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No longer a mysterious invader: first insights into the population biology of the tanaid *Sinelobus vanhaareni* from the southern Baltic Sea

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Abstract
Temporal changes in the abundance and population biology were studied in the non-indigenous tanaid *Sinelobus vanhaareni* colonising artificial substrates (PVC plates) submerged in the shallow coastal waters of the Gulf of Gdańsk (southern Baltic Sea). Individuals were collected three times, in July (early summer), August (midsummer) and October (early autumn) 2019, with the number of samples analysed (PVC plates) ranging from 10 to 12 per season. *S. vanhaareni* occurred with 100% frequency in all three sampling periods, with the lowest and highest densities of 667 ind. m^{-2} and 9,689 ind. m^{-2}, respectively. The most common density (in 74% of all samples) did not exceed 4,000 ind. m^{-2}. Furthermore, no temporal changes in this parameter were observed ($p > 0.05$). The study population ($n = 2{,}216$) consisted of juveniles, females (non-reproductive, pre-ovigerous and ovigerous) and males, ranging in size from 0.84 mm to 4.07 mm. Females of *S. vanhaareni* were longer than males and outnumbered them sixfold. The female-biased sex ratio increased over time. The presence of ovigerous females and juveniles in the population indicates that this species reproduces at least from June to October. The number of embryos per female ranged from 8 to 54 (mean 23 ± 10, $n = 58$) and increased significantly ($p < 0.05$) with female body length. These findings show that *S. vanhaareni* is characterised by several life traits that favour the rapid establishment of a stable and abundant population in non-native regions.

Keywords
Non-indigenous species; Peracarida; Gulf of Gdańsk; Biofouling; Life traits

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1. Introduction

Biological invasions and unnoticed introductions of non-indigenous species (NIS) resulting from human activity are among the most pressing issues in environmental sciences today (Rilov and Crocks, 2009; Turbelin et al., 2017; Ros et al., 2023). Thanks to the development of monitoring programmes and modern techniques such as DNA barcoding and environmental DNA (e-DNA), detecting and controlling the spread of NIS is becoming increasingly easier (Adura and Planes, 2017; Borrell et al., 2017; Fonseca et al., 2023). Although the number of detected NIS is increasing, small, difficult-to-identify taxonomic groups remain the largest source of cryptic invasion (Guerra-Garcia et al., 2023; Stępień et al., 2023). An example of such organisms are crustaceans of the superorder Peracarida, which, due to t he absence of planktonic larvae, are considered to have low dispersal ability (Johnson et al., 2001). This is well illustrated by the reproductive biology of the small peracarid crustacean, *Tanais dulongi*, whose fertilised eggs are retained in a marsupium formed by oostegites, where embryonic development takes place, followed by hatching into benthic manca stages (manca I–III), which are released directly into the parental habitat with no planktonic dispersal stage (Johnson and Attramadal, 1982). Despite their limited natural dispersal potential, previous studies on peracarid crustaceans have demonstrated that individual species can be readily introduced as stowaways via ship hull fouling and successfully establish their populations in new habitats, where they often remain unrecognised and undetected for long periods of time (Martinez-Laiz et al., 2019; Ros et al., 2020). One species of Peracarida whose invasive potential is almost completely overlooked is *Sinelobus vanhaareni*, a representative of the order Tanaidacea. This species was discovered in the Netherlands in 2006 by van Haaren and Soors (2009), initially misidentified as *Sinelobus stanfordi* (Richardson, 1901), a taxon known to be widely distributed (Sieg, 1980; WoRMS Editorial Board, 2025). After taxonomic re-examination, the species was reassigned to *S. vanhaareni* (Bamber, 2014). To date, it has been recorded in six countries bordering the North Sea: Belgium, Denmark, Germany, Great Britain, the Netherlands and Sweden, five countries bordering the Baltic Sea: Denmark, Estonia, Finland, Germany and Poland and in one country bordering northeast Atlantic Ocean: France (van Haaren and Soors, 2009; Lackschzewitz et al., 2014; Brzana et al., 2019; Svedholm, 2021; Ashelby, 2022; Gagnon et al., 2022; AquaNIS, 2025; Gouillieux et al., 2026). The first records of *S. vanhaareni* in seaports and their surroundings, as well as in marinas and on boat hulls, indicate that two routes – maritime shipping and recreational boating – played an important role in its primary and secondary spread (van Haaren and Soors, 2006; Brzana et al., 2019; Outinen et al., 2021; Ashelby, 2022; Gangon et al., 2022). Through the former, *S. vanhaareni* may have been introduced to Europe, from the northeast Pacific, where its presence was confirmed by molecular studies (Stępień and Jażdżewska, 2025; Gouillieux et al., 2026).

Based on its current distribution in the European seas, it is assumed that *S. vanhaareni* tolerates a wide range of temperatures in the temperate zone, where it inhabits limnetic to euhaline waters characterised by a salinity range of 0.4–37 (van Haaren and Soors, 2006; Brzana et al., 2019; Outinen et al., 2021; Ashelby, 2022; Gouillieux et al., 2026). As a representative of both infauna and epifauna, *S. vanhaareni* inhabits a variety of habitats, such as soft bottoms (e.g. mud, clay, sand) or natural and artificial hard substrates (e.g. oyster reefs, stones, rocks, underwater structures) (van Haaren and Soors, 2006; Brzana et al., 2019; Gangon et al., 2022; Brzana and Janas, 2025; Gouillieux et al., 2026). This species was also found in vegetated habitats and among filamentous green algae (Ashelby, 2022; Gangon et al., 2022). Considering the above information on the ecology of this species, it can be concluded that *S. vanhaareni* is an opportunist, coping well with various environmental conditions, which favours its widespread distribution and the formation of high-density aggregations, sometimes reaching tens of thousands of individuals per square meter (Brzana et al., 2019). However, the high density of *S. vanhaareni* is not only due to its wide tolerance to various environmental factors, but also to favourable population traits (e.g., a favourable sex ratio, prolonged reproductive activity, multiparity, short generation time, and a large number of offspring). Unfortunately, these issues remain largely unknown, even though the population of this species was first recorded in Europe almost two decades ago (van Haaren and Soors, 2009). Knowledge of the sex and size (age) structure of the population, as well as the potential for offspring production, is crucial to understanding the success of *S. vanhaareni* in non-native regions. With a large number of individuals collected for other research (Outinnen et al., 2021) during three periods of 2019, i.e. early summer, midsummer and early autumn, we conducted studies aimed at determining the density, size and sex structure, as well as reproductive potential of *S. vanhaareni* inhabiting the southern Baltic Sea (Gulf of Gdańsk, Poland).

2. Material and methods

2.1 Sampling site and design

Sinelobus vanhaareni was obtained from samples collected in 2019 at the marina of the National Sailing Centre in Gdańsk (Gulf of Gdańsk, Poland) during testing of a biofouling assessment protocol for recreational boats and marinas (COMPLETE, 2018; Outinen et al., 2021; Figure 1).

The material was collected using sets of two PVC settlement plates (15 × 15 cm), aligned horizontally on a rope at a depth of 0.5 m and 1.0 m below the water surface. A total of 18 sets (36 PVC plates) were installed at the beginning of the growing season, i.e. in May 2019, and then one-third of them were removed three times: in July 2019 (early summer, immersion time 49 days), August 2019 (midsummer, immersion time 91 days) and October 2019 (early autumn, immersion time 143 days). Due to losses, the number of plates (samples) collected in July was lower than expected. While removing the sets, the temperature (± 0.1°C) and salinity of the water (± 0.1) were determined at each sampling location using a Multi 350i meter (WTW, Poland). The temperature in July, August and October 2019 was respectively 20.8°C, 20.9°C and 15.2°C, while the salinity was 6.7, 6.6 and 5.6.

After removal from the water, each PVC plate was placed in a separate box filled in situ with water and transported to the laboratory, where the fouling material was gently scraped off (from both sides) with a hand scraper, sorted on a 1 mm sieve, and then preserved in 4% formaldehyde solution for further qualitative and quantitative studies of the fouling communities. The results of these studies, which showed that *S. vanhaareni*i was one of fifteen identified cryptogenic and non-indigenous fouling taxa and at the same time the second (after barnacle Amphibalanus improvisus) most abundant species, were described by Outinen et al. (2021). Density (ind. m^{-2}) was determined based on the number of identified *S. vanhaareni* individuals collected from each PVC plate in relation to the double (upper and lower) surface of 0.045 m^2.

2.2 Laboratory procedures

Taxonomic identification of *S. vanhaareni* was performed based on the species' morphological traits described by Bamber (2014). Body length was measured (± 0.01 mm) from the anterior margin of the cephalothorax to the posterior margin of the pleotelson under a Nikon SMZ800 stereo

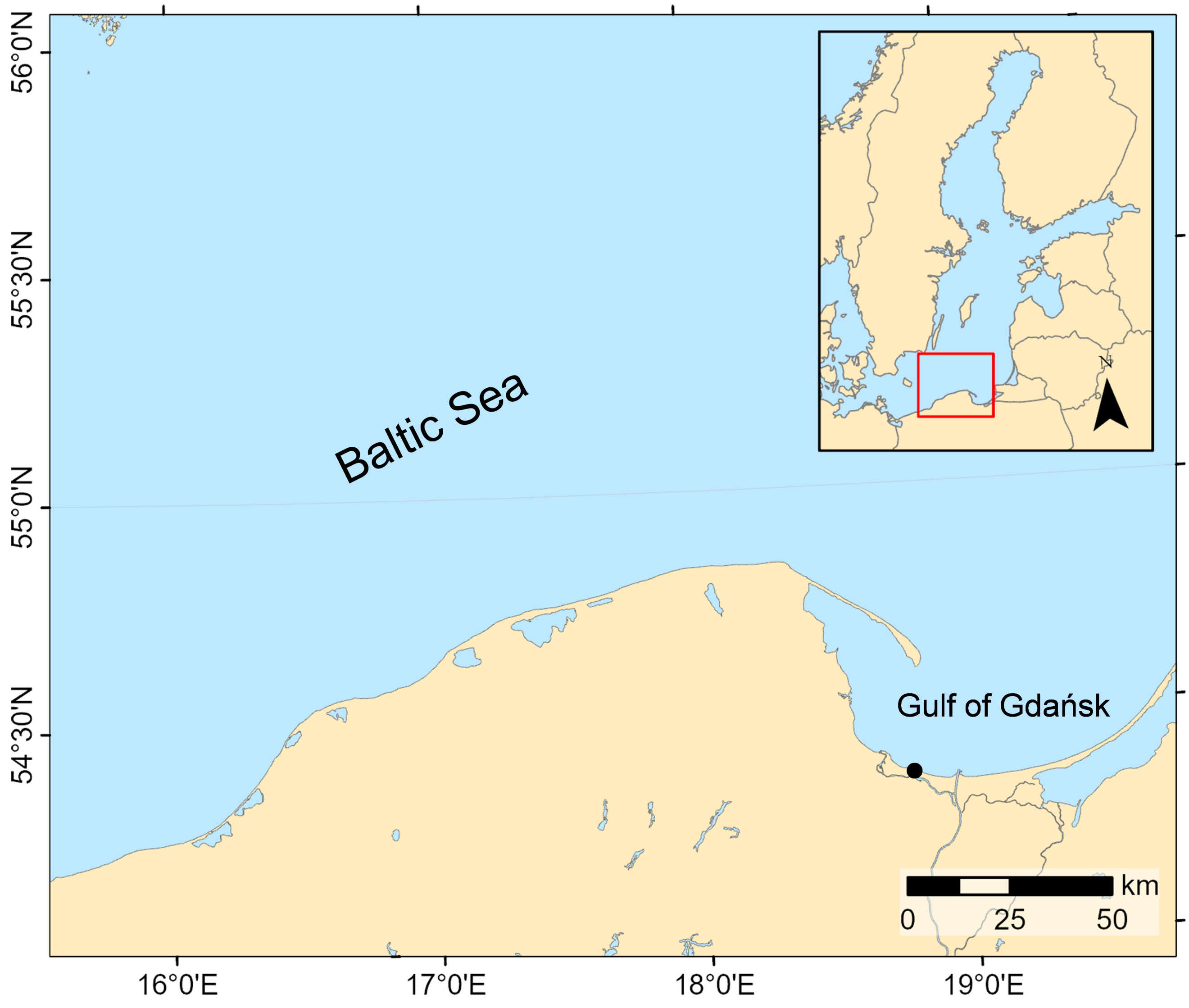

Figure 1. Location of the sampling site, i.e. the marina of the National Sailing Centre in Gdańsk (black dot).

microscope (Nikon, Poland) equipped with a DSFi1U2 digital camera (5 Mpx) using NIS-elements BR 3.0 software (Nikon, Japan). Sex was determined based on sexual dimorphic traits following Bamber (2014), including a narrower anterior part of the cephalothorax, numerous aesthetascs on the antennules and enlarged chelipeds in males (Figure 2a). Specimens lacking developed male or female characters were classified as juveniles. Among females, three categories were distinguished according to Alves et al. (2023): 1 – non-reproductive females (individuals with adult appearance but no signs of reproductive activity, Figure 2b), 2 – pre-ovigerous (preparatory) females (individuals with bud-shaped oostegites, Figure 2c) and 3 – ovigerous (copulatory) females (individuals with a fully developed marsupium, empty or with embryos inside, Figure 2d). The term ‘embryo’ refers to all stages of development of unhatched offspring. In ovigerous females with intact marsupia, embryos were gently removed and counted. Due to the fact that some *S. vanhaareni* individuals were damaged during sampling (scraping), the total number of undamaged (complete) individuals used in the study of size and sex structure was lower than the total number of collected individuals. The sex ratio was calculated based on the total number of males and the total number of females, whereas reproductive activity was estimated based on the proportion males and pre- and ovigerous females (Kneib, 1992). All individuals were grouped into size (body length) classes of 0.20 mm to establish

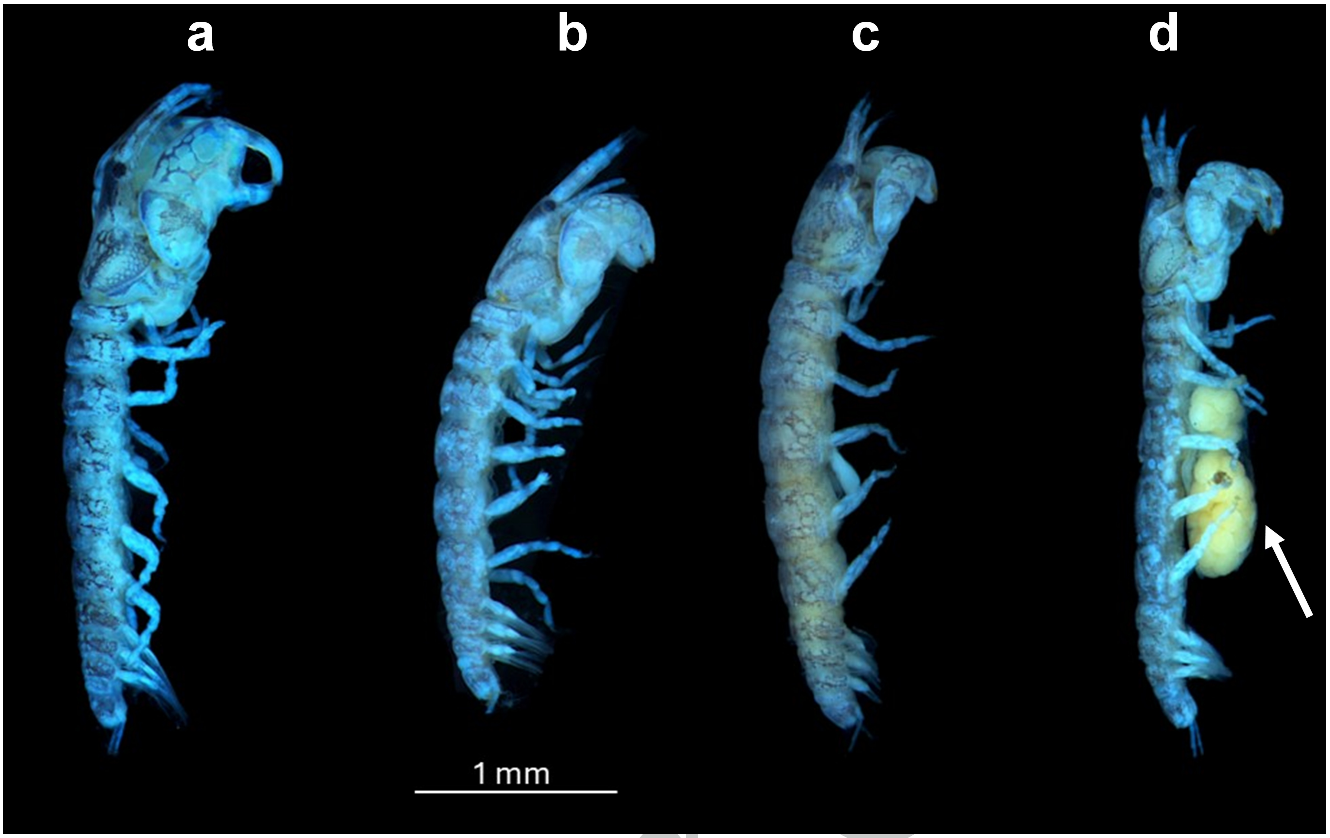

Figure 2. *Sinelobus vanhaareni*: adult male (a), non-reproductive female (b), pre-ovigerous female with small oostegites developed at the base of the fourth pair of pereopods (c), and ovigerous female with a marsupium (marked with an arrow) filled with eggs (d) (photo by Anna Stępień).

a size frequency distribution.

2.3 Statistical analysis

After checking the normality of the data distribution using the Shapiro–Wilk W test, non-parametric Kruskal–Wallis and Mann–Whitney tests were applied to assess temporal changes in density and length or differences in length between sexes and developmental stages. Differences in the proportions of individuals between the sampling periods were tested using the two-sample proportion Z-test. Due to the lack of normal distribution and the presence of outliers in most data groups, descriptive statistics using the median and interquartile range (IQR) were used. Box plots, showing the minimum, first quartile (Q1), median (Q2), mean, third quartile (Q3), and maximum values, were used for the graphical presentation of data. The significance of the correlation coefficient in the relationship between the number of embryos and the female body length was tested using linear regression analysis ($y = ax + b$). The coefficient of determination (R^2) and its significance were calculated, as well as the regression equation coefficients (slope and intercept). The significance level for all statistical analyses was set at $p < 0.05$. They were performed using Statistica 13.1 software (StatSoft, Poland).

3. Results

3.1 Temporal changes in abundance

In all three sampling periods, i.e. July, August and October 2019, *S. vanhaareni* occurred with a frequency of 100%, being present on each of the 34 PVC plates collected (Figures 3 and 4a). Although both the lowest and highest densities, 667 ind. m^{-2} and 9,689 ind. m^{-2}, respectively, were recorded during midsummer (August 2019), this parameter did not differ significantly ($p > 0.05$) between subsequent sampling periods (Figure 4a). In as many as 74% of samples, *S. vanhaareni* occurred with a density of up to 4,000 ind. m^{-2} (Figure 4b).

3.2 Sex structure, reproductive activity and fecundity

Of the total 5,270 individuals collected, 2,216 (42%) were included in the analysis; 889 individuals were collected in July, 751 in August and 576 in October 2019. Of these, 2.1% were juveniles, 13.4% were males, and 84.5% were females. The sex ratio was female-biased, with the proportion of females increasing over time, from 3.7:1 in July to 7.9:1 in August, reaching 18.9:1 in October (Figure 5). Non-reproductive individuals predominated among all females, accounting for 72.8% of the total. Pre-ovigerous

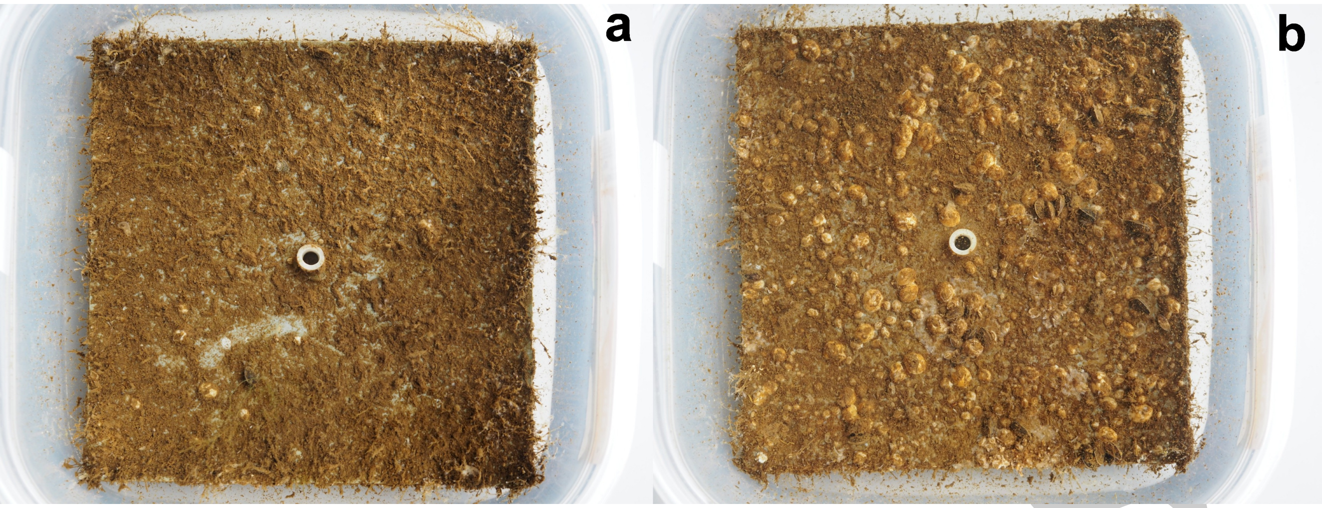

Figure 3. Sample photo of the upper (a) and lower side (b) of the PVC plate, on which the highest density of *Sinelobus vanhaareni* was recorded in August 2019 (photo by Radosław Brzana).

and ovigerous females accounted for 3.2% and 24.0%, respectively. The proportion of males together with pre- and ovigerous females in the population was significantly higher ($p < 0.05$) in July 2019 compared to October 2019, 39.4% and 31.8%, respectively. While in the following months the proportion of pre- and ovigerous females significantly increased ($p < 0.05$) from 18.3% to 26.9%, the proportion of males decreased ($p < 0.05$) from 21.0% to 4.9% (Figure 5).

The number of embryos estimated based on 58 ovigerous females (length range 1.93–3.33 mm, mean 2.50 ± 0.32 mm) ranged from 8 to 54 (mean 23 ± 10) and increased significantly ($p < 0.05$) with female body length (Figure 6).

3.3 Size structure

The smallest individual analysed was 0.84 mm long, and the largest was 4.07 mm long (median 2.11 mm). The length of females ranged from 1.10 mm to 4.07 mm (median 2.11 mm) and was 62% greater than that of males (range 1.27 mm to 3.10 mm, median 2.17 mm; Figure 7a). The difference in body length between the two sexes was significant ($p < 0.05$). Although the greatest lengths were recorded in non-reproductive females (seen as outliers in Figure 7a), this group was significantly ($p < 0.05$) smaller than pre-ovigerous and ovigerous females, with medians of 1.99 mm ($n = 1{,}363$), 2.31 mm ($n = 60$) and 2.37 mm ($n = 449$), respectively.

The body length of all individuals did not differ significantly ($p > 0.05$) between the sampling periods (Figure 7b), with a median length ranging from 2.09 mm in July 2019 (range 1.1 mm to 3.55 mm) to 2.13 mm in August 2019 (range 0.84 mm to 4.07 mm). No temporal differences ($p > 0.05$) were found in the length of individuals in the studied groups, i.e. juveniles, females (from all categories) and males.

Although the distribution of body lengths of all individuals in the population did not show a normal (Gaussian) pattern, as many as 51% of all analysed individuals (males and females) were of medium size, i.e. they belonged to the body length classes in the range of 1.81–2.40 mm (Figure 8). Individuals from smaller (< 1.80 mm) and larger (> 2.41 mm) length classes accounted for 23% and 26% of the total, respectively. The size structure of *S. vanhaareni* individuals varied over time (Figure 9). The proportion of medium-sized individuals from three length classes in the range of 1.81–2.40 mm was significantly ($p < 0.05$) higher in July than in October, with values of 56% and 27%, respectively (Figure 9a,c). On the other hand, the proportion of smaller individuals from length classes below 1.60 mm was significantly ($p < 0.05$) lower in July than in October, with values of 9% and 27%, respectively (Figure 9a,c). The proportion of larger individuals from length classes above 2.61 mm was significantly higher ($p < 0.05$) in August (16%) than in July and October, when it amounted to 10% (Figure 9).

4. Discussion

S. vanhaareni is one of seven species belonging to the genus *Sinelobus*, six of which have been described relatively recently, i.e. less than two decades ago (WoRMS Editorial Board, 2025). With the exception of the earliest identified species, *S. stanfordi*, there is no information on the population traits of other species of this genus (Gardiner, 1975; Ambrosio et al., 2014; Ferreira et al., 2015; César and Becerra, 2019). Our knowledge of other tanaid populations from temperate environments is also fragmentary. This likely stems from the time-consuming nature of collecting and conducting taxonomic and biological analyses of such small organisms, and perhaps also from limited knowledge of their ecosystem functions. However, since we know that

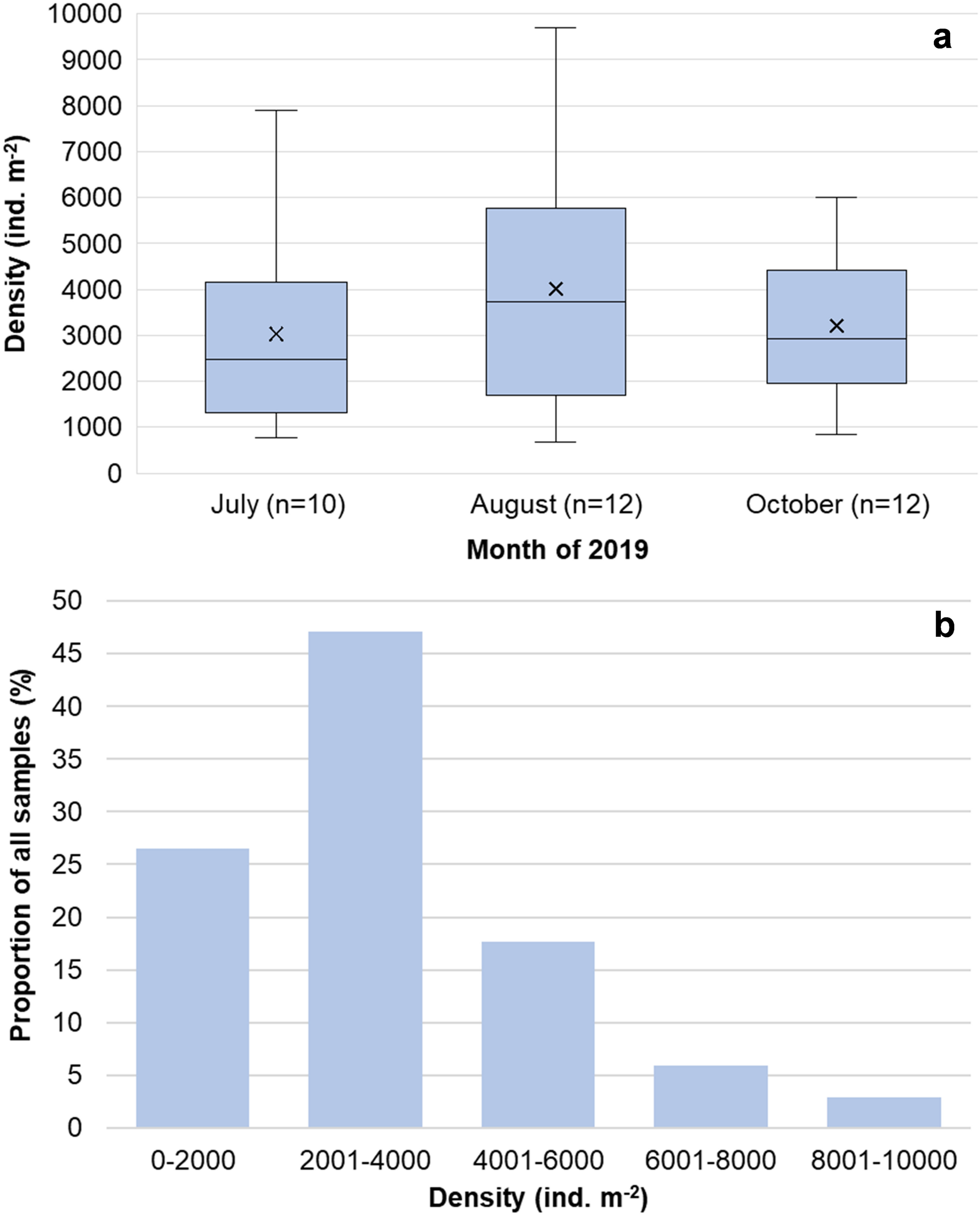

Figure 4. Box and whisker plot showing the distribution of *Sinelobus vanhaareni* density data across the sampling periods (a) and the proportion of samples with different densities of this species among all (n = 34) collected samples (b); n – number of individuals.

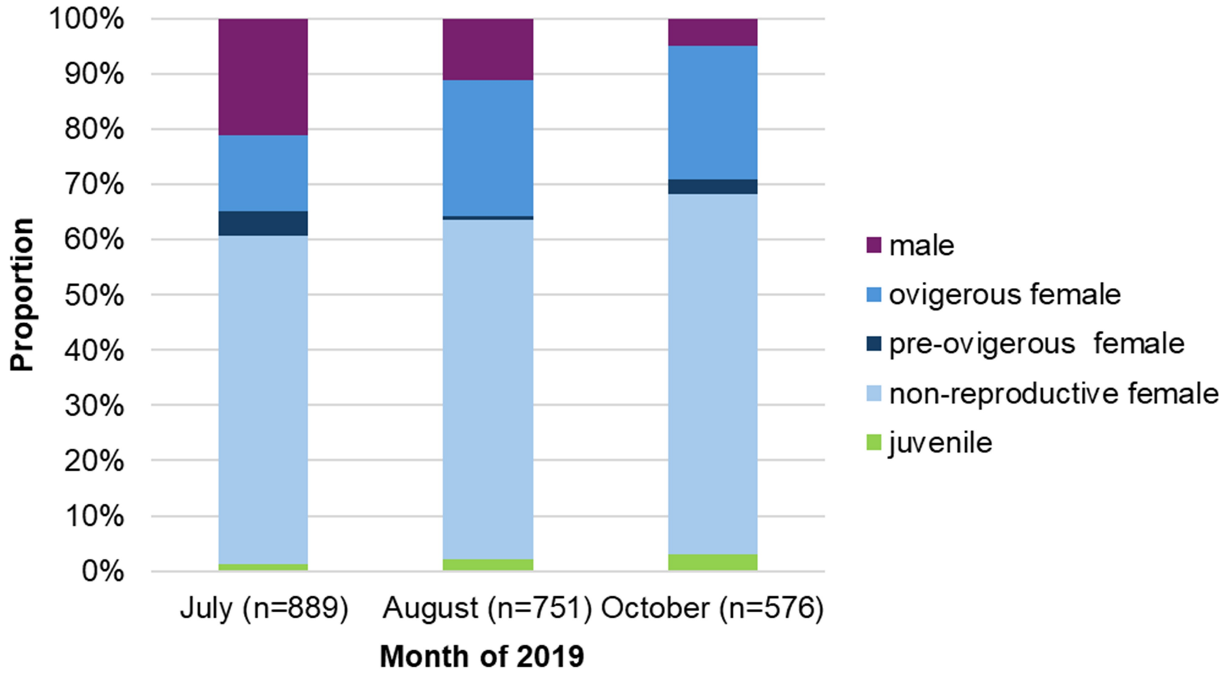

Figure 5. Proportion of juveniles, females from different categories, and males of *Sinelobus vanhaareni* among all analysed individuals in subsequent sampling periods; n – number of individuals.

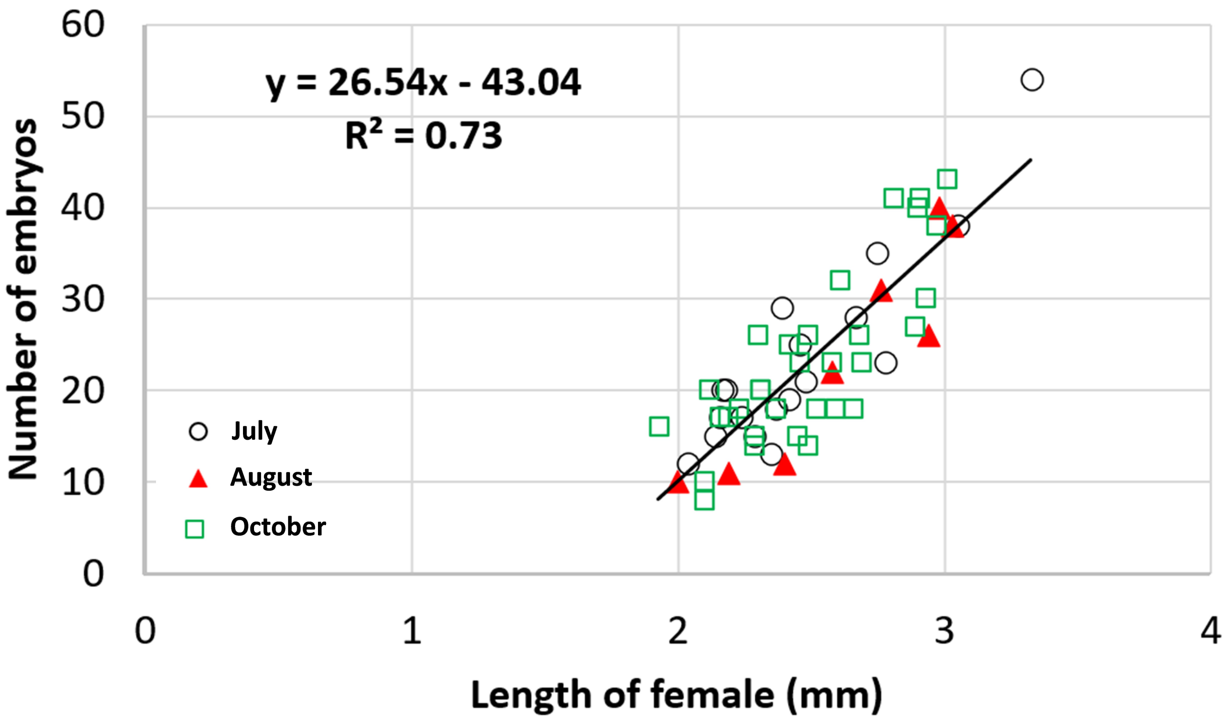

Figure 6. Relationship between the number of embryos and the total length of ovigerous females of *Sinelobus vanhaareni*.

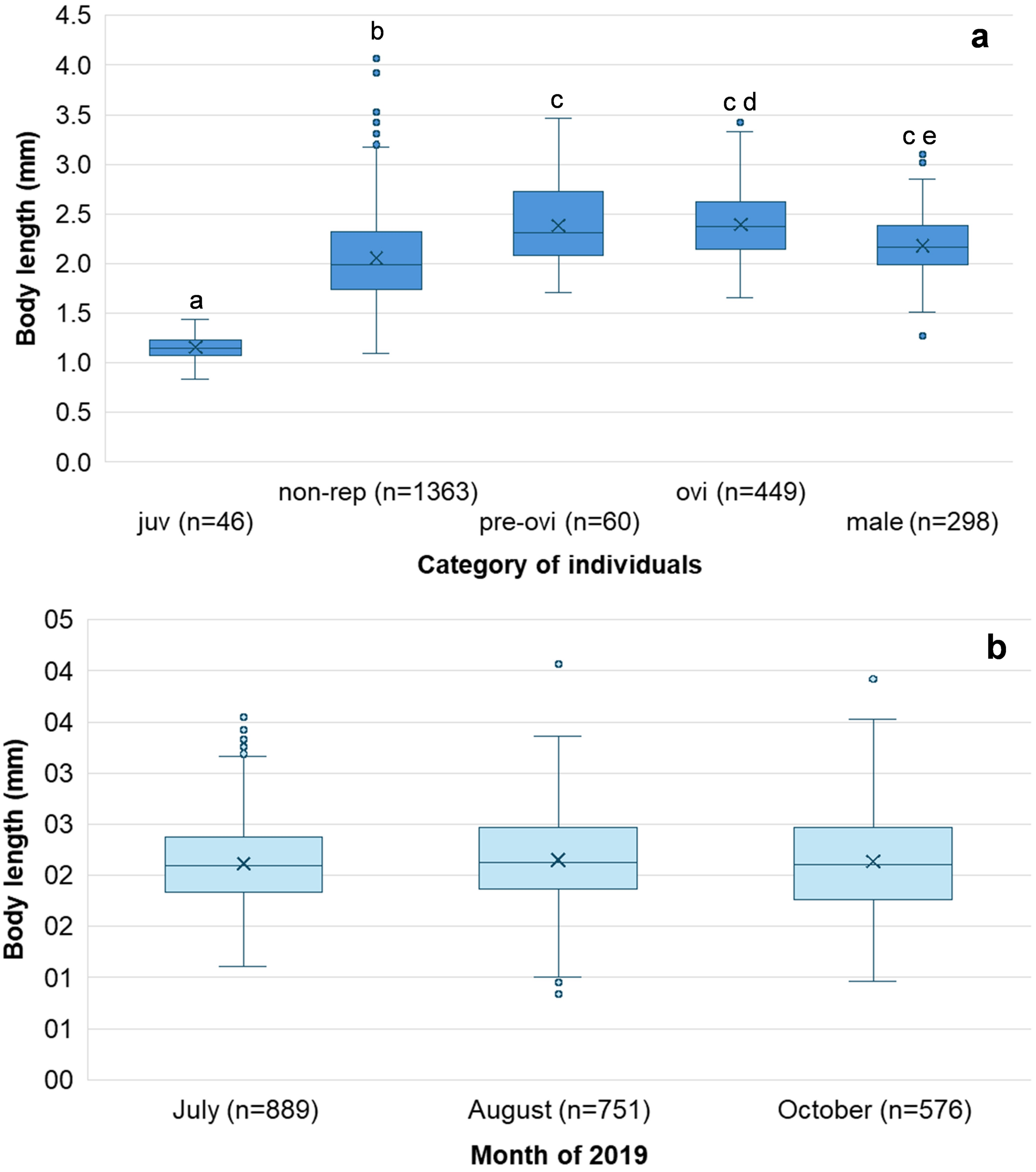

Figure 7. Box and whisker plots comparing: body length of juveniles (juv), non-reproductive females (non-rep), pre-ovigerous females (pre-ovi), ovigerous females (ovi) and males (a) and body length of all individuals of *Sinelobus vanhaareni* collected in subsequent sampling periods (b); different letters indicate significant differences ($p < 0.05$) between groups, n – number of individuals.

these species form large populations that feed on bacteria, benthic microalgae or detritus, among other things, and also serve as food for higher-level consumers, we can assume that they undoubtedly influence the transfer of matter and energy in inhabited ecosystems. They may also compete with co-occurring species (e.g. from the order Amphipoda) for environmental resources (Outinen et al., 2021). Knowledge of life history traits allows us, on the

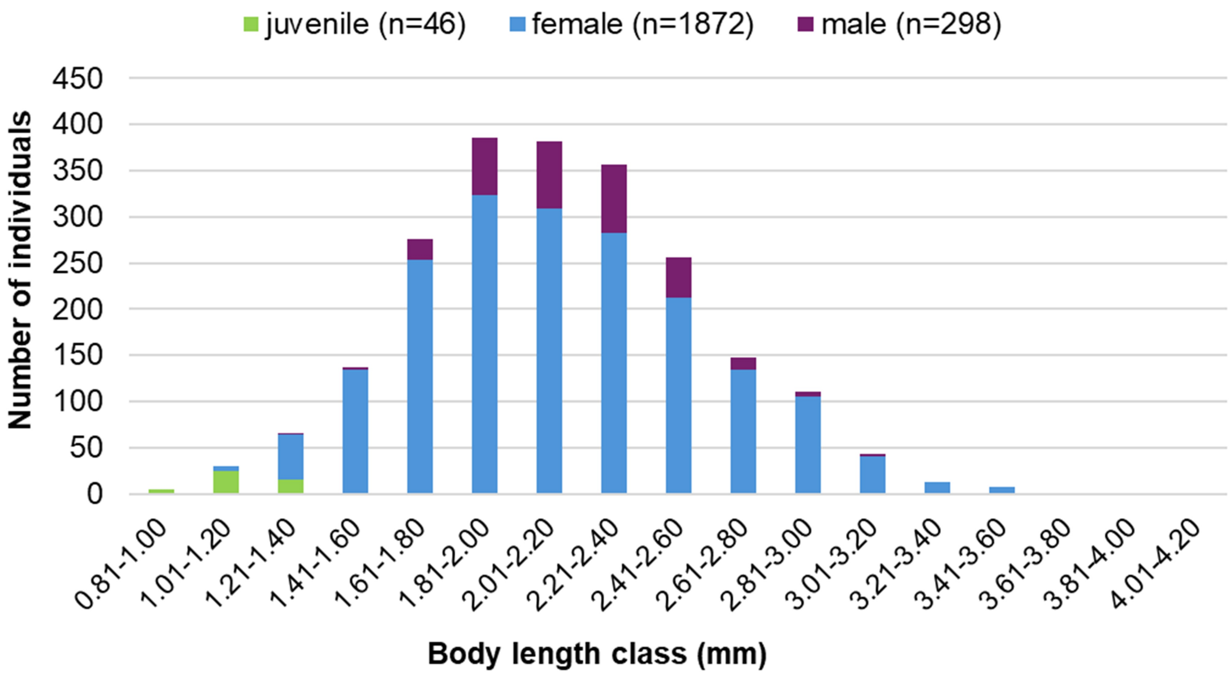

Figure 8. Size distribution of all analysed *Sinelobus vanhaareni* individuals represented by juveniles, females and males, based on body length; n – number of individuals.

one hand, to understand population functioning, and on the other hand, together with long-term data, to extrapolate trends. Such insights are necessary, for example, in the context of species management and predictive modelling. For this reason, the present study, which provides new knowledge about the *S. vanhaareni* population, is an important addition to existing knowledge.

The maximum recorded body lengths of female and male *S. vanhaareni* were greater than those previously described by Bamber (2014), Ashelby (2022), and Gouillieux et al. (2026), respectively (Table 1). However, this may be due to the significantly larger number of individuals analysed than in previous studies on this species. Regardless, it can be noted that although *S. vanhaareni* appears to be one of the larger species among representatives of the genus, with only *Sinelobus pinkenba* (4.1 mm) and *S. stanfordi* (4.6 mm) being larger (Bamber, 2008; Ferreira et al., 2015), for most *Sinelobus* species, size measurements are only known from the holotype, so the maximum lengths may actually be larger (Edgar, 2008; Bamber, 2014; Rishworth et al., 2019). *S. vanhaareni* is also a larger species than the co-occurring (native) *Heterotanais oerstedii*, reaching a maximum body length of 2.6 mm, but smaller than other tanaids, such as *Zeuxo holdichi* or *Tanais dulongii*, which reach a maximum length of 5.35 mm and 5.94 mm, respectively (Jażdżewski, 1969; Rumbold et al., 2014; Dauvin et al., 2023). Although it is difficult to determine the lifespan of *S. vanhaareni* without data on size and sexual structure covering the entire year, looking at the sizes of the analysed individuals and other species from the temperate zone, it can be estimated that it lives for about 12–16 months, i.e. longer than the smaller *H. oerstedii*, whose lifespan is one year, and shorter than the larger *Z. holdichi*, which lives for 16 months (Jażdżewski, 1969; Dauvin et al., 2023).

The fact that females of *S. vanhaareni* reach greater maximum body lengths than males (Table 1) can be explained by sex-specific life history strategies, complex development trajectories, e.g. the presence of more instars and investment in production of marsupia. Rumbold et al. (2012) demonstrated that females reach a greater asymptotic length than males, despite their slower growth rates. Growth modelling revealed that female development is prolonged and involves a greater number of instars, whereas males grow faster but reach a smaller final size. This indicates that differences in body size are primarily due to differences in the duration of development rather than growth efficiency (Hamers et al., 2000; Rumbold et al., 2012, 2014). Fecundity is a key selective driver contributing to the larger body size in females. Rumbold et al. (2012) reported a strong positive correlation between female body length and brood size, with female size accounting for over 80% of the variation in the number of eggs. As with other peracarid crustaceans, reproductive output in *T. dulongii* is constrained by the capacity of the marsupium, making larger body size directly advantageous to females in terms

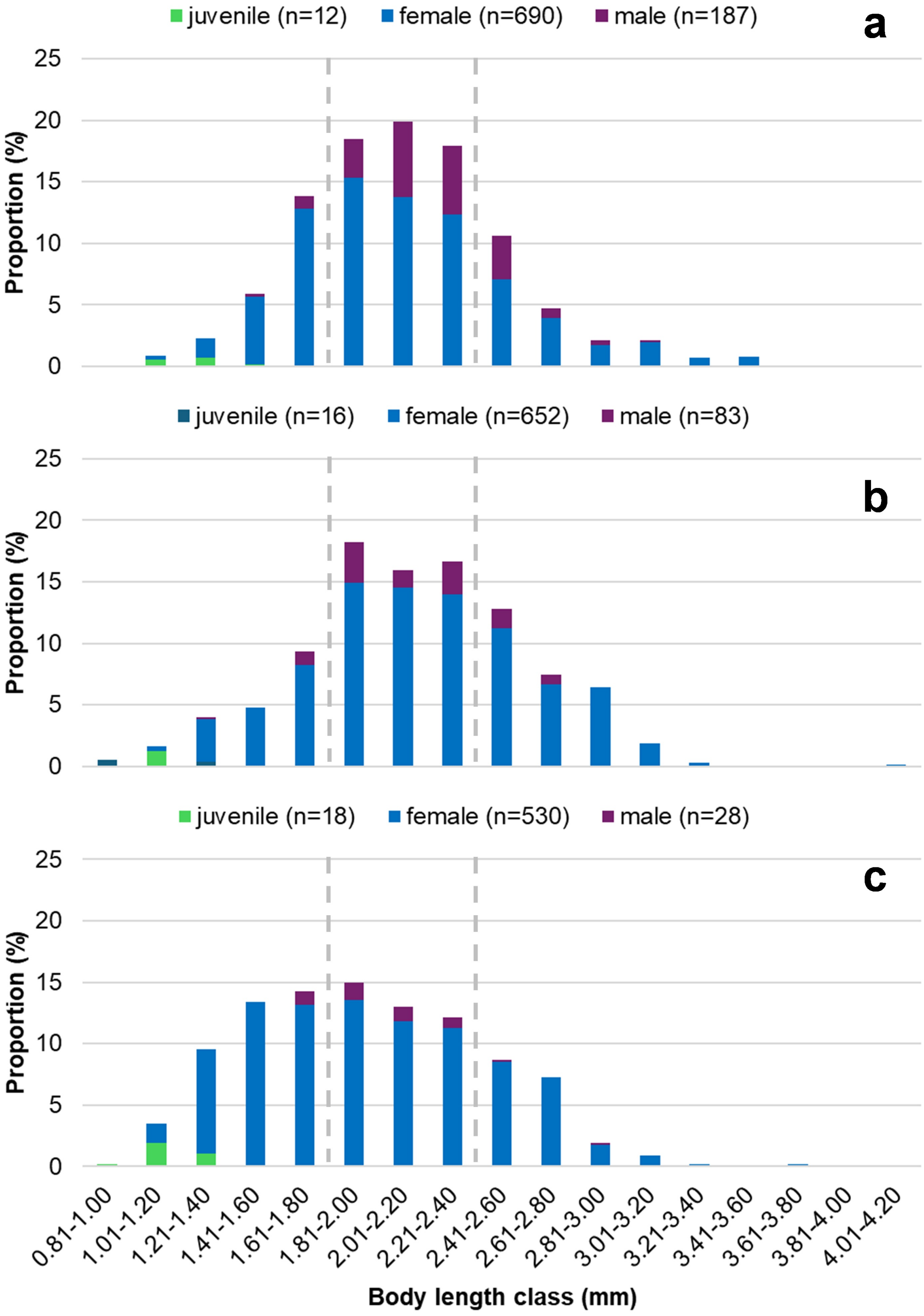

Figure 9. Proportion of juveniles, females and males of *Sinelobus vanhaareni* in body length classes for three months, i.e. July 2019 (a), August 2019 (b) and October 2019 (c); n – number of individuals.

Table 1. Length range in female and male *Sinelobus vanhaareni* from different locations in Europe.

Female length (mm)			Male length (mm)	Site	Reference
All	Pre-ovigerous	Ovigerous			
–	1.9–2.0	1.7–2.7	1.5–2.7	North Sea	Bamber (2014) van Haaren and Soors (2009)
0.9–3.3	–	1.5–2.8	1.6–2.4	Thames Estuary	Ashelby (2022)
1.77–3.27	–	1.77–2.49	1.75–2.77	French Atlantic coast	Gouillieux et al. (2026)
1.1–4.1	1.7–3.5	1.7–3.4	1.3–3.1	Baltic Sea	present study

Table 2. Length and number (n) of analysed females as well as the number of embryos and in selected tanaid species; a and b refer to coefficients (slope and intercept, respectively) in the linear relationship between the number of embryos and the length of females.

Species	n	Female length (mm)	Embryo number		a	b	Reference
			range	mean ± SD			
Zeuxo holdichi	89	2.6–4.0	5–89	24 ± 17	18.70	−24.11	Dauvin et al. (2023)
Tanais dulongii	50	2.7–5.8	–	39 ± 15	17.52	−36.35	Rumbold et al. (2015)
Sinelobus stanfordi	64	2.1–4.3	5–37	18 ± 8			Ferreira et al. (2015)
Sinelobus vanhaareni	58	1.9–3.3	8–54	23 ± 10	26.54	−43.04	present study

of reproductive success (Masunari, 1983; Messing, 1983). The largest individual of *S. vanhaareni* analysed was a non-reproductive adult female, as were *Chondrochelia dubia*, *Monokalliapseudes schubarti* and *Nototanais antarcticus* (Błażewicz-Paszkowycz, 2001; Leite et al., 2003; Pennafirme and Soares-Gomes, 2009; Alves et al., 2023). This may be explained either by a progressive decline in growth with age or multiparity in *S. vanhaareni* females, which has also been suggested in the case of other tanaids (e.g., *S. stanfordi*, *H. oerstaedii*, *C. dubia*, *T. dulongii*, *Tanais tinhauae*), where an overlap in size between non-reproductive and ovigerous females has also been observed (Bückle Ramirez, 1965; Johnson and Attramadal, 1982; Toniollo and Masunari, 2007; Rumbold et al., 2014; Leite et al., 2003; Alves et al., 2023).

The larger size of females compared to males of *S. vanhaareni* may also result from a shorter lifespan or fewer moults of the opposite sex, which has also been observed in other tanaids (Bückle Ramirez, 1965; Toniollo and Masunari, 2007; Rumbold et al., 2012). Males of *S. vanhaareni* are also characterised by higher mortality, as indicated by t he female-biased sex ratio. The dominance of females over males in this species is greater than in some other tanaids, e.g. in *S. stanfordi* (2.3:1), *M. schubartii* (2.7:1) or *Z. holdichi* (4.3:1) and lower than in *C. dubia* (17:1) (Leite et al., 2003; Ferreira et al., 2015; Alves et al., 2023; Dauvin et al., 2023). Furthermore, the female-biased sex ratio in *S. vanhaareni* increased in subsequent months, reaching very high values in October, when males accounted for only 5% of individuals of both sexes. Such seasonal changes in the dominance of females over males were also observed in populations of other species, e.g. *Z. holdichi*, where the sex ratio increased from less than 4.0:1 in April–August to 10.9:1 and 12.6:1 in November and December, and a maximum of 13.1:1 in February (Dauvin et al., 2023). Apart from the shorter lifespan of males, the most likely explanation for their low proportion in the *S. vanhaareni* population compared to other species seems to be a higher mortality rate caused by aggressive behaviour resulting from competition for females or by predation pressure when leaving the tubes to search for females (Borowsky, 1983).

Since juveniles of *S. vanhaareni* were present as early as July and then remained with ovigerous females throughout the entire study period, it can be concluded that breeding of this species in the southern Baltic Sea lasts at least from June to October. Similar observations were made in northern parts, i.e. in Finnish waters, where ovigerous females were observed from July to September, but no sampling was carried out outside this period (Gangon et al., 2022). Ashelby (2022), who studied *S. vanhaareni* from the tidal River Thames, also found ovigerous females in August 2019 and 2020, but not in April 2019. The higher proportion of males together with pre- and ovigerous females indicates greater reproductive activity of *S. vanhaareni* in early summer compared to early autumn. Unfortunately, the lack of data for the entire year makes the picture of reproduction of this species incomplete. It seems very likely that reproduction of *S. vanhaareni* does not occur or is very limited during colder periods of the year. On the other hand, Brzana and Janas (2025) recorded *S. vanhaareni* on artificial substrate at a shallow depth (2 m), still at high densities in April 2016 (on average above 6,000 ind. m^{-2}) and lower densities (on average about 1,500 ind. m^{-2}) in November 2016. In addition to the fact that low temperatures are not conducive to the growth and development of many invertebrates inhabiting the shallow waters of the southern Baltic Sea (Sokołowski et al., 2017), reduced food resources (e.g. bacteria, microalgae) may also be a factor. The native tanaid *H. oerstedii* inhabiting the same region (Gulf of Gdańsk, southern Baltic Sea) reproduces mainly in late spring and late summer, ceasing in winter and early spring (Jażdżewski, 1969). Furthermore, two generations have been reported in this species, i.e. the first reproducing in late spring by overwintering individuals and the second, produced by the first generation in late summer (Bückle Ramirez, 1965). The dominance of medium-sized individuals in *S. vanhaareni* in July, along with an increased proportion of the largest individuals in August, may reflect a generation of overwintered individuals that reproduced in the summer. In contrast, the significant increase in the proportion of small individuals in October likely indicates the recruitment of a new generation resulting from summer reproduction. It is therefore interesting to see whether *S. vanhaareni* also exhibits bivoltinism, which allows for double exploitation of favourable conditions, or whether, as suggested by Dauvin et al. (2023), being a tanaid from a temperate environment, it has only one cohort and one age group per year, i.e. it exhibits univoltinism. Unfortunately, without complete data on its life history, this interpretation should be treated as a hypothesis.

The fecundity of the studied *S. vanhaareni* females is very similar to that recorded in this species from the French Atlantic coast by Gouillieux et al. (2026), who analyzed the marsupial content of only three brooding females of 2.18–2.49 mm length, obtaining 14–21 eggs per marsupium. It is also worth emphasising that females of *S. vanhaareni*, despite their small size range, had on average more or a similar number of embryos in their marsupial pouch compared to females of the larger *S. stanfordi* and *Z. holdichi*, respectively (Table 2). Furthermore, the slope coefficient in the linear relationship between the number of embryos and female length reaches the highest value in *S. vanhaareni* compared to other species, e.g. *Z. holdichi* and *T. dulongii* (Table 2). This indicates the greatest increase in the number of embryos in the marsupial pouch with changes in the female's body length. Based on the intercepts and slopes for the linear relationship between the number of embryos and female length (Table 2), it can be concluded that a 3 mm long *S. vanhaareni* female will carry as many as 37 embryos in its marsupium, whereas females of *Z. holdichi* and *T. dulongii* will carry only 32 and 16 embryos, respectively.

The results of this study also show that *S. vanhaareni* has the ability to rapidly colonise submerged surfaces, similarly to other tanaids, e.g. *Z. holdichi* from the coastal waters of northern France (Dauvin et al., 2023). However, while dense populations of *S. vanhaareni* were observed just six weeks after the fouling plates were submerged, it took four months for the latter species. The short time needed to colonise a hard substrate may be due to the large number of *S. vanhaareni* in the marina in Gdansk, where many different submerged artificial surfaces (piers, boat hulls, etc.) create a perfect habitat for fouling communities. Furthermore, recent research shows that *S. vanhaareni* prefers artificial substrates to natural ones, especially at shallower depths (Brzana and Janas, 2025). It is highly likely that in these studies, tanaids were attracted not only by the type of substrate but also by new food sources, i.e. microfouling (bacteria and diatoms), which usually appear within a few hours of immersion in water. Although its swimming ability is limited, short-distance movements or drifting from nearby underwater structures enable *S. vanhaareni* to reach new substrates, while its curved and strongly developed claws on pereopods 4–6 enhance its attachment capability (Bamber, 2014; Dauvin et al., 2023).

The density of *S. vanhaareni* did not vary throughout the study period, which is not surprising given that it covered the growing season with optimal conditions for growth and reproduction. Interestingly, the maximum recorded density was almost five times lower than that recorded in 2014 on PVC plates submerged in the Port of Gdynia (Brzana et al., 2019). However, this was shortly after the first record of this species in Poland, so the population could have been in an expansion phase characterised by a strong increase in size, whereas after a few years, it entered a phase of stability with fluctuations in size (Geburzi and McCarthy, 2018). Regardless of this, the maximum recorded density of *S. vanhaareni* was three times lower than that of the closely related *S. stanfordi* (3,200 ind. m^{-2}) from the vegetated bottom and more than twice lower than that of other species from the temperate zone, e.g. *Z. holdichi* (21,120 ind. m^{-2}) inhabiting artificial substrates (blocks) or Apseudopsis latreillii (23,000 ind. m^{-2}) living on soft bottoms (Ambrosio et al. 2014; Ferreira et al. 2015; Dauvin et al., 2020, 2023). However, the density of *S. vanhaareni* may have been underestimated by about half due to the calculation method, which was based on the total area of the PVC plate (upper and lower), even though there were significantly more individuals on the upper surface than on the lower one (A. Stępień, pers. obs.). In addition, the use of a 1 mm mesh sieve could have led to an underestimation of the results, as it did not capture all juveniles. However, the use of a sieve with a smaller mesh of 0.5 mm also does not guarantee the collection of juveniles, as reported by Dauvin et al. (2023). These authors hypothesised that the low number of juveniles may also be due to their settling on sediments or substrates near the artificial substrates used for the study.

Our findings show that *S. vanhaareni* exhibits adaptations for rapid establishment of a large and stable population (with a high proportion of medium-sized individuals capable of reproduction) within fouling communities. This is facilitated, among other things, by a large number of medium-sized individuals in the population, especially females, which may be multiparous and which, despite their relatively small size, produce a large number of offspring. However, since the results analysed in this work were obtained based on the material collected for other studies, further research on the biology and ecology of this species is necessary, covering the entire year, especially due to its establishment in environments diversified in terms of environmental factors.

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Supplementary material

Supplementary material associated with this article can be found here.

CRediT authorship contribution statement

Monika Normant-Saremba: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft. Joanna Hegele-Drywa: Investigation, Writing – review & editing. Radosław Brzana: Investigation. Writing – review & editing. Marta Gellert: Writing – review & editing. Michalina Ścibik-Murawska: Investigation. Anna Stępień: Methodology, Writing – review & editing. Magdalena Błażewicz: Methodology, Writing – review & editing.

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Conflict of interest

None declared.

Data availability

Data will be made available on request.

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