POLISH POLAR RESEARCH
vol. 32, no. 3, pp. 253–262, 2011 doi: 10.2478/v10183-011-0016-6

Parasite community structure of cod from Bear Island (Barents Sea) and Pomeranian Bay (Baltic Sea)

Ewa SOBECKA [1*], Ewa ŁUCZAK [1], Beata WIĘCASZEK[2] and Artur ANTOSZEK[2]

[1] *Zachodniopomorski Uniwersytet Technologiczny, Zakład Fizjologii i Patologii Ryb, ul. Kazimierza Królewicza 4, 71-550 Szczecin, Poland*
*<ewa.sobecka@zut.edu.pl> * corresponding author*

[2] *Zachodniopomorski Uniwersytet Technologiczny, Zakład Systematyki Ryb, ul. Kazimierza Królewicza 4, 71-550 Szczecin, Poland*

Abstract: A total of 142 cods: 60 from the South-East Ground of Bear Island and 82 from the Pomeranian Bay (Baltic Sea) were examined for their ecto- and endoparasites. Twenty different parasite species, comprising one Myxosporea, three Cestoda, four Digenea, seven Nematoda, three Acanthocephala and two Crustacea were found. The parasite component communities comprised 1446 individuals (17 species, six higher taxa) from the Bear Island and 6588 individuals (nine species, three higher taxa) from Pomeranian Bay. The observed parasite host specificity was low, and the intensity in a single fish ranged from one to 279 specimens. The eudominant parasite species were *Echinorhynchus gadi*, *Hemiurus levinseni* and *Contracaecum osculatum*. The dominant parasite communities from the Bear Island were nematodes, but acanthocephalans dominated in cod from the Baltic Sea. It appears that one group of parasites, better adapted for the specific conditions of the macrohabitat, has replaced another. The most prevalent parasites were *E. gadi*, *Anisakis simplex*, *C. osculatum* and *Hysterothylacium aduncum*, and the mean values of crowding were the highest for *E. gadi* and *Pomphorhynchus laevis*. The nematode *Camallanus lacustris* was noted in this host species for the first time. Only six species of parasites were common to cod from both fishing grounds.

Key words: Arctic, Bear Island, Baltic Sea, *Gadus morhua*, parasite diversity.

Introduction

The composition and structure of parasite communities vary greatly depending on host organisms. However, there is a limited knowledge on how species richness and the structure of host fish communities affect the species richness and community structure of fish parasites or both components at an infracommunity level. Numerous studies have recognized parasitism as a significant factor affecting the natural population dynamics of the host (Hudson and Dobson 1989). Parasites are

known to potentially decrease the survival or reproduction of host populations (Minchella and Scott 1991), and parasitism is now taken into account in the study of biodiversity (Viggers et al. 1993; Sasal et al. 2000). As parasites may have negative effects on their hosts, it is of great importance to characterize the determinants of parasite species diversity (Poulin and Morand 2000), especially of such economically and ecologically important fish species as Atlantic cod (*Gadus morhua* L.).

Atlantic cod inhabits the Northwest to Northeast Atlantic, including the region around Bear Island in the Barents Sea, as well as the Baltic Sea. It is an epibenthic-pelagic species widely distributed throughout a variety of habitats, from the shoreline down to the continental shelf (Froese and Pauly 2010).

The composition of the parasite fauna of cod is influenced by the relatively long life span of cod, its heterogeneous and readily available diet, as well as its spawning and feeding migrations. Information on cod parasite fauna in Polish waters (Baltic Sea) is scarce (Markowski 1933; Janiszewska 1938; Rokicki 1975, 1995). Cod from the Pomeranian Bay and adjacent basins have not yet been studied.

The present studies were undertaken due to the limited knowledge of the parasite fauna of the cod inhabiting such extremely different macrohabitats as the Pomeranian Bay and the area around Bear Island. The comparison of parasite communities from both fishing grounds was especially taken into consideration.

Material and methods

The study involved a total of 142 cods, 60 from the area of Bear Island on the South-East Ground (73°30’ N and 19°02’ E) caught at a depth of around 300 m in April 2002, and 82 from Pomeranian Bay, caught at a depth of 10 m (54°02’ N, 14°45’ E and 53°89’ N, 14°20’ E) in March and November 2002. All data are summarized in Table 1.

Parasitological examination focused on: the skin, vitreous humor, eye lens, mouth and nasal cavities, gills, heart, liver, gonads, spleen, gastrointestinal tract, kidney, gallbladder, swim bladder, and peritoneum: parasites found in the fish were determined by viewing the specimens under light microscopy and immersed

Table 1

Basic data of cod from Bear Island (BI) and Pomeranian Bay (PB)

Fishing ground	*n**	Body mass [g]		Standard length [mm]		Fulton’s coefficient value [K]	
		λ	SD	λ	SD	λ	SD
BI	60	638.21 (275 – 1200)	158.16	420.68 (330 – 500.5)	30.74	0.80 (0.63 – 0.95)	0.07
PB	82	712.33 (300 – 2780)	454.21	370.6 (260 – 620)	70.11	1.13 (0.653 – 1.69)	0.21

*number of fish specimens

in glycerine, lactic acid, or preserved in 75% ethyl alcohol. Helminths were stained using alum-carmine and mounted in Canada balsam.

The results were analyzed according to the following traits:

1. Quantitative descriptors of parasite populations such as: percent contribution of each parasite species to the represented systematic group, prevalence (%), infection intensity, abundance (relative density), crowding, frequency (as a % contribution of particular species and higher taxa in the community) and dominance (%), which, apart from allowing for the quantification of the parasite as a part of the community, allowed for ranking them to the appropriate class (Pojmańska 1993; Czachorowski 2004). Five classes of domination were assumed: eudominants (>10%), dominants (5.1% to 10%), subdominants (2.1% to 5%), recedents (1.1% to 2,0%) and subrecedents (<1%). Descriptive statistics pertaining to parasite infections were calculated separately for each sampling position (Rózsa *et al.* 2000; Reiczigel 2003).

2. The following elements were estimated with respect to the quantitative structure of the component parasite species: richness (*S*), Shannon-Weaver species diversity index (*H'*), Berger-Parker species dominance index (*D*) and Jaccard faunistic (species) similarity coefficient (*Wxy*) (Trojan 1992; Kennedy and Hartvigsen 2000).

3. Characteristics of parasite communities (Esch et al. 1988). Parasites in the larval stage and adults whose developmental cycle occurs only in water environments were assigned to autogenic parasite communities. The community of allogenic parasites (in the larval stage) was composed only of parasites, whose development cycle is partialy associated with aquatic environment and partly with terrestrial environment (Złotorzycka *et al.* 1998). Considering host specificity the parasites were classified as generalists or specialists (Price 1980).

Results

All studied fish were infected and all parasite species inhabiting the fish were generalists. The parasite component communities comprised 20 species: 19 countable species and 1 species not countable, in the form of spores. 1446 individuals (17 species, six higher taxa) were recorded in cod from the area of Bear Island and 6588 individuals (nine species, three higher taxa) in cod from the Pomeranian Bay. Parasites belonging to the Myxosporea, Digenea, Cestoda, Nematoda, Acanthocephala and Copepoda were observed. Spores of the myxosporean *Zschokkella hildae* (Auerbach, 1910), the digeneans *Hemiurus levinseni* (Odhner, 1905), *Brachyphallus crenatus* (Rudolphi, 1802), *Podocotyle atomon* (Rudolphi, 1802) and *Derogenes varicus* (Müller, 1784), the cestodes *Grillotia erinaceus* (van Beneden, 1858), and *Pyramicocephalus phocarum* (Fabricius, 1780), the nematode *Cucullanus cirratus* (Müller, 1777), the acanthocephalan *Corynosoma semerme* (Forssell, 1776) and the crustaceans *Clavella adunca* (Strom, 1762) and *Lernaeocera branchialis* (L., 1767)

Table 2

Descriptive statistic of parasites from cod caught at Pomeranian Bay (PB) and Bear Island (BI) sampling stations

Parasite / Fishing ground		Prevalence		Intensity			Abundance		Crowding	
		%	95% Confidence limit*	Mean	Median	95% Confidence limit**	Mean	95% Confidence limit	Mean	95% Confidence limit
PB	1.	1.2	0.0007–0.0650	1.00	1.00	0.00–0.00	0.01	0.00–0.04	1.00	0.00–1.00
	2.	9.8	0.0458–0.1815	1.88	1.00	1.13–3.50	0.18	0.07–0.41	3.27	1.22–5.13
	3.	6.1	0.0244–0.1382	3.40	3.00	2.20–4.80	0.21	0.06–0.46	4.06	2.50–5.67
	4.	2.4	0.0044–0.0836	1.00	1.00	0.00–0.00	0.02	0.00–0.06	1.0	0.00–1.00
	5.	97.6	0.9134–0.9956	74.18	61.50	60.74–88.25	72.37	60.18–88.12	129.2	108.60–157.91
	6.	28.0	0.1930–0.3897	3.00	1.00	1.78–5.39	0.84	0.44–1.66	8.68	3.10–13.21
	7.	1.2	0.0007–0.0650	2.00	2.00	0.00–0.00	0.02	0.00–0.07	2.00	0.00–2.00
	8.	51.2	0.4020–0.6225	12.64	4.00	7.02–27.43	6.48	3.63–15.34	75.59	13.55–140.43
BI	1.	11.9	0.0570–0.2271	1.29	1.00	1.00–1.57	0.15	0.05–0.27	1.44	1.00–1.73
	2.	67.8	0.5494–0.7903	3.22	3.00	2.50–4.95	2.19	1.59–3.42	7.11	3.41–14.95
	4.	66.1	0.5299–0.7728	7.41	3.00	5.25–11.15	4.90	3.22–7.39	18.47	10.59–27.88
	5.	54.2	0.4149–0.6707	4.03	2.00	2.88–5.91	2.19	1.42–3.37	8.41	5.43–12.83
	6.	67.8	0.5494–0.7903	4.47	3.00	3.27–7.68	3.03	2.08–5.19	12.40	5.32–24.93
	7.	35.6	0.2446–0.4891	2.76	2.00	2.24–3.29	0.98	0.63–1.41	3.34	2.70–4.01
	9.	1.8	0.0010–0.0951	1.00	1.00	1.00–1.00	0.02	0.00–0.05	1.00	0.00–1.00
	10.	10.2	0.0453–0.2096	1.00	1.00	0.00–0.00	0.10	0.03–0.17	1.00	0.00–1.00
	11.	10.2	0.0453–0.2096	4.67	2.50	1.83–8.00	0.47	0.14–1.15	7.86	2.33–10.25
	12.	52.5	0.3978–0.6535	13.19	10.00	9.55–19.61	6.93	4.66–10.61	26.68	17.08–38.84
	13.	1.7	0.0009–0.0903	1.00	1.00	1.00–1.00	0.02	0.00–0.05	1.00	0.00–1.00

* Confidence intensity for prevalence (Sterne's exact method up to N = 1000, adjusted Wald method for N >1000)

**Bootstrap (BCa) confidence limits for the mean intensity, mean abundance and mean crowding

1 – *Ascarophis arctica*, 2 – *Anisakis simplex*, 3 – *Camallanus lacustris*, 4 – *Contracaecum osculatum*, 5 – *Echinorhynchus gadi*, 6 – *Hysterothylacium aduncum*, 7 – *Pseudoterranova decipiens*, 8 – *Pomphorhynchus laevis*, 9 – *Grillotia erinaceus*, 10 – *Cucullanus cirratus*, 11 – *Derogenes varicus*, 12 – *Hemiurus levinseni*, 13 – *Podocotyle atomon*

were found only in cod from Bear Island. The cestode *Diphyllobothrium* sp., the nematode *Camallanus lacustris* (Zoega, 1776) and the acanthocephalan *Pomphorhynchus laevis* (Müller, 1776) were recorded only in cod from the Pomeranian Bay. The nematodes *Pseudoterranova decipiens* (Krabbe, 1878), *Hysterothylacium aduncum* (Rudolphi, 1802), *Anisakis simplex* (Rudolphi, 1809), *Contracaecum osculatum* (Rudolphi, 1802), and *Ascarophis arctica* (Poljansky, 1952), and the acanthocephalan *Echinorhynchus gadi* (Müller, 1776), were present in fish from both fishing grounds (Tables 2 and 3).

The acanthocephalan *E. gadi* was the most commonly (prevalence = 97.6%) and abundantly (abundance = 72.37) (Table 2) recorded parasite in cod from the Pomeranian Bay (from 1 to 279 specimens per fish). The prevalence of *E. gadi* in cod from the area of Bear Island amounted to 54.2% (one to 19 specimens per

Table 3

Structure of cod parasitic fauna (countable) from Bear Island an Pomeranian Bay

Taxon	Species	L/A	Bear Island			Pomeranian Bay		
			n	%*	% of group**	*n*	%	% of group
Cestoda	*G. erinaceus* van Beneden, 1858	L	2	0.14				
	Diphyllobothrium sp.	L				1	0.02	
	P. phocarum (Fabricius, 1780)	L	2	0.14				
	Σ		4		0.27	1		0.02
Digenea	*H. levinseni* Odhner, 1905	A	486	33.61				
	D. varicus (Müller, 1784)	A	36	2.49				
	P. atomon (Rudolphi, 1802)	A	1	0.07				
	B. crenatus (Rudolphi, 1802)	A	1	0.07				
	Σ		524		36.20			
Nematoda	*A. arctica* Poljansky, 1952	A	9	0.62		1	0.02	
	A. simplex (Rudolphi, 1809)	L	138	9.54		14	0.21	
	H. aduncum (Rudolphi, 1802)	L/A	198	13.69		84	1.27	
	C. cirratus Müller, 1777	A	7	0.48				
	C. osculatum (Rudolphi, 1802)	L	296	20.47		2	0.03	
	P. decipiens (Krabbe, 1878)	L	55	3.80		2	0.03	
	C. lacustris (Zoega, 1776)	A				17	0.25	
	Σ		703		48.60	120		1.82
Acantho-cephala	*P. laevis* (Müller, 1776)	A				533	8.08	
	E. gadi (Müller, 1776)	A	129	8.92		5934	90.07	
	C. semerme (Forssell, 1904)	L	6	0.41				
	Σ		135		9.33	6467		98.16
Crustacea	*C. adunca* (Strøm, 1762)	A	79	5.46				
	L. branchialis (Linnaeus, 1767)	A	1	0.07				
	Σ		80		5.53			

L – larva, A – adult

n – number of parasite specimens

* percent of parasites from particular fishing ground

** percent of the taxonomic group of parasites in parasite community

fish). The most prevalent parasites in this area were the larvae of the nematode *A. simplex* (prevalence = 67.8%), while the digenean *H. levinseni* was recorded with the highest mean intensity (20.09, 1 to 57 specimens per fish). This parasite was not found in cod from the Pomeranian Bay.

The most numerous group of parasites from the Bear Island area were nematodes and digeneans (frequency = 48.6% and 36.2%, respectively). Acanthocephalans, crustaceans and cestodes were recorded less frequently (Table 3). In cod from the Pomeranian Bay, the most numerous were acanthocephalans. Nematodes contributed 1.82% of all parasites from this fishing ground, and cestodes only 0.02%.

Table 4

Index of dominance of the parasite community components in particular fishing grounds [%]

Species/fishing ground	BI	PB
H. levinseni	33.61	
D. varicus	2.49	
P. atomon	0.07	
B. crenatus	0.07	
G. erinaceus	0.14	
Diphyllobothrium sp.		0.01
P. phocarum	0.14	
A. arctica	0.62	0.01
A. simplex	9.54	0.21
H. aduncum	13.58	1.27
C. cirratus	0.48	
C. osculatum	20.47	0.03
P. decipiens	3.8	0.03
C. lacustris		0.25
P. laevis		8.09
E. gadi	8.92	90.07
C. semerme	0.35	
C. adunca	5.46	
L. branchialis	0.07	

Among the parasites from the area of Bear Island, three species were eudominants, two were dominants, three were subdominants, and eight were subrecedents. In the Pomeranian Bay eudominants, dominants and recedents were represented by one species each; six species were subrecedents. The indices of dominance of the parasite community components in particular fishing grounds are presented in Table 4.

The parasite community components of the cod digestive tract was composed of helminths from four higher taxonomic taxa: Digenea, Cestoda, Nematoda and Acanthocephala. No digeneans were found in cod from the Pomeranian Bay. The richest group according to the number of species (seven species) were Nematoda.

Values of the Shannon-Weaver species diversity index for parasitic Metazoa (all parasites included, except *E. gadi*), for digestive tract parasite community, and for the community of nematodes, were definitively higher for the parasites around Bear Island (Table 5). On the other hand, the Berger-Parker species dominance index was higher for the community of parasitic Metazoa and parasites from the digestive tract of cod from the Pomeranian Bay. The Jaccard faunistic similarity coefficient amounted to 30%.

Autogenic parasites belonged to the Digenea, Cestoda, Nematoda, Acanthocephala and Crustacea. Parasites were either in larval stage or adult stages, except

Table 5

Shannon-Weaver species diversity index (*H'*) and Berger-Parker species dominance index (*D*) value for three cod parasite communities from the Bear Island (BI) and Pomeranian Bay (PB)

Index	*H'*		*D*	
Fishing ground	BI	PB	BI	PB
All parasites	1.65	0.37	21.83	90.07
Parasites of alimentary tract	1.85	0.81	20.16	90.07
Nematodes	2.125	0.21	32.26	12.00

of *H. aduncum*, which occurred in both stages. A greater richness of species was found in the community of autogenic parasites of cod from Bear Island than from the Pomeranian Bay (17 species and 8 species, respectively).

The allogenic parasite was a cestode *Diphyllobothrium* sp. (one specimen), recorded in a cod from Pomeranian Bay.

Discussion

The ecological basis of biocenosis diversity was described by Thienemann (1918). This author established the concepts that greater habitat diversity (with both abiotic and biotic factors) results in greater biodiversity, and that habitat disturbance reduces biodiversity but can lead to a substantial success of the surviving species. In waters with a high concentration of nutrients (*i.e.* in environments where only few "ecological niches" are available), a smaller number of species can exist near their optimum. The number as well as the species diversity is therefore smaller when compared to waters less eutrophic. However, the species present are more numerous, and sometimes found in great quantities (Krebs 2001). The parasitic fauna of cod from the two fishing grounds follows this rule. The fauna differs both in species composition, and prevalence of particular parasites. A markedly lower species number was observed in the Baltic fishing ground, where water salinity ranged between 5‰ and 7‰. This value is too high for many freshwater parasites while on the other hand, too low for marine species. Cod parasites from Pomeranian Bay are typical marine (common for both fishing grounds) and euryhaline species. They all have a complex life cycle and are passively passed through the food chain to fish, which are intermediate (paratenic) or definitive hosts. The dominant species was the acanthocephalan *E. gadi*, constituting over 90% of the parasitic Metazoa found. Metazoa infect cod as early as in the juvenile stage and with time the parasite accumulation surpasses its mortality (Pilecka-Rapacz and Sobecka 2004).

Apart from higher values of infection intensity it was observed that cod from the Pomeranian Bay were in better condition. Thus, parasite species diversity in

the digestive tract is, in all likelihood, a more important factor affecting the condition of the fish host than the actual quantity of parasites.

None of the cod parasites from both fishing grounds were oioxenic (specific to a single host) (Sobecka and Piasecki 2005). Only fish from Bear Island were a microhabitat for the myxosporean *Zschokkella hildae*, spores of which were also recorded in cod from the White Sea (Auerbach 1912; Bazikalova 1932; Šulman et al. 1993) and North Sea (Hellberg et al. 2008). This parasite have been used to discriminate stocks of cod in northern Norway (Hemmingsen et al 1991). *Z. hildae* was noted in the gall bladder of *Phycis blennioides*, *Melanogrammus aeglefinus* and some other gadid fish (Lom and Dykova 2006), but it is likely that this is the only region of the Atlantic Ocean where this parasite occurs in cod. The cestode *G. erinaceus*, whose larvae were found in one cod specimen, is recorded in this region very rarely. The adult parasites were found most recently in *Amblyraja radiata* (referred to as *Raja radiata*) by Poljansky 1955 and Beveridge and Campbell 2007.

Digeneans were noted only in cod from the Bear Island fishing ground. *H. levinseni* is largely a parasite of gadiforms and salmonids from the north Atlantic Ocean, the Arctic Ocean and the north Pacific Ocean (Gibson and Bray 1986). *D. varicus* is a common parasite of cod, it has been found also in more than hundred species of fish (Hemmingsen and MacKenzie 2001). *B. crenatus* in the Baltic Sea is common in Cottidae and Pleuronectidae, less frequent in those of family Gadidae. (Moravec 2004); *P. atomon* has been recorded from a large number of fish species from the eastern Canadian coast to the Barents Sea (Appy and Burt 1982).The two last-mentioned digenean species have been found in cod caught in the north-eastern shore of the Bornholm Island and Kiel Fjord (Möller 1975; Køie 1984) however, in later years these parasites are not recorded in the Baltic cod. The digeneans have a complex life cycle and their distribution coincides with the geographical distribution of the intermediate hosts, therefore in the Baltic Sea the water salinity lower than 12‰ is probably a barrier for their expansion (Möller 1978).

The highest degree of crowding of cod parasites from the Pomeranian Bay was noted for the acanthocephalans *E. gadi* and *P. laevis*, while from Bear Island, the digenean *H. levinseni* and the nematode *C. osculatum* were most crowded. The size of the infrapopulation inhabiting an individual host (crowding) is a major component affecting the parasite environment, often influencing both morphological and life-history characters (the so-called density-dependent characters) in different parasite taxa. In the case of a single parasite individual the crowding equals intensity (Reiczigel *et al.* 2005).

Nematodes showed a significantly lower intensity of infection of Baltic cod; nematode larval stages have a better chance of transmission in waters of higher salinity by drifting with oceanic currents. The second commonest group present were acanthocephalans, dominating cod from the Baltic Sea. This phenomenon creates the impression that one group of parasites replaced another, being better adapted for the specific conditions of the macrohabitat.

The isolation of the Baltic Sea basin (Johannesson and André 2006) is likely a factor influencing parasite fauna composition and the decreasing salinity from west to east limits the distribution of many parasites (Zander and Reimer 2002).

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Received 28 February 2011
Accepted 13 June 2011