



## Establishment of the Ponto-Caspian predatory cladoceran *Evadne anonyx* in the eastern Gulf of Finland, Baltic Sea

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### Abstract

The Ponto-Caspian predatory cladoceran *Evadne anonyx* G.O. Sars, 1897 was first recorded in the eastern Gulf of Finland in the zooplankton samples collected during summer 2000. Most likely, *E. anonyx* invaded the gulf in the late 1990s from the Caspian Sea via the Volga-Baltic waterway through the transport of ballast water of ships. Between 2000 and 2004, the population densities of *E. anonyx* increased in the eastern Gulf of Finland more than 10-fold, indicating successful establishment of the new Ponto-Caspian invader in the Baltic Sea.

**Key words:** onychopods, invasive crustaceans, establishment, *Evadne anonyx*, Baltic Sea, invasion, nonindigenous

### Introduction

The Ponto-Caspian basin is one of the principal donor regions of alien species for the Baltic Sea area. It is currently connected to the Baltic Sea basin by a complicated hydrographic network, where the Volga-Baltic waterway represents the main invasion corridor (Panov et al. 1999). The Gulf of Finland is the terminal upper link of this corridor, and can be considered as one of the most vulnerable areas in the Baltic to the invasions of alien species. For example, during the last two decades, several Ponto-Caspian species of invertebrates and one fish species invaded the Gulf of Finland (Panov et al. 2003, Rodionova et al. 2005, Ojaveer 2006). The most recent Ponto-Caspian invaders to the Baltic, two predatory planktonic cladocerans *Cercopagis pengoi* (Ostroumov) and *Cornigerius maeoticus* (Pengo, 1879) most likely were introduced in the gulf through the transport of ballast water of ships entering Baltic Sea via the Volga-Baltic waterway (Krylov et al. 1999, Panov et al. 1999, Rodionova et al. 2005). In the present study we report the establishment in the eastern Gulf of

Finland of the third representative of the Ponto-Caspian onychopods, *Evadne anonyx* G.O. Sars, 1897 (Crustacea: Cladocera: Onychopoda), a common zooplankton species from the Caspian Sea.

### Methods

Zooplankton samples were collected in the eastern Gulf of Finland every 10–14 days in June–October over nine years (1996–2004) at two stations: at a deepwater (25 m) station in the region of the Primorsk oil terminal (station P1 with geographic coordinates 60°20' N, 28°44' E), and a shallow water (14 m) station near St. Petersburg (station 21, 60°06' N, 29°42' E) (Figure 1). The samples were collected with the use of a quantitative Juday net, 0.21 m in diameter with a mesh size of 100 µm, in three replicates from surface layer (10–0 m). The samples collected were fixed with a 4% formalin solution and subsequently processed under laboratory conditions, including determination of the species composition, abundance and biomass of the zooplankton organisms, and the size and sex structures of the populations of alien species. In addition, water temperature and conductivity was

measured in the surface layer (at depths 0.5 and 10 meters) during each sampling effort.

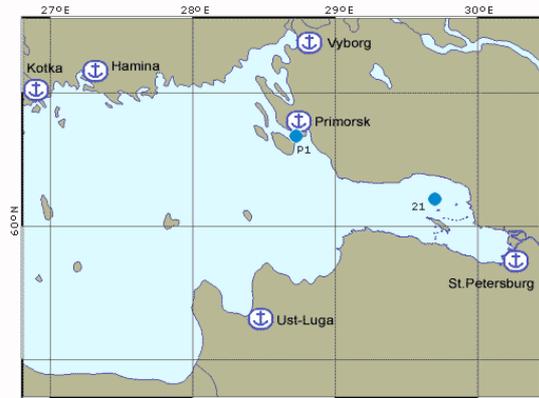


Figure 1. Location of sampling sites in the eastern Gulf of Finland.

## Results

The Ponto-Caspian *Evadne anonyx* was first detected in the Baltic Sea, in a sample collected on July 9, 2000, at the deepwater monitoring station P1 in the Primorsk oil terminal area. This sample included two specimens, a parthenogenetic female (Figure 2) and juvenile. During the remainder of the summer of 2000, parthenogenetic females of *E. anonyx* were present in the zooplankton at low densities (1-6 individuals per cubic meter), while in the late September sample two sexual (gamogenetic) females with resting winter eggs were found (Figure 3).

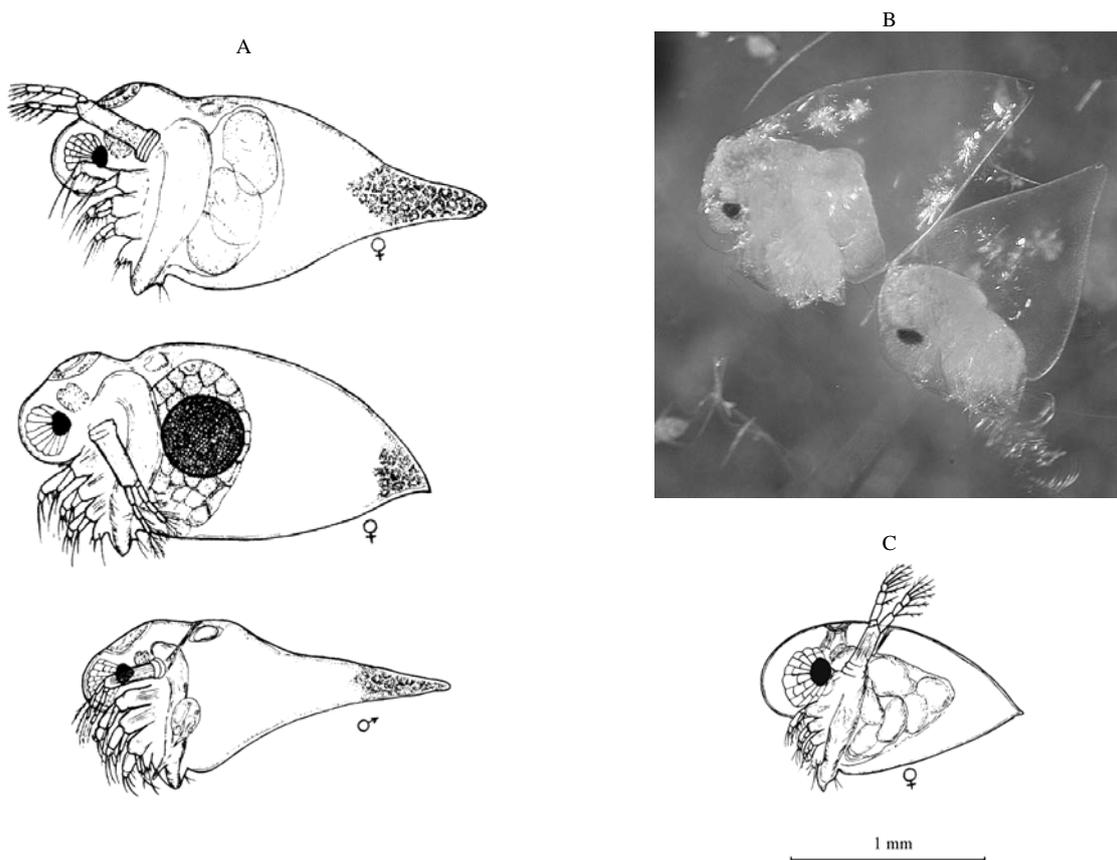


Figure 2. *Evadne anonyx* from the Caspian (A) and the Baltic Sea (B) populations, and *Evadne nordmanni* (C). Drawings of *E. anonyx* from the Caspian and *E. nordmanni* are from Rivier (1998) (modified).

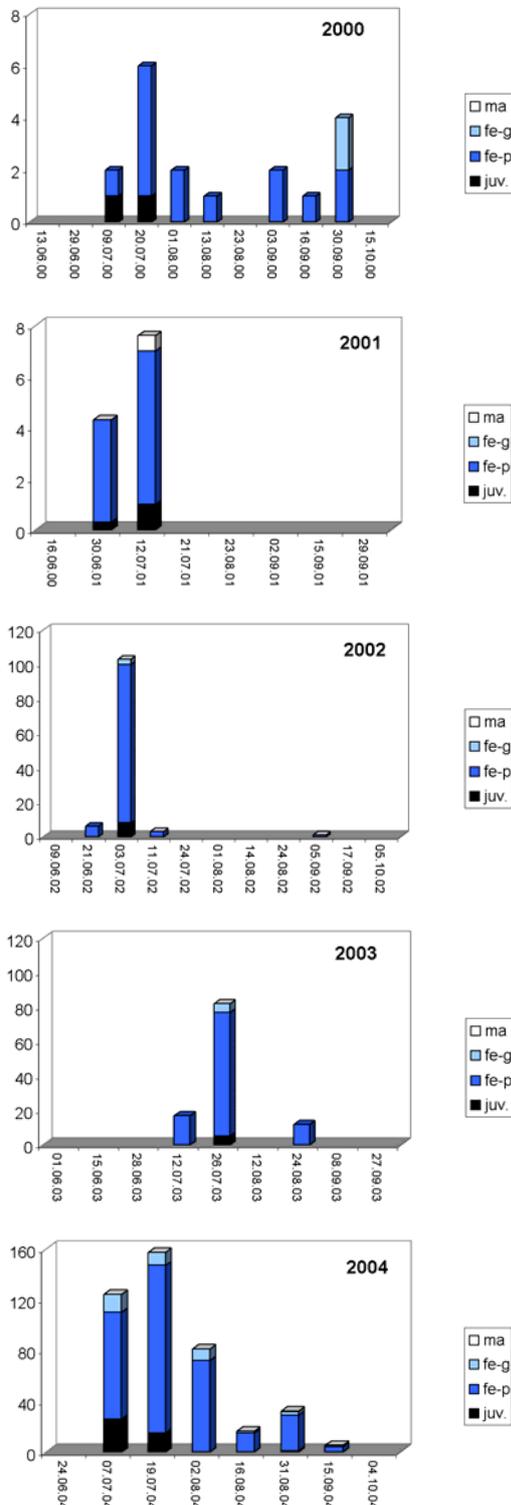


Figure 3. Population dynamics of *Evadne anonyx* in 2000-2004 in the eastern Gulf of Finland, monitoring station P1 (abundance, ind.m<sup>-3</sup>: ma – males, fe-g – gamogenetic females, fe-p – parthenogenetic females, juv. – juveniles).

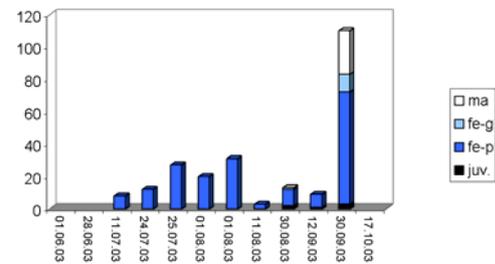


Figure 4. Population dynamics of *Evadne anonyx* in 2003 in the easternmost Gulf of Finland, monitoring station 21 (abundance, ind.m<sup>-3</sup>: ma – males, fe-g – gamogenetic females, fe-p – parthenogenetic females, juv. – juveniles).

The mean body length and height of *E. anonyx* averaged 0.50 and 0.65 mm for juveniles, 0.66 and 1.06 mm for parthenogenetic, 0.65 and 1.08 mm for gamogenetic females, and 0.51 and 0.86 mm for gamogenetic males (Annex 1). Fecundity in the parthenogenetic and gamogenetic females of *E. anonyx* averaged 3.9 (from 1 to 6) and 1.7 (from 1 to 2) eggs per individual, respectively. *E. anonyx* from the studied population were smaller than individuals from the Caspian population, but larger than *Evadne nordmanni* Loven, the congeneric species native for the Baltic (Figure 2).

In 2001, *E. anonyx* was recorded in zooplankton only in late June and July. As in the previous year, they were at low densities of less than 10 individuals per cubic meter. The following year, *E. anonyx* also appeared in late June, and reached peak abundance exceeding 100 individuals per cubic meter in early July. During the remainder of the summer of 2002, *E. anonyx* was absent from the samples, and only a single parthenogenetic female was found in September (Figure 3).

In 2003, *E. anonyx* was recorded at high densities at an additional monitoring station in the easternmost Gulf of Finland, in the vicinity of St. Petersburg (station 21, Figure 1). At this station the species was recorded in zooplankton regularly from July to September, with abundant males and gamogenetic females appearing in late September (Figure 4). During the following year, *E. anonyx* was found at high densities (more than 10-fold increase in abundances compare to 2000-2001) during most of the summer in zooplankton

in the Primorsk oil terminal area, showing both parthenogenetic and gamogenetic reproduction in the summer (Figure 3).

During 2000-2004, *E. anonyx* first appeared in the zooplankton in late June-early July at temperatures between 17-18°C. In the autumn, *E. anonyx* were not found in the zooplankton at temperatures below 11°C. Typically, populations of this species reached maximum densities in July at water temperatures of around 20°C. However, in 2003 at station 21 the highest density of *E. anonyx* was observed in late September (Figure 4). Generally, in the eastern Gulf of Finland *E. anonyx* were found at temperature and salinity ranges of 11– 24.5°C and 1-3 PSU, respectively. Abundance and biomass of *E. anonyx* in the zooplankton for sampling during 2000-2004 are provided in Annex 2.

## Discussion

*Evadne anonyx* is a native species from the Caspian and Aral Seas (though not currently present in the Aral due to increased salinity), and estuarine areas of the Black and Azov seas (Sars 1897, 1902, Behning 1935, 1938; Mordukhai-Boltovskoi and Negrea 1965; Mordukhai-Boltovskoi and Rivier 1987). Because *E. anonyx* is a rare species in the latter areas, it is most likely that *E. anonyx* was introduced to the eastern Baltic directly from the Caspian, where this species is regularly found in the zooplankton. However, genetic analysis of the newly established Baltic populations and of populations from the potential donor areas is needed to confirm this hypothesis.

Unlike other invasive onychopods that have invaded recently the Baltic Sea (*Cercopagis pengoi* and *Cornigerius maeoticus*), *E. anonyx* has no recent invasion history in the Ponto-Caspian basin, and was not among the Ponto-Caspian species previously predicted to invade the eastern Gulf of Finland (see Panov et al. 1999). In the first qualitative risk assessment for Ponto-Caspian invasive onychopods, conducted in late 1990s after invasion of *Cercopagis pengoi* into the Baltic Sea and the North American Great Lakes, Panov et al. (1999) predicted invasions of the Neva estuary (eastern Gulf of Finland) by only two common Ponto-Caspian onychopod species with known invasion histories: *Cornigerius maeoticus* and *Podonevadne trigona*. Indeed, in 2003 *Cornigerius maeoticus* was first recorded in the Neva estuary (Rodionova et al.

2005). However, the first new onychopod invader following the invasion by *Cercopagis pengoi* into the Baltic was *Evadne anonyx*, first recorded in the Primorsk oil terminal area in 2000. Before its invasion in the eastern Baltic, *E. anonyx* was not considered a risk species because it had no invasion history and was not considered capable of living below salinities of 9 PSU (Rivier 1998). According to our data from the eastern Gulf of Finland, *E. anonyx* successfully established in areas with water salinities of 1-3 PSU. Unexpected invasion of *E. anonyx* into the Baltic Sea may indicate that the most common Ponto-Caspian onychopods (*Podonevadne trigona*, *P. camptonyx*, *P. angusta*, *Polyphemus exiguus*, *Evadne prolongata*) might also pose some risk of long-distance transfer if appropriate pathways of introduction become available (such as shipping along the Volga-Baltic waterway).

Taking into account the existence of an invasion corridor from the eastern Baltic Sea to the Great Lakes of North America, which has been showed by the genetic studies for *Cercopagis pengoi* and *Bythotrephes longimanus* (Cristescu et al. 2001, Berg et al. 2002), there is some level of risk of long-distance transfer of *E. anonyx* to North America. Establishment of this species in the Great Lakes is unlikely because *E. anonyx* requires more mineralized water (above 1 PSU), but introduction of *E. anonyx* to estuaries of the North American east coast seems more probable. Although, many cases of freshwater adaptation by brackishwater invaders have been documented (Lee and Bell 1999, Lee 1999).

High levels of sexual reproduction in the Baltic Sea population of *E. anonyx* during the summer (specifically in 2004, see Figure 3) may facilitate both long-distance transfer of *E. anonyx* within and outside Baltic, and its further invasion success in recipient ecosystems, as was the case for invasive *Cercopagis pengoi* (Panov et al. 2004). More than a 10-fold increase in abundances of *E. anonyx* during 2000-2004 indicate successful establishment of new Ponto-Caspian invasive onychopod crustacean in the eastern Gulf of Finland. Consequences of the invasion of this new predatory species for the zooplankton community of the gulf is not clear and require further study.

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## Annex 1

Morphological characteristics of *Evadne anonyx* from the eastern Gulf of Finland (L – length, mm, H – height, mm)

| Stage/sex | N   | Lmin        | Lmax        | Lmean       | Hmin        | Hmax        | Hmean       |
|-----------|-----|-------------|-------------|-------------|-------------|-------------|-------------|
| juv.      | 82  | 0,39(±0,04) | 0,58(±0,05) | 0,50(±0,07) | 0,65(±0,05) | 0,88(±0,06) | 0,80(±0,09) |
| fe-p      | 311 | 0,56(±0,06) | 0,71(±0,09) | 0,66(±0,06) | 0,88(±0,04) | 1,1(±0,05)  | 1,06(±0,1)  |
| fe-g      | 38  | 0,55        | 0,72        | 0,65(±0,09) | 0,95        | 1,1         | 1,08(±0,1)  |
| ma        | 42  | 0,40        | 0,55(±0,06) | 0,51(±0,1)  | 0,69        | 0,88(±0,03) | 0,86(±0,2)  |

ma – males, fe-g – gamogenetic females, fe-p – parthenogenetic females, juv. – juveniles

## Annex 2

Records of *Evadne anonyx* in the eastern Gulf of Finland in 2000-2004\*

| Location        | Geographic coordinates |               | Record date | Species abundance (ind./m <sup>3</sup> ) | Species biomass (mg/m <sup>3</sup> ) | Collector      |
|-----------------|------------------------|---------------|-------------|--|--------------------------------------|----------------|
|                 | Latitude, °N           | Longitude, °E |             |  |                                      |                |
| Gulf of Finland |                        |               |             |  |                                      |                |
| Station P1      | 60.3333                | 28.7333       | 09.07.2000  | 2  | 0.245                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 20.07.2000  | 6  | 0.945                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 01.08.2000  | 1  | 0.226                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 13.08.2000  | 1  | 0.246                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 03.09.2000  | 2  | 0.114                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 30.06.2001  | 4  | 0.656                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 12.07.2001  | 8  | 1.797                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 21.06.2002  | 6  | 1.197                                | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 03.07.2002  | 104                                      | 14.557                               | P.V. Bolshagin |
| Station P1      | 60.3333                | 28.7333       | 11.07.2002  | 3  | 0.488                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 05.09.2002  | 1  | 0.114                                | P.V. Bolshagin |
| Station 21      | 60.1000                | 29.7000       | 11.07.2003  | 8  | 1.592                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 12.07.2003  | 17                                       | 1.786                                | P.V. Bolshagin |
| Station 21      | 60.1000                | 29.7000       | 24.07.2003  | 29                                       | 2.950                                | V.E. Panov     |
| Station 21      | 60.1000                | 29.7000       | 25.07.2003  | 27                                       | 2.700                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 26.07.2003  | 82                                       | 7.546                                | P.V. Bolshagin |
| Station 21      | 60.1000                | 29.7000       | 01.08.2003  | 20                                       | 1.800                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 24.08.2003  | 12                                       | 0.828                                | P.V. Bolshagin |
| Station 21      | 60.1000                | 29.7000       | 30.08.2003  | 12                                       | 1.036                                | V.E. Panov     |
| Station 21      | 60.1000                | 29.7000       | 12.09.2003  | 9  | 0.705                                | V.E. Panov     |
| Station 21      | 60.1000                | 29.7000       | 30.09.2003  | 94                                       | 7.897                                | V.E. Panov     |
| Station 21      | 60.1000                | 29.7000       | 04.07.2004  | 93                                       | 12.881                               | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 07.07.2004  | 124                                      | 16.196                               | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 19.07.2004  | 157                                      | 30.760                               | V.E. Panov     |
| Station 21      | 60.1000                | 29.7000       | 01.08.2004  | 1  | 0.207                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 02.08.2004  | 81                                       | 7.802                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 16.08.2004  | 16                                       | 2.265                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 31.08.2004  | 32                                       | 5.064                                | V.E. Panov     |
| Station P1      | 60.3333                | 28.7333       | 15.09.2004  | 6  | 0.910                                | V.E. Panov     |

\* Full reference to the data: Rodionova NV and Panov VE (2006) Establishment of the Ponto-Caspian predatory cladoceran *Evadne anonyx* in the eastern Gulf of Finland, Baltic Sea. *Aquatic Invasions* 1(1): 7-12