

***Cercopagis pengoi* (Cladocera)
in the Gulf of Finland: environmental variables
affecting its distribution and interaction with
*Bosmina coregoni maritima***

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Abstract. The Ponto-Caspian predatory cladoceran *Cercopagis pengoi* was first found in the Gulf of Finland in 1992. The distribution of the species was followed in 1997–2002 in relation to selected most important abiotic and biotic environmental factors. The abundance of *C. pengoi* was best explained by thermal stratification and density of Cladocera. The significant negative correlations between the vertical distribution of the small cladoceran *Bosmina coregoni maritima* and the abundance of *C. pengoi* indicate that *C. pengoi* affects the vertical distribution of its potential prey *B. c. maritima*.

Key words: *Cercopagis pengoi*, invasion, Baltic Sea, *Bosmina coregoni maritima*.

INTRODUCTION

The invasive living organisms have become one of the most serious threats to the aquatic ecosystems during the last 10–20 years causing unpredictable and irreversible changes in the recipient ecosystems (Carlton, 1996; Ruiz et al., 1999). The transfer of ballast water between ports has served as an important vector, enabling the invasion of many aquatic species to new habitats (Carlton & Hodder, 1995). Taking into account the position of the Gulf of Finland as an active area of international shipping routes and large ports, the high rate of alien species introductions into the gulf and their possible negative impacts on the environment, the Gulf of Finland should be considered as a “hot spot” in the Baltic Sea region.

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The most recent planktonic newcomer in the Gulf of Finland and the whole Baltic Sea is the predatory cladoceran *Cercopagis pengoi*. The species was first observed in the Gulf of Finland in 1992; most likely it was introduced as a result of ballast water releases (Ojaveer et al., 2000). During the second half of the 1990s the species colonized almost the whole Baltic Sea from the north (Bothnian Bay) to the south (Gulf of Gdansk) (e.g., Bielecka et al., 2000; Gorokhova et al., 2000). Unfortunately, there are few data available on the effect of the environment on the dynamics of *C. pengoi* and the impact of the species on the native biota in the Gulf of Finland (e.g. Krylov et al., 1999; Uitto et al., 1999).

The aim of the present study is to relate the distribution of *C. pengoi* to various abiotic and biotic variables and to test whether *C. pengoi* affects the distribution of its potentially essential prey *Bosmina coregoni maritima* in the Gulf of Finland. The study is based on the zooplankton and environmental monitoring data collected in 1997–2002.

MATERIAL AND METHODS

Zooplankton samples were collected under the frame of the Estonian National Monitoring Programme. The strategy and frequency of sampling varied between years. The samples were taken at stations near Tallinn Bay in 1997–2002 and in Narva Bay in 2001–2002 (Fig. 1). The sampling was done fortnightly from March

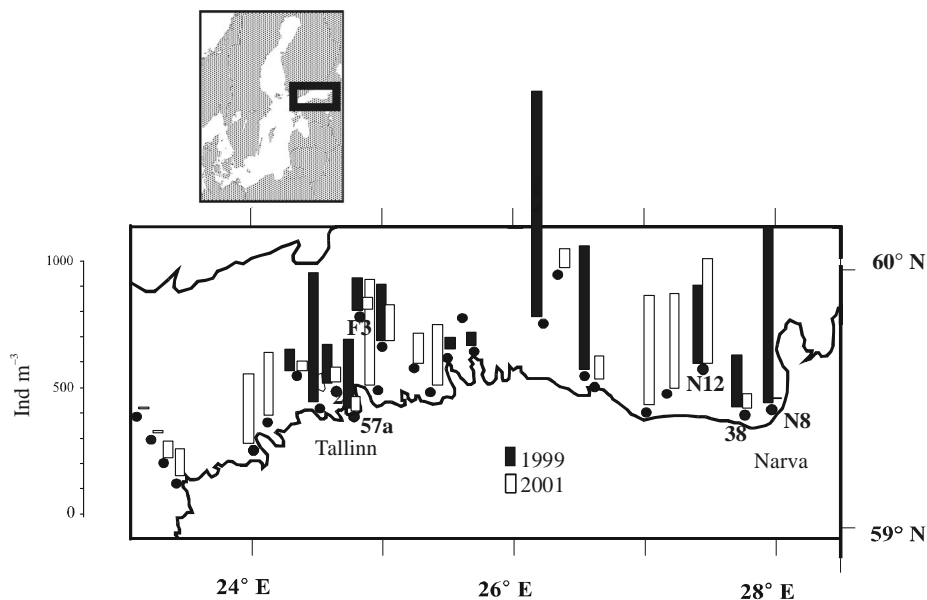


Fig. 1. Location of sampling stations and abundance of *Cercopagis pengoi* (ind m⁻³) in August 1999 and 2001. Frequent sampling was performed at stations 57a, 2, and F3 (Tallinn) and N12, N8, and 38 (Narva).

to August and monthly in September to November. The data on the horizontal distribution of *C. pengoi* in the whole coastal area of the Gulf of Finland were obtained in August 1999 and in August 2001. The samples were collected by means of vertical tows with Juday closing plankton net (mesh size 90 μm , mouth area 0.1 m^2) and preserved in 4% formalin. In order to calculate the abundance of *C. pengoi*, all individuals in a sample were counted.

The effect of *C. pengoi* on the vertical distribution of *B. c. maritima* was studied using samples from July to September 1999 and 2001, i.e. the years of most representative sampling and relatively high abundance of *C. pengoi*. The percentage of the population of *B. c. maritima* above and below the thermocline was calculated.

Additional environmental parameters used in statistical analyses were temperature, salinity measured with CTD, Secchi depth, and chlorophyll *a* measured in integrated water from depths 0–10 m according to HELCOM (1988) recommendations. These parameters were routinely monitored during zooplankton sampling. STATISTICA 6.0 and Primer 5.0 were used for statistical analyses.

RESULTS AND DISCUSSION

The highest density of *C. pengoi* was estimated at 814 ind m^{-3} at the coastal station of Narva Bay in September 2002. Population densities over 700 ind m^{-3} were observed annually since 1999. In 2000, however, the maximum density was only 220 ind m^{-3} . As sampling was ended at the beginning of August and the sampling frequency was relatively low, the potential peak period of the population was probably not observed. No massive occurrence of *C. pengoi* was observed in 1997 and 1998. The average density of *C. pengoi* when present in a sample was 154 ind m^{-3} in 1997–2002. Excluding a few samples taken below the thermocline the average was 190 ind m^{-3} .

Thermal stratification was an important variable for the dynamics of *C. pengoi* (see BIOENV analysis below). The density of the cladoceran increased with rising temperature stratification (e.g., with decreasing wind stress). Differences in thermal stratification may explain the large-scale variability of *C. pengoi* populations in different basins of the Baltic Sea. For example, the southern coastal areas of the Gulf of Finland are hydrodynamically more active than its less exposed northern coasts and the Gulf of Riga. Also, the densities of *C. pengoi* were about 5–10 times higher in the Gulf of Riga and less exposed areas of the Gulf of Finland than at our sampling sites (Uitto et al., 1999; Ojaveer et al., 2004; and this study).

Although the frequency of sampling was relatively low, some conclusions on the seasonal dynamics of *C. pengoi* in the Gulf of Finland can be drawn. The cladoceran was usually first observed at temperatures above 15°C in July. The highest densities were found a few weeks after the initial occurrence. The population disappeared at temperatures below 15°C in September–October. Earlier studies have

also stressed the importance of temperature for the development of *C. pengoi* in the Baltic Sea area (Avinski, 1997; Uitto et al., 1999; Ojaveer et al., 2004). The cercopagids are considered typical warm-water species and the mass occurrence of *C. pengoi* coincides with high water temperature (Ojaveer & Lumberg, 1995; Krylov et al., 1999; Uitto et al., 1999). However, some specimens can be found at temperatures below 10°C, but no mass occurrence at such temperatures has been reported. In some cases *C. pengoi* had two density peaks during the same season. A similar behaviour has been earlier recorded in the Neva estuary (Krylov et al., 1999).

The abundance of *C. pengoi* was best explained by thermal stratification and density of Cladocera (BIOENV Spearman $\rho = 0.543$). There was a significant but weak correlation between the densities of *B. c. maritima* and *C. pengoi* (linear correlation analysis $R = 0.23$, $p < 0.05$).

The two species tend to share the same habitat in the Gulf of Finland. There were only two samples where the abundance of *B. c. maritima* exceeded 1000 ind m⁻³ and *C. pengoi* was not present. The average abundance of *B. c. maritima* in samples with *C. pengoi* was 6600 ind m⁻³. The effect of predatory *C. pengoi* on the potential prey species *B. c. maritima* was estimated by the Spearman correlation product between the abundance of *C. pengoi* and the percentage of *B. c. maritima* above the thermocline. The results revealed that *B. c. maritima* tended to stay below the thermocline at higher abundances of *C. pengoi* above the thermocline ($R = -0.61$, $p < 0.01$). Two BIOENV analyses, one with environmental variables and abundance of *C. pengoi* and the other with abundances of all zooplankton species, were performed to seek the best combination of environmental variables determining the distribution of *B. c. maritima* (Table 1). Almost all combinations of zooplankton species with a high correlation to *B. c. maritima* contained nauplii of *Balanus improvisus* and *Keratella cochlearis*. Often also *C. pengoi* was included. BIOENV with only environmental parameters and abundance of *C. pengoi* included pointed most frequently to *C. pengoi* as the prime factor determining the distribution of *B. c. maritima*. It is unlikely that the nauplii of *B. improvisus* or *K. cochlearis* have some direct impact on the vertical distribution of *B. c. maritima*. There are probably some other environmental factors that influence all three species in the same way. The predatory *C. pengoi* may on the other hand be one of the main factors causing changes in the vertical distribution of *B. c. maritima*. No diurnal vertical migration of *C. pengoi* has been recorded in the Baltic Sea area and the majority of the population are located in the upper water layer (Gorokhova et al., 2000). Hence, the deeper water layers may be considered as a refuge for the prey species such as *B. c. maritima*.

Previous studies from other basins show that the introduction of *C. pengoi* has in many cases led to significant changes in the composition and abundance of zooplankton in recipient ecosystems (Kotta et al., 2004; Ojaveer et al., 2004). The cladoceran is a voracious predator, which feeds on smaller cladocerans and copepod nauplii (A. Lankov, H. Ojaveer, A. Põllumäe & M. Simm, unpubl. data).

Table 1. Results of two BIOENV analyses indicating the most important factors determining the vertical distribution of *Bosmina coregoni* in the Gulf of Finland

BIOENV: 1, Zooplankton taxa determining the distribution of <i>Bosmina</i>			
Variable	Number of variables	Correlation	Selections
1 <i>Cercopagis pengoi</i>	2	0.464	4, 8
2 <i>Acartia</i> spp.	3	0.41	4, 8, 9
3 <i>Balanus improvisus</i> nauplii	4	0.392	1, 4, 8, 9
4 Bivalvia larvae	1	0.389	8
5 Cyclopidae	3	0.384	1, 4, 8
6 <i>Eurytemora affinis</i>	5	0.365	1, 4, 8, 9, 15
7 <i>Evadne nordmanni</i>	5	0.364	1, 4, 6, 8, 9
8 <i>Keratella cochlearis</i>	4	0.356	4, 6, 8, 9
9 <i>Keratella cruciformis</i>	5	0.353	1, 4, 8–10
10 <i>Keratella quadrata</i>	3	0.353	4, 8, 12
11 Calanoid nauplii			
12 <i>Pleopsis polyphemoides</i>			
13 <i>Podon intermedius</i>			
14 <i>Synchaeta baltica</i>			
15 <i>Synchaeta monopus</i>			
16 <i>Temora longicornis</i>			

BIOENV: 2, Various factors determining the location of <i>Bosmina</i>			
Variable	Number of variables	Correlation	Selections
1 Month	1	0.245	3
2 Daylight	2	0.241	3, 8
3 <i>Cercopagis pengoi</i>	3	0.235	3, 5, 8
4 Station No./Horizon	2	0.213	3, 5
5 Station depth	3	0.194	3, 8, 9
6 Temperature at the end of tow	4	0.187	3, 5, 7, 8
7 Temperature at the start of tow	4	0.186	3, 5, 8, 9
8 Salinity	4	0.181	3, 5, 6, 8
9 Number of zooplankton taxa	3	0.18	3, 7, 8
	3	0.171	3, 6, 8

Relying on the current database, it is impossible to say whether the average abundance of *B. c. maritima* has decreased after the invasion of *C. pengoi* in the Gulf of Finland as it happened in the Gulf of Riga (Kotta et al., 2004; Ojaveer et al., 2004). The current data reveal no significant decline of *B. c. maritima* in the Gulf of Finland.

Temperature stratification and the density of cladocerans seem to be the most important environmental variables explaining the distribution of *C. pengoi* in the Gulf of Finland. As indicated in this study densities of the alien species are high enough to have an impact on the distribution of its potential prey *B. c. maritima*.

Our study points to the need of manipulative experiments in order to demonstrate the causative links between the dynamics of *C. pengoi* and the native zooplankton communities in recipient ecosystems.

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***Cercopagis pengoi* (Cladocera) Soome lahes:
erinevate keskkonnaparameetrite mõju ruumilisele
jaotusele ja suhtele liigiga *Bosmina coregoni maritima***

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Cercopagis pengoi leiti Soome lahest esmakordselt 1992. aastal. Aastatel 1997–2002 läbi viidud uuringute järgi vaadeldi liigi levikut ja selle sõltuvust tähtsamatest abiootilistest ja biootilistest keskkonnateguritest. *C. pengoi* jaotust mõjutasid kõige tugevamalt vee termiline kihistumine ja vesikirbuliste arvukus. Oluline korrelatsioon *C. pengoi* arvukuse ja *Bosmina coregoni maritima* vertikaalse jaotuse vahel näitab, et *C. pengoi* põhjustab oma potentsiaalse toiduobjekti *B. c. maritima* vertikaalset migratsiooni.