Evadne anonyx G. O. Sars, 1897 – the first record of this Ponto-Caspian cladoceran in the Gulf of Gdańsk (Baltic Sea)*

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Abstract

Evadne anonyx, a new invasive Ponto-Caspian species, was detected for the first time in the Gulf of Gdańsk in the summer of 2006. Seven years probably elapsed from the first record of *E. anonyx* in the Baltic Sea (Gulf of Finland) to the first one in the Gulf of Gdańsk. Although the species was found at 10 out of 13 stations in rather low densities (not exceeding 6 indiv. m^{-3}), all the developmental stages of *E. anonyx* were present (juveniles as well as adults – parthenogenetic females, gamogenetic females and males) in the plankton material investigated.

1. Introduction

The introduction of alien species intensified during the second half of the 20th century. As a consequence, biological invasions on a global

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scale are currently one of the greatest threats to terrestrial and aquatic ecosystems. These phenomena are dynamic in both time and space (Drake 2009).

Introductions of allochthonous species into the Baltic Sea have been observed for many years (Krylov et al. 1999, Laine et al. 2006, Orlova et al. 2006, Rodionova & Panov 2006, Antsulevich 2007, Bielecka & Mudrak 2010, Jaspers et al. 2011, Zaiko et al. 2011). Within the zooplankton, three new invasive species of Cladocera and one ctenophoran have been recorded in the last 25 years (Bielecka et al. 2000, Rodionova et al. 2005, Rodionova & Panov 2006, Janas & Zgrundo 2007). Cladocera make up a significant part of the Baltic zooplankton both in numbers and in biomass, especially in summer. Since the early 1990s, the list of cladocerans has been extended by the Ponto-Caspian crustaceans *Cercopagis pengoi*, *Cornigerius maeoticus* and *Evadne anonyx* (Ojaveer & Lumberg 1995, Krylov et al. 1999, Panov et al. 1999, Rodionova et al. 2005, Rodionova & Panov 2006). In the Polish coastal zone, and that includes the Gulf of Gdańsk, only *C. pengoi* has been recorded so far (Bielecka et al. 2000, Duriš et al. 2000, Bielecka et al. 2005, Olszewska 2006, Bielecka & Mudrak 2010).

Evadne anonyx is an endemic species from the Ponto-Caspian basin (Mordukhai-Boltovskoi 1995). Its author classified it among the Caspian Polyphemoidae, which make up the Podonidae group. This marine species, originating from the tertiary period, occurs in shallow water plankton (Mordukhai-Boltovskoi 1995). The environmental preferences of *E. anonyx* from the Caspian Sea were described by Aladin (1995), who stated that the salinity and temperature tolerance ranges for *E. anonyx* were from 4 to as much as 30 PSU and from 11.4 to 26.4°C respectively. That author found that this species, which used to be more widespread, was forced to abandon the Aral Sea because of increasing salinity, and the Sea of Azov and Black Sea because of growing contamination.

The first published report of *E. anonyx* in the Baltic Sea, from the Gulf of Finland, related to August 2004 (Litvinchuk 2005). According to Rodionova & Panov (2006), however, the first specimens of this species were found in the Primorsk oil terminal area in the Gulf of Finland four years earlier. This information was again corrected, this time by Põllupüü et al. (2008), who found that *E. anonyx* had been observed in the central Gulf of Finland (Tallinn Bay) as early as 1999.

The aim of the present work was to report the first signs of the invasion of the Gulf of Gdańsk by *E. anonyx* G. O. Sars 1897 and to describe the extent of its range there in 2006.

2. Material and methods

Plankton material was collected in the Gulf of Gdańsk from February to December 2006. The samples were taken from the eastern (Krynica Morska profile – K1–K4, Świbno profile – Sw2–Sw4) and western (Mechelinki station – M2, Sopot profile – So1–So4 and J23) parts of the gulf (Figure 1, Table 1). Hauls were made to a maximum depth of 40 m using a closing Copenhagen plankton net (mesh size 100 μm) from the vessel 'Oceanograf 2'. The biological material was preserved in 4% formaldehyde solution. The overall zooplankton community analysis was done in the laboratory. All individuals of *Evadne anonyx* were separated according to the characteristics outlined by Rivier (1998): the number of setae on the exopodites of thoracic limbs I–IV – 2.2.2.1 respectively – and the rounded shape of the cauda. All the animals were counted, their developmental stages and sex (based on the contents of the brood pouch and body shape) identified, and measured (only undamaged specimens). The statistical analysis – the correlation coefficient between environmental variables and the abundance of *E. anonyx* – was carried out using Statsoft software STATISTICA v.9.1 (StatSoft, Inc. 2010).

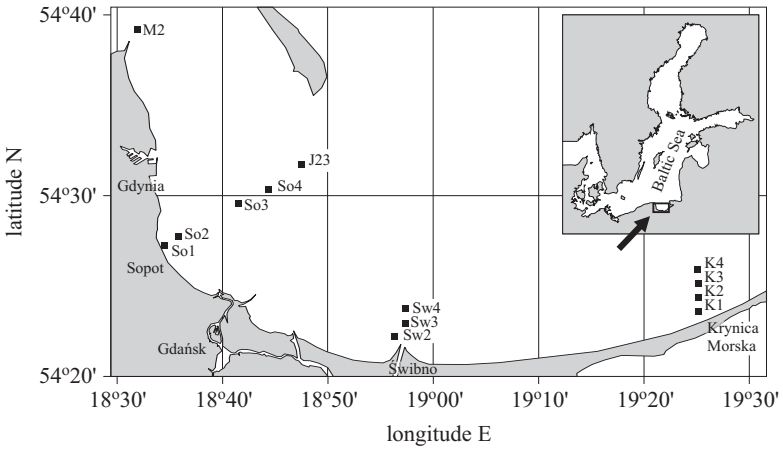

Figure 1. Location of sampling stations in the Gulf of Gdańsk in 2006

3. Results

The first presence of the alien species *Evadne anonyx* (Figure 2) was noted in 2006, when specimens were collected at 10 out of 13 stations in the Gulf of Gdańsk. The species was observed in two months, at the beginning and the end of July, and in the second half of August, in 18 out of 50 hauls made in both months (Table 1). The species was not found at stations

Figure 2. Female of *Evadne anonyx* from the Gulf of Gdańsk (photo by L. Bielecka)

So2 (Sopot profile) and K2 and K4 (Krynica profile). In July and August, the respective abundances of the *E. anonyx* population were 0.33–2.0 and 0.11–6.0 indiv. m^{-3} (Table 1). The highest abundance (6 indiv. m^{-3}) was recorded in the eastern Gulf of Gdańsk, in the surface water (0–5 m) at station K1 (Krynica profile). All the specimens of this cladoceran were found to down to a maximum depth of 20 m (Table 1). In the period when *E. anonyx* occurred, the water temperature ranged from 4.2°C (station J23, August, 20 m depth) to 23.6°C (station So4, July, surface water), and the salinity from 4.6 PSU (stations So3 and So4, July, surface water and 10 m depth) to 7.5 PSU (stations So3, J23 and Sw3, August, 10 and 20 m depth). The maximum abundance was recorded at 19°C and 7.2 PSU (surface water) (Table 1). The occurrence of *E. anonyx* was positively correlated with water temperature using a Pearson correlation coefficient of 0.2891 ($p < 0.05$) (Figure 3). There was, however, no statistically significant correlation between the abundance of this species and the salinity. The *E. anonyx* population included all developmental stages: juveniles, parthenogenetic females, gamogenetic females and males (Table 1). Juvenile specimens were observed mainly in July. In that month they were the only constituent of the population at stations M2, So3 and So4. In August, however, they were found only once at K3 station in the 0–10 m water layer (Table 1). Parthenogenetic females with 2–9 eggs in the brood chamber were recorded at most stations (down to 20 m depth) in both months. Gamogenetic females and males appeared only in August at stations M2, J23 and Sw2 at 0–10 m depth (Table 1). All gamogenetic females carried two resting eggs in their brood chamber.

Table 1. Records of *Evadne anonyx* in the Gulf of Gdańsk in 2006 (July and August), (Stage/Sex: J – juveniles, P – parthenogenetic females, G – gamogenetic females, M – males)

Station	Latitude (N)	Longitude (E)	Date	Water column [m]	T [°C]*	S [PSU]*	Species abundance [indiv. m^{-3}]	Stage/Sex
M2	54°39.0′	18°33.8′	04.07.2006	0–10	22.1–18.5	6.1–6.4	2	J
M2	54°39.0′	18°33.8′	17.08.2006	0–10	18.6–18.5	7.0–7.0	3	J, P, G
So1	54°27.0′	18°34.8′	04.07.2006	0–5	22.5–20.8	6.1–6.1	2	P
So3	54°29.7′	18°43.7′	04.07.2006	0–10	23.2–16.5	4.6–6.9	1	P
So3	54°29.7′	18°43.7′	17.08.2006	0–10	19.3–6.9	6.0–7.5	1	J
So4	54°30.7′	18°46.0′	04.07.2006	0–10	23.6–16.9	4.6–6.9	1	J
J23	54°32.0′	18°48.2′	04.07.2006	0–10	23.1–13.9	5.0–7.1	0.33 (one individual in 3.06 m^3)	P
J23	54°32.0′	18°48.2′	04.07.2006	10–20	13.9–11.4	7.1–7.2	1	P
J23	54°32.0′	18°48.2′	17.08.2006	0–10	19.0–10.7	6.4–7.4	4	P, G, M
J23	54°32.0′	18°48.2′	17.08.2006	10–20	10.7–4.2	7.4–7.5	1	P
Sw2	54°22.6′	18°57.7′	18.08.2006	0–10	19.3–10.4	7.2–7.5	1	P, G
Sw3	54°23.2′	18°58.0′	29.07.2006	0–10	21.8–18.2	6.3–7.1	2	P
Sw3	54°23.2′	18°58.0′	18.08.2006	0–10	19.3–10.5	7.2–7.5	1	P
Sw3	54°23.2′	18°58.0′	18.08.2006	10–20	10.5–9.0	7.5–7.5	0.11 (one individual in 8.7 m^3)	P
Sw4	54°24.8′	18°58.8′	18.08.2006	0–10	19.1–18.2	7.3–7.3	2	P
Sw4	54°24.8′	18°58.8′	18.08.2006	10–20	18.2–5.3	7.3–7.5	0.34 (one individual in 2.94 m^3)	P
K1	54°23.7′	19°26.9′	18.08.2006	0–5	19.0–18.5	7.2–7.3	6	P
K3	54°24.6′	19°26.3′	18.08.2006	0–10	19.4–16.8	7.3–7.3	4	J, P

*The temperature and salinity were measured at the boundaries of the depth of each water layer.

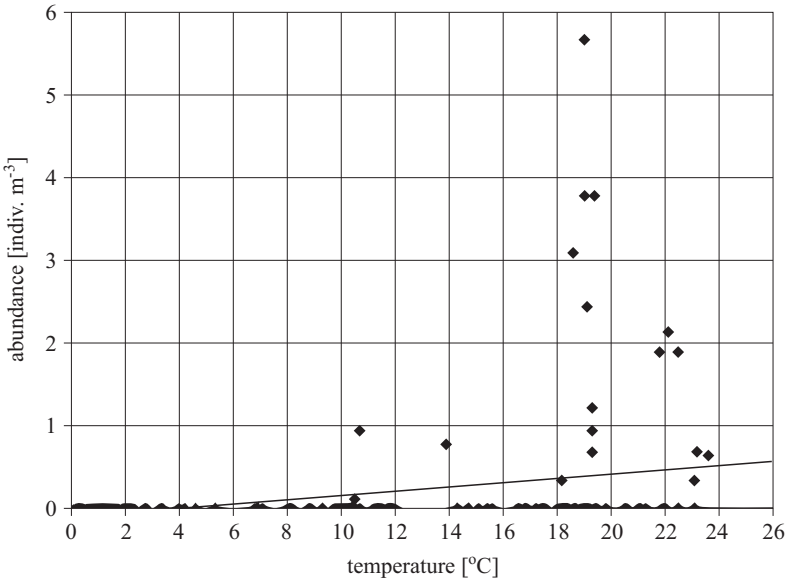

Figure 3. Correlation between the abundance of *Evadne anonyx* and observed water temperature

Table 2. Morphometric data [mm] of *Evadne anonyx* from the Gulf of Gdańsk in 2006

Stage/Sex	N	L_{mean}	SD	H_{mean}	SD
juveniles	10	0.88	± 0.13	0.55	± 0.07
parthenogenetic females	18	0.97	± 0.16	0.62	± 0.15
gamogenetic females	3	1.16	± 0.09	0.77	± 0.02
males	5	0.64	± 0.03	0.39	± 0.01

Representatives of different developmental stages were subjected to morphometric analysis, i.e. body length and height (Table 2). A total of 36 specimens were measured; most of them (18 individuals) were parthenogenetic females. The mean body length and height of particular developmental stages were the following: juveniles – 0.88 mm and 0.55 mm, parthenogenetic females – 0.97 mm and 0.62 mm, gamogenetic females – 1.16 mm and 0.77 mm, males – 0.64 mm and 0.39 mm (Table 2).

4. Discussion

The history of the introduction of *Evadne anonyx* into the Baltic Sea began in 1999 in the Gulf of Finland (Põllupüü et al. 2008). Since then, the species has managed to colonise not only the Gulf of Finland

but also waters farther west (the Gulf of Riga). Its abundance has been gradually increasing – ca ten-fold in six years. The maximum abundance was observed in 2004 (157 indiv. m^{-3}) (Rodionova & Panov 2006), and in 2006 it was 120 indiv. m^{-3} (Põllupüü et al. 2008). The results of the present study demonstrate the further expansion of *E. anonyx*. This Ponto-Caspian species was found in the Gulf of Gdańsk for the first time in July 2006. It was observed in the eastern and western Gulf of Gdańsk down to a maximum depth of 20 m until the second half of August in rather low densities, not exceeding 2 and 6 indiv. m^{-3} in July and August respectively. A similarly low abundance, less than 1 indiv. m^{-3}, and the occurrence of the species in shallow waters was recorded at the beginning of the invasion of *E. anonyx* in the Gulf of Finland (Rodionova & Panov 2006, Põllupüü et al. 2008). We consider it probable that a period of seven years elapsed between the first record of *E. anonyx* in the Baltic Sea and the first one in the Gulf of Gdańsk. This is the same period of time as in the case of the expansion of another cladoceran alien to the Baltic Sea, *Cercopagis pengoi*, which appeared for the first time in the Gulf of Riga in 1992 (Ojaveer & Lumberg 1995) and in the Gulf of Gdańsk in 1999 (Bielecka et al. 2000, Duriš et al. 2000). In addition, at the beginning of its expansion into the Gulf of Gdańsk the *E. anonyx* population seemed to be rather unevenly distributed – it was not recorded at three stations: So2, K2 and K4. A similar trend was observed in the case of *C. pengoi* – initially the species was recorded rather irregularly (Bielecka & Mudrak 2000).

In the eastern Baltic Sea *E. anonyx* is most abundant in summer, in June and July (Rodionova & Panov 2006, Põllupüü et al. 2008). Generally, *E. anonyx* was recorded in the eastern Gulf of Finland at a water temperature of 11–24.5°C and a salinity of 1–3 PSU, with the first specimens appearing at 17–18°C (Rodionova & Panov 2006). However, other results were obtained by Põllupüü et al. (2008), who investigated a larger part of the Gulf of Finland (Tallinn Bay and Narva Bay) and the Gulf of Riga (Pärnu Bay). These authors found that *E. anonyx* was constantly present in the plankton when the water temperature reached 15°C, with its maximum density being recorded at 16–20°C and 12–13 PSU (Põllupüü et al. 2008). In the Gulf of Gdańsk *E. anonyx* was observed somewhat later in the year. It appeared at the beginning of July when the water temperature was 11.4–23.6°C and was present for a shorter period of time – only a month and a half. Its abundance was correlated positively with water temperature. The ranges of water temperature and salinity during the occurrence of this cladoceran were 4.2–23.6°C and 4.6–7.5 PSU respectively. As indicated in an earlier study, *E. anonyx* is a thermophilic species with a wide range of tolerance to salinity (Aladin 1995).

In 2006 the population of *E. anonyx* in the Gulf of Gdańsk included specimens representing all developmental stages. Parthenogenetic females were collected most frequently, during most of the study period, whereas gamogenetic females and males were found only in August. According to Mordukhai-Boltovskoi (1995), *E. anonyx* and other Caspian cladocerans reproduce rapidly by parthenogenesis during summer. The dominance of parthenogenetic females of *E. anonyx* was also observed by Põllupüü et al. (2008) and Rodionova & Panov (2006). In the Gulf of Gdańsk, there were 2–9 eggs in the brood chambers of parthenogenetic females and 2 in the brood chambers of gamogenetic females. Rodionova & Panov (2006) and Põllupüü et al. (2008) reported that the parthenogenetic fecundity for this species was 1–9 eggs/embryos and that the gamogenetic fecundity was 1–2 resting eggs.

With respect to the mean body length and height of this new cladoceran in the Gulf of Gdańsk, the males were the smallest (L – 0.64 mm, H – 0.39 mm) and gamogenetic females were the largest (L – 1.16 mm, H – 0.77 mm). These data are comparable with those of Rodionova & Panov (2006), but the body heights stated in that paper were greater than the body lengths, which conflicts with the body proportions we found for *E. anonyx*. Presumably, lengths and heights were accidentally switched in Rodionova & Panov (2006). If this assumption is correct, then *E. anonyx* from the Gulf of Gdańsk is morphologically similar to its conspecifics from the Gulf of Finland, except for the smaller size of males collected in the Gulf of Gdańsk. However, one should bear in mind that the biometric data for *E. anonyx* from the Gulf of Gdańsk are still rather sparse as only 36 individuals were measured.

Because of the relatively low biodiversity in the Baltic Sea, alien species can probably colonise relatively unsaturated ecological niches rather easily. Many successful invasions have been observed there and some of their effects have been described (Leppäkoski et al. 2002, Ojaveer et al. 2004, Orlova et al. 2006, Põllupüü et al. 2008). Since invasions of alien species to the Baltic Sea are a widespread phenomenon, there is an urgent need for the systematic and comprehensive monitoring of the Baltic Sea environment. This is especially crucial in the case of newly introduced species, such as *E. anonyx*, which require further investigation. Põllupüü et al. (2008) consider that, because of its high reproductive potential, *E. anonyx* could in the future make up a substantial proportion of the diet of planktivorous fish. On the other hand, Rodionova & Panov (2006) suggest that *E. anonyx* could mimic the invasion of the Great Lakes of North America by *Cercopagis pengoi*. We believe it is only a question of time before *E. anonyx* starts to expand its range of occurrence. The appearance of an *E. anonyx* population

in the Gulf of Gdańsk in 2006 could be regarded as an initial stage of its further invasion.

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