a few weeks. Thus, the construction of new underwater structures (piers, windfarms, breakwaters, etc.) that provide hard substrates can favor the spread of *S. vanhaareni*, which may be important in marine conservation planning (Mačić et al. 2018).

We recorded *S. vanhaareni* in salinities between 4.9 and 7.3 PSU, which was within the range reported in Dutch and Belgian waters by van Haaren and Soors (2009), who found the species in salinity ranging from 3.1 to 13.2 PSU, with one specimen recorded in 1.5 PSU. Due to the tolerance to such low salinities, it can be assumed that *S. vanhaareni* could also populate estuaries and lagoons in the Polish coastal zone. Rishworth et al. (2018) has summarized the literature data on *Sinelobus* habitats and emphasized its wide temperature and salinity tolerance, which apparently make those species adapted to living in hostile, or even ephemeral environments, e.g. intertidal or estuarine lagoons.

S. vanhaareni was accompanied by taxa typical for the region and the types of substrates studied. The taxonomic composition slightly varied between the sites due to differences in depth, the type of substrate and orientation of the substrate (Dziubińska 2011b; Brzana & Janas 2016). At this point, it is not possible to say how the taxonomic composition of the communities studied affected *S. vanhaareni*.

In general, given the wide dispersal in a relatively short period of time (especially considering the lack of a larval stage), as well as the high abundance, it can be concluded that *S. vanhaareni* is a highly opportunistic species. None of the other non-native species introduced into the Gulf of Gdańsk in recent years (e.g. *Mytilopsis leucophaeata*, *Rangia cuneata*, *Palaemon macrodactylus* or *Melita nitida*) has achieved such a colonization success (Dziubińska 2011a; Janas & Tutak 2014; Janas et al. 2014; Brzana et al. 2017; Normant-Saremba et al. 2017). Moreover, *S. vanhaareni* seems to be more tolerant of environmental factors

Table 2

Comparison of the main taxonomic features used to distinguish *S. vanhaareni* from *H. oerstedii* (Haaren & Soors 2009; Bamber 2014; personal observations)

Feature	*Sinelobus vanhaareni* Bamber, 2014	*Heterotanais oerstedii* (Krøyer, 1842)
Max body length	3.0 mm	2.0 mm
External pigmentation	Dark mottling on dorsal surface of the entire body	Creamy white body with no mottling
Thorax	Pereonites rounded or trapezoidal in shape, which creates notched lateral edges of the animal	Pereonites more rectangular in shape, which makes the notching less visible
Pleon	4 pleonites and pleotelson	5 pleonites and pleotelson
	Each of pleonites 1–3 twice as long as pleonite 4	Pleonites 1–5 subequal in length
	Pleonite 1 narrowed anteriorly, which makes the entire pleon well pronounced	Pleonite 1 rectangular in shape, which makes the entire pleon less distinct
	3 pairs of ventral pleopods on pleonites 1–3	5 pairs of ventral pleopods on pleonites 1–5
	Two rows of plumose setae on dorsal side of pleonites 1–3	No plumose setae on dorsal side of pleon

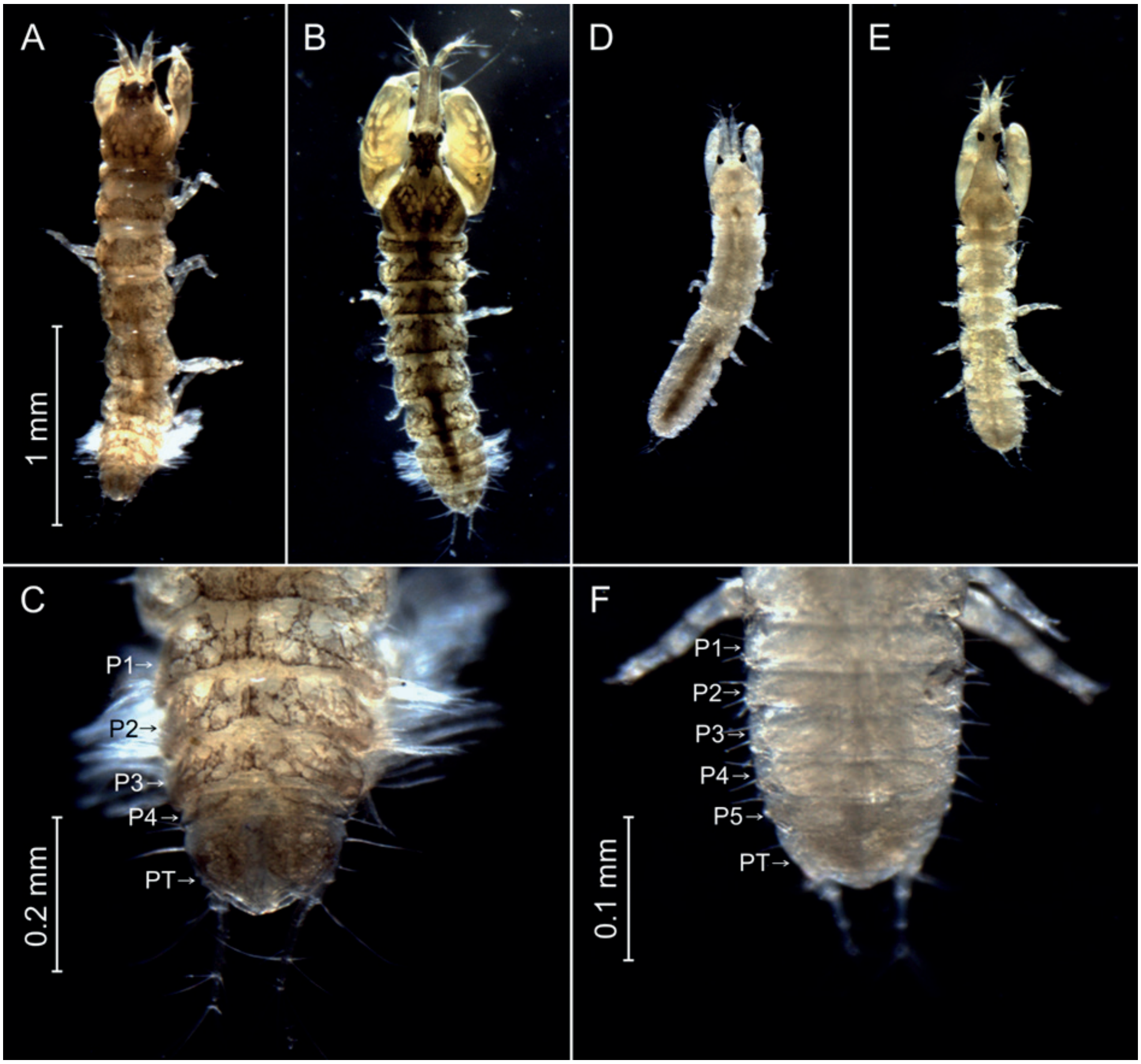

Figure 2

Non-native and native representatives of Tanaidacea collected in the Gulf of Gdańsk, *S. vanhaareni*: A – female, B – male, C – pleon and *H. oerstedii*: D – female, E – male, F – pleon (P – pleonite; PT – pleotelson). The scale bar on photograph A applies to photographs B, D and E as well.

than native *H. oerstedii*, which, as we know from the literature, has similar habitat preferences in this region (Żmudziński 1974; Szaniawska 2018). The latter species was reported from shallow, hard substrates (both natural and artificial), where it is one of the most abundant species, with densities exceeding 7500 ind. m^{-2} (Grzelak & Kukliński 2010; Janas & Kendzierska 2014; Brzana & Janas 2016). *S. vanhaareni* therefore poses a potential threat to native *H. oerstedii* in terms of competition for resources. However, there is as yet no information on the impact of *Sinelobus* species on biodiversity and ecosystem services. It can be assumed that, due to its high abundance, *S. vanhaareni* may serve as prey for small predatory invertebrates and juvenile fish and thus affect the food web. It is worth noting that, as with other demersal organisms, the tube-building behavior of *Sinelobus* is an important biological trait (Gardiner 1975; Moore & Eastman 2015). In some Baltic coastal areas, the introduction of *S. vanhaareni* may lead to a significant increase in the number of tube-dwellers, which are represented on hard surfaces mainly by *H. oerstedii* and much less abundant Corophiidae (Grzelak & Kukliński 2010; Brzana & Janas 2016). It has been reported that some predators may prefer tube-dwelling prey over free-living prey (Schmitt & Coyer 1983). Gallagher et al. (1983) observed that the presence of tube-dwelling tanaids may facilitate larval recruitment of several benthic species on soft sediments. It has also been suggested that macrofaunal tubes on seagrass blades may positively affect the biodiversity and abundance of meiofauna (Peachey & Bell 1997). On the other hand, the presence of ampeliscid tubes has been reported as preventing other macrofaunal species from colonizing habitats (Schaffner & Boesch 1982). For now, however, these are only speculations that can be confirmed or disproved based on the results of further research on the biology and ecology of *S. vanhaareni*, a new and abundant taxon within the fouling communities of the Gulf of Gdańsk.

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