Chapter 7
Invasive Species *Palaemon Elegans* Rathke, 1836, (Caridea: Palaemonidae) as the Only Species of Palemon Shrimps in Water Bodies of the Kaliningrad Region

S. A. Sudnik and Yu. E. Egorova

Abstract Globalization of the problem of the introduction of aquatic organisms apparently necessitates monitoring of the state of their fauna and primarily in open water bodies. For the first time, this study has assessed the species diversity of shrimp from the genus Palaemon in water bodies of the Kaliningrad region, which is relevant due to the ecological plasticity known for a number of species that promotes their successful dispersal and acclimatization. Palaemon elegans is known to have lived in this region since about 2000; Palaemon adspersus, Palaemon macrodactylus, and Palaemon varians, recorded in waters of Germany and Poland, are potential invaders into water bodies of the region, and their invasion has not been previously estimated. Species identification of 2498 individuals collected in the study water bodies in 2006–2018 revealed only one species—Palaemon elegans Rathke, 1836; the structure of the mandibles was an unambiguous distinguishing character for its identification; a number of other characters varied. The identified sporadic individuals (0.3%) with a two-segmented mandibular palp, which exhibited unusual combinations of other characters, were referred to as atypical representatives of P. elegans. Invasive P. elegans was currently the only palemon species in waters of the Kaliningrad region. An additional analysis of taxonomically important plastic and meristic characters of the structure of the rostrum, pereopods 2, and mandibles performed for 300 individuals of the species specified the diagnosis of Palaemon elegans Rathke, 1836, from water bodies of the Kaliningrad region. Now, it takes into account the morphological variation in shrimp from the southeastern Baltic Sea and the Kaliningrad Bay.

Keywords Invaders southeast · Baltic · Kaliningrad bay · Shrimp

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7.1 Introduction

Shrimp of the Palaemon genus are widespread in the World Ocean and belong to the family Palaemonidae, the leader among invasive species (Burukovsky 2017). Rockpool shrimp, Palaemon elegans Rathke, 1836, is an invasive species with a wide range due a high degree of eurybionticity (tolerant to salinity of 2–45 ‰, temperature of 2–25 °C), a wide food spectrum (benthophage, detritophage, necrophage), and planktonic larva. Having penetrated in the East Atlantic, the species invaded the Baltic, Mediterranean, Black, and Azov seas; it has been recorded in the Caspian and Aral Seas, the Suez Canal, the Red and Arabian Seas, and the Persian Gulf (Katajisto et al. 2013; CABI 2021). In 2010, P. elegans was found in the Western Atlantic (MIT Sea Grant College Program2010). Shrimp are found in the diet of fish, including commercial fish (European eelpout, round goby, flounder, cod) (Gruszka and Więcaszek 2004). It is an object of commercial and amateur fishing (European… 2021). Until the 1990s, the species was recorded in the western Baltic Sea (Köhn and Gosselck 1989), but in the early 21 century, probably due to human introduction, it widely spread in the southern and the northeastern Baltic Sea (Janas and Tutak 2014). Successful acclimatization of P. elegans in new water bodies and food competition may be accompanied by the displacement of native palemon species, as it happened in waters of Germany and Poland (Grabowski 2006). In 2000–2001, the species was first encountered in the Kaliningrad Bay and the southeastern Baltic Sea (Ezhova 2009), where it is now abundant. A number of studies report the aspects of P. elegans biology (Tsigvintsev 2008; Ezhova 2009; Burukovsky 2012; Gusev 2012; Miroshnichenko 2018; Sudnik and Egorova 2019). Three more species (Palaemon adspersus Rathke 1836, Palaemon macrodactylus MJ Rathbun 1902, and Palaemon varians (Leach 1814)) confined to waters of Germany and Poland (González-Ortegón 2006; Janas and Tutak 2014) could invade waters of the Kaliningrad region; however, no special studies of the palemon fauna in the region have been performed. Data on biodiversity and distribution of hydrobionts are of huge significance in developing monitoring programs for alien species to manage water systems. We assessed taxonomically significant plastic and meristic characters for 2498 shrimps from the southeastern Baltic Sea and the Kaliningrad Bay and found an almost absolute predominance of Palaemon elegans Rathke, 1836. Individuals with a two-segmented mandibular palp (0.3%) that exhibited unusual combinations of other characters were referred to as atypical representatives of P. elegans; the mandible structure was an unambiguous character for species identification. Invasive P. elegans is currently the only palemon species in waters of the Kaliningrad region.

7.2 Materials and Methods

The aim of this study was to analyze the species diversity of shrimp Palaemon spp. in waters of the Kaliningrad region. Material: 2498 palemon individuals collected

by the authors and employees from Kaliningrad State Technical University in 2006–2018 using a shrimp dredge (1 m wide, 0.5 m vertical opening, 5 mm mesh) in the southeastern Baltic Sea, and with an ISO 10870:2012 hydrobiological landing net (0.5 mm mesh) (Table 7.1) in the Kaliningrad Bay; fixation with 8% formaldehyde solution. For species identification, a key was used (Burukovsky 2017) with the diagnoses of the species taken from data by (Köhn and Gosselck 1989), who described them for shrimp from water bodies in Germany.

Species identification of 2498 individuals (Table 7.2: general analysis) was performed with regard to the species characters: the rostrum size, the distribution of teeth on its sides, the structure of the mandible palp, cheliferous legs (pereopods 2). For identification of species Palaemon elegans, the following diagnosis was used: the rostrum is straight or slightly curved upward; the maximum width of its ventral surface is greater than that of the dorsal one; the rostrum length is approximately equal to the carapace length, its distal end does not extend beyond the distal edge of scaphocerites, it is bifurcated; the rostrum dorsal side with 7–10 (usually 8–9) teeth, of which 3 (rarely 2) are located on the carapace behind the eye orbit; the underside of the rostrum with 3–4 teeth; mandibles with a two-segmented palp; in pereopods 2, carpus are longer than merus and shorter than propodus; the dactylus length is 0.4 of the manus length.

For 300 individuals identified as Palaemon elegans, additional analysis was performed (Table 7.2) to specify the diagnosis of the species from water bodies of the Kaliningrad region. It included assessment of a number of plastic and meristic characteristics of the structure of the rostrum and pereopods 2. An MBS-10 binocular micrometer with an accuracy of 0.01 mm was used to measure the length of the exoskeleton segments (see Fig. 7.1): carapace (CL; from the lower edge of the eye

Table 7.1 Palemon shrimp material

Collection period, year	Water body	Depth, m	Number of individuals, ind.	
			General analysis	Additional analysis
2006—2018	Kaliningrad Bay, vistula spit, kosa VILL	0.1–0.5	2171	237
2009	Baltic sea, Kulikovo VILL	1.0–1.5	81	
2010, 2014, 2015	Baltic sea, Rybachy VILL, Donskoye VILL	0.1–1.0	246	63
Total			2498	300

Source Compiled by the authors

Table 7.2 Results of species identification of palemon shrimp from water bodies in the Kaliningrad region

Collection period, year	Water body	Number of individuals, ind. (% in harvest)	
		Typical representatives of *Palaemon elegans*	Atypical representatives of *Palaemon elegans*
2006–2013, 2018	Kaliningrad bay	1302	–
2015, 2016		864	5 (0.9%)
2009	Baltic sea, Kulikovo settlement	78	3 (3.8%)
2010, 2014, 2015	Baltic sea, Rybachy settlement, Donskoye settlement	246	–
Total		2490 (99.7%)	8 (0.3%)

Source: Compiled by the authors

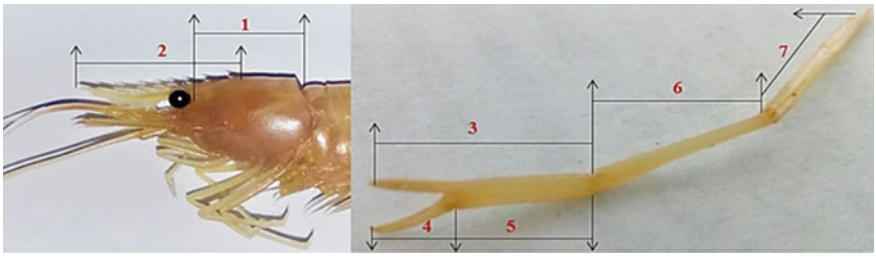

Fig. 7.1 Measuring the length of shrimp exoskeleton segments (orig.): 1—carapace; 2—rostrum; pereopods 2: 3—propodus; 4—dactylus; 5—manus; 6—carpus; 7—merus (orig.)

orbit to the middle of the posterior carapace edge), rostrum (LR; from the end of the rostrum to the eye orbit; the procedure for measuring the length of pereopods 2 segments (propodus (Lp), manus (Lm), dactylus (Ld), carpus (Lc), merus (Lmer)) is shown in Fig. 7.1. The analysis of the rostrum structure assessed the variability in its size (variations in the LR / CL index), data on the number of teeth on the rostrum and their distribution on its dorsal and ventral sides, which was expressed by formula (1) compiled by the authors based on the description of the rostrum structure in the diagnosis of P. elegans:

$$x + y + z / v \tag{7.1}$$

where x is the number of subapical teeth; y, z are the number of dorsal teeth located before (y) and behind (z) the posterior edge of the eye orbit; v is the number of ventral teeth (see Fig. 7.2).

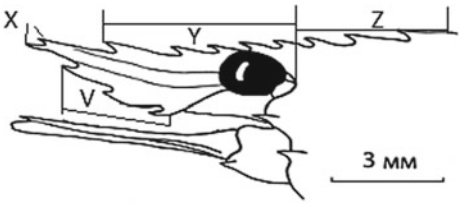

Fig. 7.2 Designations of the teeth in the formula for the rostrum of palemon shrimp (orig.)

The study of the structural features of pereopods 2 assessed the variability in the size of the carpus (relative to the sizes of the propodus and merus using the indices: Lc / Lp and Lc / Lmer) and dactylus (relative to the size of the manus using the index Ld / Lm), in accordance with the diagnosis of the species.

The variation in characters was evaluated by standard statistical methods "Microsoft Office Excel".

7.3 Results

The species identification performed for 2498 palemon individuals from water bodies in the Kaliningrad region revealed virtually absolute predominance of *Palaemon elegans* Rathke, 1837, with characters typical of this species (Table 7.2).

In addition, sporadic individuals (Table 7.2) found in the Baltic Sea in 2009 and at the entrance to the Kaliningrad Bay in 2015–2016 corresponded to the genus Palaemon (Burukovsky 2017) in appearance, but differed in characters from Palaemon elegans and other palemon species, supposed invaders in water bodies of the region (P. adspersus, P. macrodactylus, P. varians). The rostrum of the shrimp was different in shape and size (the LR/CL index could be less than 0.7), in number (only 6–8 or 12 dorsal teeth), in the pattern of teeth distribution on the rostrum, and in the structure of the claw of pereopods 2 (the length of the dactylus attained 0.7 and more of that of the manus); one individual could exhibit a combination of characters typical of different species. This indicates morphological variation of the studied characters. However, all the individuals had mandibles with two-segmented palps, which refers them to atypical representatives of the species Palaemon elegans.

Description of typical representatives of Palaemon elegans from water bodies in the southeastern Baltic Sea and the Kaliningrad Bay

All the individuals had mandibles with two-segmented palps. Tables 7.3 and 7.4 summarize the results of assessing the variability in the rostrum size (variation in the LR/CL index), and the number and position of teeth on the rostrum (according to its formula). In most of the individuals, the rostrum length was slightly less than that of the carapace; however, the differences found were insignificant (Table 7.3), which correlates with the data obtained for species from Germany (Köhn and Gosselck 1989): "the length of the rostrum and the carapace are approximately equal". The

Table 7.3 Characteristics of the rostrum size in shrimp *Palaemon elegans*

Variability in the relative size of the rostrum	Share of individuals, %	Index LR / CL	
		Range	Mean ± standard deviation
Rostrum length = carapace length	0.3	1.00	–
Rostrum length < carapace length	85.2	0.34–0.99	0.82 ± 0.14
Rostrum length > carapace length	14.5	1.01–1.34	1.06 ± 0.14

Source Compiled by the authors

Table 7.4 Characteristics of the rostrum formula in shrimp *Palaemon elegans*

Rostrum formula	2 + 4 + 3/3	2 + 5 + 2/ 3	2 + 5 + 3/3	2 + 6 + 2/3	2 + 6 + 3/3	2 + 5 + 3/4	2 + 6 + 3/4
Share of individuals, %	47.3	17.9	28.9	3.8	1.2	0.6	0.3

Source Compiled by the authors

number of dorsal teeth (including 2 permanent subapical teeth) attained 9 in 65.2% of the total number of individuals, 10 in 33.3% of the individuals, and 11 in 1.5% of the individuals. The number of teeth located before the posterior edge of the orbit amounted to 4 and 5 in 47% of the individuals, and 6 in 5% of the individuals. The number of teeth behind the posterior edge of the orbit amounted to 3 in the majority (78%) of shrimps, and 2 in the rest (22%) of the individuals. Almost all the individuals (99%) had 3 ventral teeth, and some of them had 4 ventral teeth (Table 7.4).

Table 7.5 presents the results of the analysis of taxonomically significant indices in P. elegans, which show the segment length ratios for pereopods 2. In 85–89% of the individuals, the carpus was longer than the merus and shorter than the propodus (or equal to it); the individuals with the dactylus length less than the manus length dominated (97%). In general, these data were similar to those obtained for P. elegans from water bodies in Germany (Köhn and Gosselck 1989): "the carpus of pereopods 2 is typically longer than the merus and shorter than the propodus; the dactylus is much shorter than the manus."

The structure of the rostrum and pereopods 2 in P. elegans was found to vary, and a number of its specific characters were similar to those of other 3 palemon species that can inhabit this region, therefore, the structure of their mandibles should be assessed to identify palemon species from water bodies of the Baltic Sea basin: a two-segmented palp is an apparent and sufficient character of P. elegans species; the absence of the palp is characteristic of P. varians; in case of a three-segmented palp of mandibles, the remaining characters should be assessed to identify the species: P. adspersus or P. macrodactylus (Burukovsky 2017; Van Couwelaar 2003). Our data

Table 7.5 Characteristics of the structure of pereopods 2 in *Palaemon elegans*

Length ratio of segments for pereopods 2	Share of individuals, %	Index value	
		Range	Mean ± standard deviation
		Lc / Lmer	
Carpus length > merus length	85	1.02–1.23	1.15 ± 0.04
Carpus length < merus length	15	0.87–0.98	0.94 ± 0.08
		Lc / Lp	
Carpus length ≤ propodus length	89	0.41–1.00	0.75 ± 0.19
Carpus length > propodus length	11	1.03–1.50	1.15 ± 0.19
		Ld / Lm	
Dactilus length ≤ manus length	97	0.18–1.00	0.50 ± 0.22
Dactilus length > manus length	3	1.06–1.55	1.26 ± 0.24

Source Compiled by the authors

specify the diagnosis of species Palaemon elegans Rathke 183 from water bodies in the Kaliningrad region: mandibles with a two-segmented palp; rostrum length is 0.86–1.06 of the carapace length, its distal end does not extend the distal edge of scaphocerites, 2 subapical teeth, 9–11 (typically 9–10) teeth on the dorsal side, of which 3 (rarely 2) teeth are located behind the eye orbit, 3 (rarely 4) teeth on the ventral side. In pereopods 2, the carpus length is 1.15 ± 0.04 of the merus length and 0.75 ± 0.19 of the propodus length; dactylus length attains 0.50 ± 0.22 of the manus length.

7.4 Discussion

Globalization of the problem of species introduction and extensive transportation communication between the countries of the Baltic region necessitate regular monitoring of the fauna of palemon shrimp in water bodies of the southeastern Baltic. At present, the invasive species Palaemon elegans Rathke, 1836, is the only species from the genus Palaemon in water bodies of the Kaliningrad region. The prerequisites for dispersal of new species (primarily P. adspersus, P. macrodactylus, and P. varians) in water bodies of the region include their high tolerance to a wide range of temperature and salinity, hypoxic conditions (Grabowski 2006; Janas and Tutak 2014), and parental care behavior, which enhance their survival, dispersal and acclimatization capacity. Dispersal of these species in water bodies of the Kaliningrad region can be

restrained by narrower limits of the tolerance to environmental conditions in their larvae, the confinement of adults to certain soils. We have elaborated the basis for a biometric passport for the species Palaemon elegans from the southeastern part of the Baltic Sea and the Kaliningrad Bay; the above-mentioned interspecific differences will facilitate and simplify the identification of shrimp species from the genus Palaemon, and will help assess the invasion pathways of species and analyze populations. Further studies into various aspects of the rockpool shrimp biology are of relevance, since it is sufficiently eurybiontic to the whole range of conditions, significant for the detrital food chain and for the diet of a number of commercial fish, and an object of recreational fishing.

7.5 Conclusion

The invasion of new species into the established hydrocenoses is an urgent problem in theoretical and applied hydrobiology. The species identification of shrimp from the genus Palaemon collected in the coastal waters of the southeastern Baltic Sea and the Kaliningrad Bay in 2006–2018 confirmed the presence of only Palaemon elegans Rathke, 1836, out of four palemon species that can be found in these waters. The species inhabited these waters in the late 1990s, and now it is widespread along the coast of the region. Its successful dispersal and acclimatization in the Baltic Sea are facilitated by its high tolerance to salinity and temperature, a wide food spectrum with the dominance of plant detritus that is abundant in coastal waters, and the ability of its larvae to withstand low salinity of the desalinated waters in the Baltic Sea and the Kaliningrad Bay. This helps the species to occupy new territories, to displace and replace other species in competition for food and in unstable shallow-water conditions of the littoral zone, and makes it an interesting model object for complex studies of invasive and ecological processes in hydrobiocenoses and a candidate for coastal aquaculture.

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