Epibionts and parasites on crustaceans (Copepoda, Cladocera, Cirripedia larvae) inhabiting the Gulf of Gdańsk (Baltic Sea) in very large numbers*

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Abstract

The occurrence of epizoic filter-feeding Protozoa (*Vorticella* and *Zoothamnium*) and parasitic Protozoa (*Ellobiopsis*) on Calanoida was noticed in the Gulf of Gdańsk in 1998, 1999 and 2006. The relatively high (4–16% of all calanoids) level of infestation varied depending on the type of infestation (0.1–13% of the population of particular taxa). The dominant copepods – *Acartia* spp., *Temora longicornis* and *Centropages hamatus* – were attacked the most frequently (from 10.5% to 54% of all infested calanoids). Epibiosis and parasitism were observed on all copepod

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developmental stages (adults, juveniles and nauplii). Epibionts and parasites were located on different parts of the body, but mainly on the prosome.

Infestation by epibionts and parasites was not restricted to calanoid copepods: it was also detected in non-negligible numbers on other crustaceans, namely, Harpacticoida, Cladocera (*Bosmina* sp.) and Cirripedia larvae (nauplii) in the Gulf of Gdańsk.

1. Introduction

Epibiosis and parasitism are widespread in the zooplankton communities of marine and brackish environments (Hirche 1974, Ho & Perkins 1985, Timofeev 1997, Hu & Song 2001, Visse 2007) and also of freshwaters (Manca et al. 1996, Manca et al. 2004, Decaestecker et al. 2005). Epibiotic overgrowth and parasitic infestation most often affect pelagic Copepoda (Wiktor & Krajewska-Sołtys 1994, Timofeev 2002, Visse 2007, Walkusz & Rolbiecki 2007), but parasites can also appear on other crustaceans, e.g. Euphausiacea, Mysida (Shields 1994), Cladocera (Decaestecker et al. 2005).

Both parasitism and epibiosis are considered harmful to planktonic animals. Overgrowths of epizoic Protozoa can reduce swimming speed in Copepoda, especially when the antennae are heavily infested. Heavily-infested specimens are also more visible to predators, becoming easy prey for planktivorous animals (Chiavelli et al. 1993, Visse 2007). Kimmerer & McKinnon (1990) described cases of *Paracalanus indicus* infested with parasitic Dinoflagellata (*Atelodinium* sp.) in the Indian Ocean. They reported that dinoflagellates formed a plasmodium that wrapped around the host's body, leading to its death. Other authors examined the effect of the parasite *Ellobiopsis* sp. on the fecundity of *Calanus helgolandicus* in the Bay of Biscay. Parasitism by *Ellobiopsis* sp. has the potential to reduce the fecundity of copepods: a reduction in size of both the seminal vesicle and the developing spermatophore sac was noted in parasitised males of *C. helgolandicus* (Albaina & Irigojen 2006).

The mass occurrence of the epizoic protozoan *Myoschiston centropagidarum* on copepods such as *Eurytemora affinis* and *Acartia tonsa* in low-salinity waters adjacent to the western Baltic Sea was reported a long time ago by Hirche (1974). Visse (2007) studied the survival in the Gulf of Riga of *Acartia bifilosa* infested by *Epistylis* sp. In the 1980s a serious protozoan infestation by both epibionts (*Vorticella* and *Zoothamnium*) and parasite infestation (*Ellobiopsis*) was detected on Calanoida from the Gulf of Gdańsk (Wiktor 1993, Wiktor & Krajewska-Sołtys 1994). Since then, no other reports of infection in the Gulf of Gdańsk have been published.

Crustacea, among them Copepoda, are one of the most significant components of marine zooplankton. They comprise more than 90% of marine zooplankton; this also applies to the Baltic Sea (Bielecka et al.

2000, Żmijewska et al. 2000, Józefczuk et al. 2003, Mudrak & Żmijewska 2007). Zooplankton – an intermediate link between primary production (phytoplankton) and higher trophic levels (planktivorous) – constitute a fundamental step in the marine food web.

The main aim of the present study was to investigate taxa-specific infection by parasitic and epibiontic Protozoa on Calanoida from the Gulf of Gdańsk. We also wished to find out whether crustacean zooplankton taxa other than copepods were infected.

2. Material and methods

The study was conducted in shallow and open waters in the western and eastern parts of the Gulf of Gdańsk. Samples were also collected near the mouth of the River Vistula, where conditions are determined by the inflow of often polluted fresh waters, and to a lesser extent by seawaters. The plankton material was collected from on board the r/v 'Oceanograf-2' in 1998, 1999 and 2006, during all seasons (Table 1). Generally, samples were collected with a WP-2 plankton net or Copenhagen net (mesh size 100 m) to a maximum depth of 40 m; some hauls were made using an open-type plankton net (mesh size 50 μm) at a depth of 1 m (at the stations situated nearest the shore). Net samples were preserved immediately after collection in a 4% borax-buffered formaldehyde-seawater solution. A total of 245 samples from 24 stations were analysed. The crustacean zooplankton was identified in the laboratory under a stereoscopic microscope. Representatives of taxa belonging to Copepoda, Cladocera and Cirripedia, and the developmental stages (nauplii, copepodites I–V, mature

Table 1. Details of the plankton materials

Research areas	Profiles and stations	Research periods	Number of stations	Number of samples
Western part of the Gulf of Gdańsk	Sopot profile (So1, So2, So4 and J23)	January–November 1999	4	68
	Sopot profile (So1, So2, So3, So4)	January–November 2006	4	58
	Gdynia station (off the Marine Promenade)	January–November 1999	1	17
Eastern part of the Gulf of Gdańsk – mouth of the Vistula	Świbno profile (Sw2–Sw4)	February–November 2006	3	42
	profiles I–IV (off Sobieszewo Island)	July and October 1998	15	60

males and females) were identified. The epizoic and parasitic protozoans on crustaceans were also identified, and the degree of infestation and the location of protozoans on various body parts were investigated. Three different ranges of infestation were arbitrarily distinguished: up to $\frac{1}{3}$, from $\frac{1}{3}$ to $\frac{1}{2}$, and more than $\frac{1}{2}$ the body surface.

3. Results

Analysis of the plankton material revealed the presence of Copepoda (Calanoida: *Acartia longiremis*, *Acartia bifilosa*, *Acartia tonsa*, *Temora longicornis*, *Centropages hamatus*, *Eurytemora* sp. *Pseudocalanus* sp. and representatives of Harpacticoida – typical zoobenthic copepods), Cladocera (*Bosmina* sp. *Evadne nordmanii*, *Pleopsis polyphemoides*, *Podon* sp. and freshwater organisms) and Cirripedia larvae (*Balanus improvisus*). The parasites attached to the crustacean bodies were classified as the genus *Ellobiopsis* (Myzozoa, Ellobiopsida) (Figures 1A–C). The epizoic protozoans observed on crustaceans of the Gulf of Gdańsk belong to Peritricha (Vorticellidae). Ciliated epibionts were divided into two categories: Peritricha type I – individual organisms or tufts of organisms (like the genus *Vorticella*) and Peritricha type II – clearly branched colonies (like the genus

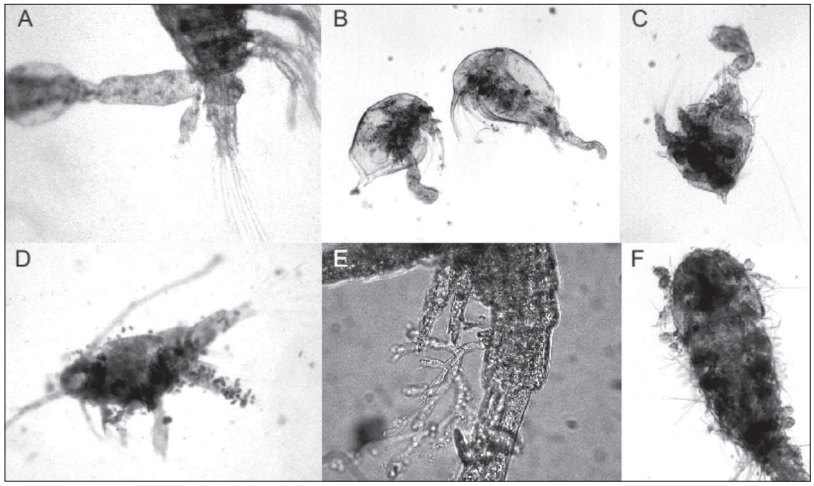

Figure 1. A) *Ellobiopsis* attached to the urosome of *Acartia tonsa*; B) *Ellobiopsis* attached to *Bosmina* sp.; C) *Ellobiopsis* attached to a Cirripedia nauplius; D) *Acartia* sp. with Peritricha I (cf. *Vorticella*) on the whole body surface; E) Peritricha II (cf. *Zoothamnium*) attached by well-defined stalk to the urosome of *Temora longicornis*; F) Peritricha II (cf. *Zoothamnium*) located on the cephalon and metasome of Harpacticoida

Table 2. Prevalence of infestation on calanoid copepods (total). Prevalence of different types of infestation on all Calanoida taxa

Type of infestation Host species	Peritricha type I (cf. *Vorticella*)	Peritricha type II (cf. *Zoothamnium*)	*Ellobiopsis*
	1998		
Copepoda (Calanoida)		16%	
Acartia spp.	2.7%	13%	9.2%
Temora longicornis	9.2%	11.1%	3.1%
Centropages hamatus	7.9%	4.3%	2.6%
	1999		
Copepoda (Calanoida)		15%	
Acartia spp.	2%	2%	8%
Temora longicornis	5%	5%	10%
Centropages hamatus	7%	4%	12%
	2006		
Copepoda (Calanoida)		4%	
Acartia spp.	0.1%	0.8%	2%
Temora longicornis	0.1%	3.5%	2.4%
Centropages hamatus	0.2%	4.5%	3.3%

Zoothamnium) (Figure 1D–F). Such discrimination was introduced owing to the deformation of the body of organisms observed in the preserved material.

Epibionts and parasites were noted on various crustacean taxa.Calanoida (Copepoda) overgrown with ciliated Protozoa (Peritricha types I and II) were observed, as were body deformations related to the presence of the parasite *Ellobiopsis* (Figure 1A, D, E) (Tables 2 and 3). These organisms were found at all research stations and in all research periods, and constituted from 4% (2006) to 16% (1998) of all Copepoda (Table 2). The prevalence of Peritricha type II was from 0.8% to 13% of the total population of each taxa (max. infestation in *Acartia* spp. in 1998), and that of *Ellobiopsis* was 2–11% (max. infestation in *Temora longicornis* in 1999). Representatives of Peritricha type I (cf. *Vorticella*) were less frequently noted on copepods – 0.1–9.2% of the population were infested (Table 2). The dominant taxa of Copepoda of the Gulf of Gdańsk were the most commonly attacked (Table 3) – *Acartia* spp. (up to 54% of all infested calanoids), *Temora longicornis* (26–49% of all infested calanoids) and *Centropages hamatus* (10.5–13% of all infested calanoids). Differences in the numbers of animals infested by Protozoa also differed according to season (Tables 2 and 3). This investigation of near-shore copepods in the Gulf of Gdańsk indicates that the infestation may relate to different

Table 3. Prevalence of infestation by epibionts and/or parasites on particular taxa of all infested calanoids

Taxa	Research period		
	1998	1999	2006
Acartia spp.	51%	54%	37%
Temora longicornis	33.5%	26%	49%
Centropages hamatus	10.5%	13%	13%
Eurytemora sp.	2.5%	2%	0.3%
Pseudocalanus sp.	1%	5%	0.8%

developmental stages. Epibiosis and parasitism, to varying degrees, were observed on adult organisms (females, males), juveniles (copepodites) and larval (nauplii) stages. All of the infestations detected on Copepoda occurred mainly on the prosome including the cephalosome, but rarely on the urosome. Usually up to $\frac{1}{3}$ of the animal body surface was overgrown with organisms; only in a few cases did they cover more than $\frac{1}{2}$ of the body area.

The epizoic protozoans, Peritricha type II, were found for the first time on copepods belonging to Harpacticoida (Figure 1F). These organisms were observed twice in June and July 2006 at the station located near the mouth of the Vistula (Sw3 – 54°23.2′N, 18°58.0°E, 20–10 m depth) at respective densities of 64 and 7 indiv. m^{-3}. They constituted 0.22% of all harpacticoids. Representatives of Cladocera (*Bosmina* sp.) (Figure 1B) infected by *Ellobiopsis* were noted in August 2006 at the Sopot 4 station (So4 – 54°30.7′N, 18°46.0′E, 30–20 m depth) at a density of 14 indiv. m^{-3}, which constituted 2.9% of the total population. The youngest Cirripedia, nauplii, (Figure 1C) with the same parasite were found in September at the Sopot 1 station (So1 – 54°27.0′N, 18°34.8′E, 5–0 m depth) at an abundance of 4 indiv. m^{-3} – these organisms represented 0.2% of the population.

4. Discussion

Eutrophication is a significant problem in the Baltic Sea (Schiewer 2008). The Gulf of Gdańsk is one of the most seriously polluted areas of the Baltic Sea and is particularly threatened by environmental degradation. The physicochemical conditions of this basin are determined by both natural and anthropogenic factors. The mixing of waters of the gulf with seawaters occurs on a very limited scale; this results in a consistently high level of pollution. The gradually worsening water pollution in this basin has led to serious biological changes (Sobol & Szumilas 1994). Among the zooplankton, the dominance of Copepoda of the genus *Acartia*, mainly

A. bifilosa and *A. tonsa* (Bielecka et al. 2000, Żmijewska et al. 2000, Józefczuk et al. 2003, Mudrak & Żmijewska 2007), and an increase in the numbers of Protozoa, free-living and colonial epibionts that grow on Copepoda (Wiktor 1993, Wiktor & Krajewska-Sołtys 1994), have been observed. According to Hirche (1974), the large-scale occurrence of protozoan colonies on Calanoida (*Eurytemora affinis* and *Acartia tonsa*) was the result of strong, progressive eutrophication. Wiktor (1993) considered that one reason for epibiosis and parasitism on copepods was the increasing pollution load and the increase in the organic matter content, hence the large-scale proliferation of Protozoa, organisms with a high metabolic rate.

Wiktor (1993) and Wiktor & Krajewska-Sołtys (1994) reported that in 1986 and 1991, 56% of *Acartia bifilosa* and 66% of *Temora longicornis* individuals were infected by Ellobiopsidae during May and that the infected specimens were most numerous in the eastern part of the Gulf of Gdańsk, especially in the vicinity of the Vistula mouth. The current study confirms the relatively large scale of this phenomenon and shows that not only Calanoida are infested by epibionts and parasites. The range of changes observed on crustacean bodies is very close to the taxonomic structure and abundance of Copepoda in the study area. The most common genus in the Gulf of Gdańsk is *Acartia* (with three species: *Acartia bifilosa*, *A. tonsa* and *A. longiremis*), *Temora longicornis* and *Centropages hamatus* (Bielecka et al. 2000, Żmijewska et al. 2000, Józefczuk et al. 2003, Mudrak & Żmijewska 2007). This may indicate that the most abundant taxa were the most frequently attacked.

For the first time representatives of other groups of crustaceans – Cladocera (*Bosmina* sp.), Harpacticoida and Cirripedia larvae (nauplii) – were found with epizoic and parasitic protozoans. To the authors' knowledge there are no data available about either epibiosis on Harpacticoida or parasitism on Cladocera or Cirripedia larvae in the Gulf of Gdańsk, although these crustaceans (especially Cladocera and Cirripedia nauplii) are present there in very high densities and may be dominant components of zooplankton. For now, however, the prevalence of the infection seems to be relatively low. There are few reports on the cladocerans infected by parasitic Ellobiopsidae, but all relate to other marine or freshwater environments (e.g. Konovalova 2008 – the Sea of Japan, Decaestecker et al. 2005 – shallow and eutrophic ponds in Belgium).

Planktonic crustaceans are the primary dietary component of many invertebrates as well as the larval and juvenile forms of fish, including commercial species (Simm & Ojaveer 2000). The present paper gives a brief description of epibionts and parasites and their hosts in the Gulf of Gdańsk, and highlights new aspects – Harpacticoida, Cladocera and

Cirripedia nauplii acting as hosts to Protozoa. Owing to the key significance of Copepoda in the Gulf of Gdańsk ecosystem in particular and the Baltic Sea as a whole, much more extensive studies need to be carried out into the condition of these animals. Future research should focus on gauging the scale of the phenomenon and on describing its dynamics, as well as the consequences for the entire Baltic Sea ecosystem.

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References

Albaina A., Irigojen X., 2006, *Fecundity limitation of Calanus helgolandicus, by the parasite Ellobiopsis sp.*, J. Plankton Res., 28 (4), 413–418, http://dx.doi.org/10.1093/plankt/fbi129.

Bielecka L., Gaj M., Mudrak S., Żmijewska M. I., 2000, *The seasonal and short-term variability of zooplankton taxonomic composition in shallow coastal area of the Gulf of Gdańsk*, Oceanol. Stud., XXIX (1), 57–76.

Chiavelli A. D., Mills E. L., Threlkeld S. T., 1993, *Host preferences, seasonality, and community interactions of zooplankton epibionts*, Limnol. Oceanogr., 38, 574–583, http://dx.doi.org/10.4319/lo.1993.38.3.0574.

Decaestecker E., Declerck S., De Meester L., Ebert D., 2005, *Ecological implications of parasites in natural Daphnia populations*, Oecologia, 144 (3), 382–390, http://dx.doi.org/10.1007/s00442-005-0083-7.

Hirche H. J., 1974, *Die Copepoden Eurytemora affinis Poppe und Acartia tonsa Dana und ihre Besiedlung durch Myoschiston centropagidarum Precht (Peritricha) in der Schlei*, Kiel. Meeresforsch., 30, 43–64.

Ho J., Perkins P. S., 1985, *Symbionts of marine copepod: an overview*, Bull. Mar. Sci., 37, 586–598.

Hu X., Song W., 2001, *Description of Zoothamnium chlamydis sp. n. (Protozoa: Ciliophora: Peritrichida), an Ectocommensal Peritrichous Ciliate from Cultured Scallop in North China*, Acta Protozool., 40, 215–220.

Józefczuk A., Guzera E., Bielecka L., 2003, *Short-term variability of mesozooplankton at two stations (Gdynia, Sopot) in the shallow water zone of the Gulf of Gdańsk*, Oceanologia, 45 (2), 317–336.

Kimmerer W. J., McKinnon A., 1990, *High mortality in a copepod population caused by parasitic dinoflagellate*, Mar. Biol., 107, 449–452, http://dx.doi.org/10.1007/BF01313428.

Konovalova G. V., 2008, *Parasitic Dinoflagellates and Ellobiopsids (Ellobiopsidae) of the Coastal Waters of the Sea of Japan*, Russ. J. Marine Biol., 34 (1), 28–37, http://dx.doi.org/10.1134/S1063074008010045.

Manca M., Beltrami M., Sonvico D., 1996, *On the appearance of epibionts on the crustacean zooplankton of a large subalpine lake undergoing oligotrophication (L. Maggiore, Italy)*, Mem. Ist. Ital. Idrobiol., 54, 161–171.

Manca M., Carnovale A., Alemani P., 2004, *Exotopic protrusions and ellobiopsid infection in zooplanktonic copepods of a large, deep subalpine lake, Lago Maggiore, in northern Italy*, J. Plankton Res., 26 (11), 1257–1263, http://dx.doi.org/10.1093/plankt/fbh117.

Mudrak S., Żmijewska M. I., 2007, *Spatio-temporal variability of mesozooplankton from the Gulf of Gdańsk (Baltic Sea) in 1999–2000*, Oceanol. Hydrobiol. Stud., 36 (2), 3–19, http://dx.doi.org/10.2478/v10009-007-0007-4.

Schiewer U., 2008, *Ecology of Baltic coastal waters*, Springer-Verlag, Berlin, 429 pp., http://dx.doi.org/10.1007/978-3-540-73524-3.

Shields J. D., 1994, *The parasitic Dinoflagellates of marine Crustaceans*, Ann. Rev. Fish Dis., 4, 241–271, http://dx.doi.org/10.1016/0959-8030(94)90031-0.

Simm M., Ojaveer E., 2000, *Dynamics of copepods and fish larvae in Prnu Bay (NE part of the Gulf of Riga) in the spring–summer period*, Proc. Estonian Acad. Sci. Biol. Ecol., 49, 317–326.

Sobol Z., Szumilas T., 1994, *Causes of poor sanitary condition of marine coastal waters of the Gulf of Gdańsk*, [in:] *Pollution and restoration of the Gulf of Gdańsk*, Mater. Seminar, Univ. Gdansk, Gdynia, 104–111, (in Polish).

Timofeev C. F., 1997, *An occurrence of the parasitic Dinoflagellata Ellobiopsis chattoni (Protozoa: Mastigophora) on the Copepod Calanus finmarchicus (Crustacea: Copepoda) and a possibility to use the parasitic as a biological tag of local populations*, Parazitologiya, 31 (4), 334–339, (in Russian).

Timofeev C. F., 2002, *The effect of the parasitic dinoflagellate Ellobiopsis chattoni (Protozoa: Mastigophora) on the winter mortality of the calanoid copepod Calanus finmarchicus (Crustacea: Copepoda) in the Norwegian Sea*, Parazitologiya, 36 (2), 158–162, (in Russian).

Visse M., 2007, *Detrimental effect of peritrich ciliates (Epistylis sp.) as epibionts on the survival of the copepod Acartia bifilosa*, Proc. Estonian Acad. Sci. Biol. Ecol., 56 (3), 173–178.

Walkusz W., Rolbiecki L., 2007, *Epibionts (Paracineta) and parasites (Ellobiopsis) on copepods from Spitsbergen (Kongsfjorden area)*, Oceanologia, 49 (3), 369–380.

Wiktor K., 1993, *The extent of infection of Calanoida in the Gulf of Gdańsk by parasitic Protozoa*, Stud. Mater. Oceanol., 64 (3), 243–253.

Wiktor K., Krajewska-Sołtys A., 1994, *Occurrence of epizoic and parasitic protozoans on Calanoida in the Southern Baltic*, Bull. Sea Fish. Inst., 132 (2), 13–25.

Żmijewska M. I., Niemkiewicz E., Bielecka L., 2000, *Abundance and species composition of plankton in the Gulf of Gdańsk near planned underwater outfall of the Gdańsk-Wschód (Gdańsk–East) sewage treatment plant*, Oceanologia, 42 (3), 335–357.