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Parasitological survey of smelt, *Osmerus eperlanus* (Actinopterygii: Osmeridae), from five estuary sites along the southern coast of the Baltic Sea

by

Małgorzata Pilecka-Rapacz[1], Wojciech Piasecki[2,*], Małgorzata Głoćko[1], Vytautas Kesminas[3], Józef Domagała[1], Gerard Wiśniewski[4], Robert Czerniawski[1]

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[1]*Division of General Zoology, Faculty of Biology, University of Szczecin, ul. Felczaka 3C, 71-714 Szczecin, Poland*

[2]*Palaeoceanology Unit, Faculty of Geosciences, University of Szczecin, ul. Mickiewicza 18, 70-383 Szczecin, Poland*

[3]*Laboratory of Ecology and Physiology of Hydrobionts, Nature Research Centre, Vilnius, Lithuania*

[4]*Pomorska Organizacja Producentów ARKA Sp. z o.o. ul. Unruga 111, 81-153 Gdynia*

* Corresponding author: *wojciech.piasecki@usz.edu.pl*

Abstract

This is the first comprehensive study covering the parasite fauna of smelt, *Osmerus eperlanus*, from five estuary sites of the southern Baltic Sea in a stretch of almost 500 km. We examined 432 smelt from: the Neman River mouth, the Vistula River mouth, Pomeranian Bay, the Oder River, and Lake Dąbie and recovered 13 species/higher-rank taxa of parasites: *Diplostomum* spp., *Posthodiplostomum cuticola*, *Eubothrium crassum*, *Proteocephalus longicolis*, *Cystidicola farionis*, *Hysterothylacium aduncum*, *Corynosoma semerme*, *Pomphorhynchus laevis*, Unionidae gen sp., *Ergasilus sieboldi*, *Argulus foliaceus*, *Piscicola geometra*, and Saprolegniaceae gen sp. Basic infection parameters such as prevalence, intensity of infection, mean intensity of infection, and the dominance index were determined. The findings of the presently reported study constitute a number of new faunistic records. There were two new host records (*Posthodiplostomum cuticola* and Saprolegniaceae gen sp.), five new host records for Poland (*Diplostomum* spp., *Pomphorhynchus laevis*, *Piscicola geometra*, *Argulus foliaceus*, and Unionidae gen sp.), and two new host records for Lithuania (*Argulus foliaceus* and Unionidae gen sp.). We carefully analyzed the relevant information from more than 100 publications on smelt parasites to compare the data with our own findings.

Key words: smelt, parasite, survey, new host record, estuary, Baltic Sea area

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Introduction

The European smelt, *Osmerus eperlanus* (Linnaeus, 1758), is a small teleost fish occurring in coastal waters, estuaries, and lakes of northern Europe from the Bay of Biscay, through British Isles, the North Sea, the Baltic Sea, reaching lakes and some coastal areas of the Kola Peninsula (White Sea), and the Pechora River. It is a widespread species with both migratory and landlocked populations (Nellbring 1989). The migratory form, living in the sea and spawning in estuaries may attain larger size (13.5-18 cm) compared to the landlocked form (8-10 cm). The smelt initially feeds on zooplankton, mainly cladocerans and copepods (Northocote & Hammar 2006), switching latter, i.e., while in the sea, to amphipods, mysids, and small fish. Because of their abundance, smelt constitute an important item in the marine food chains, being consumed by larger fish and birds (Taal et al 2014). In some countries, such as Russia, Latvia, Lithuania, Germany, Sweden, and Finland, they are also of economic importance, being directly consumed or processed as canned fish, or finally being used for production of fish oil or animal feed components (Svanberg et al. 2016). The smelt is known locally for its cucumber smell. It is not true that this smell was first characterized by Linné. In fact, the founder of the modern taxonomy compared its smell to green-leaved willow (*Salix rubra*) and sweet violet (*Viola odorata*) (Linnaeus 1758).

Because of its abundance, the important role in the food web, and the life cycle covering different environments, *O. eperlanus* is a suitable model for ecological and parasitological studies. Migratory fishes are known as hosts of diverse parasites, representing different life strategies and their parasite faunas well reflect the quality of the environment (Dogiel et al. 1961), especially under the conditions of increasing anthropogenic pressure Nellbring (1989). Population variation of smelt in Poland was studied by Rembiszewski (1970).

Parasites of smelt have not been adequately studied in many areas of its natural range, despite an apparent excess of publications dealing with this subject. We have traced over one hundred, mostly original papers describing parasites of the smelt, *O. eperlanus*, published since 1771. Our comprehensive list covers all the sources that we could possibly find, based on our best knowledge and effort. Unfortunately the information included in 22 papers is cited after other authors and we were not able to read the original text. This is because some sources (mostly Russian publications) are not accessible, despite repetitive efforts to acquire them. Fortunately, the majority of those "missing" papers report on a few parasite species only. Physically unavailable papers are not listed in the references, but the credit is given to the publication that cited these sources (Voigt 1975). Information on smelt parasites was probably also included in various ephemeral or non-reviewed reports (grey literature) that are inaccessible even to a persistent investigator. The only comprehensive review focusing on smelt parasites was published over 40 years ago by Voigt (1975). Other important review papers were authored by Pugachev & Fagerholm (1995), and Kirjušina & Vismanis (2007). We really hesitate to recommend sources like von Linstow (1872, 1889), not only because they are secondary sources but also because at least half of the names of smelt parasites listed there cannot be identified or explicitly synonymized. Interesting information can also be found in taxonomic keys and textbooks on fish parasitology and fish diseases (e.g., Dogiel et al. 1961; Byhovskij et al. 1962; Grabda 1991, Prost 1994; Jara & Chodyniecki 1999). In the majority of cases, however, data provided in such sources are of secondary nature and cannot be linked to the original authors, localities, or infection parameters. For the purpose of this study, such secondary sources are therefore not included. Some apparently original sources contain inconsistent statements regarding the originality of the reported parasite records (original vs. cited after other authors) (Voigt 1981a; 1994).

As stated above, the parasite fauna of smelt in Europe has not been studied with equal intensity in all geographic regions. The water bodies adjacent to the Gulf of Bothnia and Finland have been the most extensively studied and account for almost 70% of the available papers on this subject. There were 37 papers from (present-day) Russia, 27 from Finland, 5 from Sweden, 2 from Estonia, and 2 from Latvia. The second most frequently studied location was the southern coast of the North Sea with 14 papers from Germany (mainly the Elbe River estuary) and 4 papers from the Netherlands. There were also single publications from Denmark, Ireland, and the UK. Three articles were published in Norway and seven in Poland. The Polish records, published between 1933 and 2004, focused on the Gulf of Gdańsk, the Vistula Lagoon, and north-eastern lakes, in papers that reported 1 or 2 parasite species only, with the exception of Rokicki (1975) who found 5 parasite species in smelt from the Gulf of Gdańsk. There were only two papers on smelt parasites from Lithuania within its present borders (Marre 1931; Gecevičiūtė 1958). Until recently, a total of 8 smelt parasite species have been reported from Poland (Markowski 1933; Kozikowska 1975; Rokicki 1975; Żółtowska et al. 2001; Dziekońska-Rynko et al.

2003; Rolbiecki 2004) and 14 from Lithuania (Marre 1931; Gecevičiūtė 1958).

The aim of the presently reported study was to investigate the parasite fauna of smelt from the hitherto inadequately studied coastal areas of the southern Baltic stretching from the Oder River estuary eastward to Lithuania.

Materials and methods

Fish samples were acquired from small fishery harbors during the spring spawning migration in the areas adjacent to the respective capture sites:

- The Curonian Lagoon (CL) off the Neman River mouth near Klaipėda (part of the Neman River estuary), Lithuania (2011);
- The Gulf of Gdańsk (GG) off the Vistula River mouth (part the Vistula River estuary), Poland (2012);
- Pomeranian Bay (PB), offshore stretch from Świnoujście through Dziwnów, covering mostly Międzyzdroje and Wisełka (part the Oder River estuary), Poland (2011);
- The Oder River (OR) from Dziewoklicz through Lake Dąbie, Poland (2011);
- Lake Dąbie (LD) (part of the Oder River estuary), Poland (2001).

The fish were caught by fyke nets (CL, OR, LD) by professional fishermen or by trawling using an experimental bottom trawl net from a research vessel SNB *AR-1* (GG, PB). The smelt studied constituted a bycatch fish, occurring in small numbers, so we collected and studied all available specimens.

The number of fish collected, their parameters, and biological characteristics are provided in Table 1. Standard parasitological procedures were employed to examine the fish collected. After being delivered to a laboratory (in Szczecin and in Klaipėda), the fish were measured (standard length, SL), weighed, and examined for the presence of parasites. Parasitological necropsy covered the skin, vitreous humor of eyes, eye lenses, gills, heart, muscles, gonads, spleen, gastrointestinal tract, kidneys, swim bladder, and peritoneum. The parasites recovered from the fish were fixed and subsequently processed following commonly used helminthological methods, specific for respective taxonomic groups. Finally, the parasite specimens were identified. In total, we examined 432 smelt from 5 sites, collected during 5 surveys.

After identification of the parasites, calculations of basic quantitative parameters of parasitic infections were made, such as: prevalence, intensity, and mean intensity, as defined by Bush et al. (1997). The parasites found were divided into four categories, based on their prevalence: very common (≥ 50%), common (10%-50%), rare (4%-10%), and sporadically occurring (≤ 4%) (Pojmańska 1993). Their dominance was assessed bases on the following scale: eudominant (> 10%), dominant (5.1%-10%), subdominant (2.1%-5.0%), recedent (1.1%-2%), and subrecedent (< 1.0% of a given species) (Pojmańska 1993). Significant differences in the number of parasite taxa between the sites (surveys) were tested by one-way ANOVA, and post-hoc Duncan test ($P < 0.05$).

Results

The infection parameters of smelt differed between the sampling sites. The highest number of parasite taxa was 10 species in Lake Dąbie. Smelt from Pomeranian Bay harbored 8 parasite species, while those from the Oder River – 7 species. The lowest number of parasites was found in the fish from the Curonian Lagoon and the Gulf of Gdańsk (6 and 4, respectively). The studied fish populations, depending on the site, were infected with parasites from 40.6% up to 100%.

Table 1

Basic biometric characteristics of smelt, *Osmerus eperlanus*, from estuaries of major rivers of the southern Baltic Sea

Study site	*n*	Standard length (cm)		Weight (g)		*K*	
		Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Curonian Lagoon	51	18.5 ± 2.3	15.2-24.0	35.9 ± 13.6	13.0-66.5	0.55 ± 0.09	0.42-0.69
Gulf of Gdańsk	35	10.0 ± 1.01	8.5-12.3	5.01 ± 1.8	2.7-9.6	0.47 ± 0.04	0.40-0.53
Pomeranian Bay	128	13.0 ± 2.8	5.9-19.7	14.9 ± 10.0	1.3-51.3	0.59 ± 0.09	0.40-0.74
Oder River	98	17.5 ± 3.6	11.3-23.4	37.2 ± 20.7	7.6-86.6	0.60 ± 0.07	0.48-0.77
Lake Dąbie	120	17.5 ± 3.5	11.0-23.2	32.5 ± 15.9	10.0-75.0	0.58 ± 0.11	0.40-0.90

n = number of fish studied; *K* = Fulton's condition factor.

In the course of the presently reported study, the following parasite species (and/or higher taxa) were found: *Diplostomum* spp. MET, *Posthodiplostomum cuticola* (von Nordmann, 1832) MET; *Proteocephalus longicollis* (Zeder, 1800); *Eubothrium crassum* (Bloch, 1779); *Hysterothylacium aduncum* (Rudolphi, 1802) LRV + AD; *Cystidicola farionis* Fischer, 1798; *Pomphorhynchus laevis* (Zoega in Müller, 1776); *Corynosoma semerme* (Forssell, 1904) JUV; Unionidae gen sp. GL[1]; *Ergasilus sieboldi* von Nordmann, 1832; *Argulus foliaceus* (Linnaeus, 1758); *Piscicola geometra* (Linnaeus, 1761); Saprolegniaceae gen sp. The parasites listed above represented seven higher taxa: Digenea (2 species), Cestoda (2), Nematoda (2), Acanthocephala (2), Crustacea (2), Hirudinea (1), Mollusca (1), and Fungi (1).

Only three parasite species occurred at all five sites: *Diplostomum* spp., *Proteocephalus longicollis*, and *Hysterothylacium aduncum*. *Cystidicola farionis* was recorded at four sites, *Pomphorhynchus laevis* and *Corynosoma semerme* – at three sites, *Eubothrium crassum*, Unionidae gen sp., and *Ergasilus sieboldi* – at two sites, while the remaining parasites were observed at a single sites only.

Only three parasite species were very common: *Hysterothylacium aduncum*, *Cystidicola farionis*, and Unionidae gen sp. Two former species were very common at a single site only, and common at two other locations, while the latter parasite was very common at two sites. Two other parasites *Diplostomum* spp. and *Proteocephalus longicollis* were common (at three sites each). The remaining parasites were either rare or occurred sporadically.

Only six parasites species were eudominant: *Diplostomum* spp. (from the Gulf of Gdańsk and Pomeranian Bay), *Proteocephalus longicollis* (from the Gulf of Gdańsk), *Hysterothylacium aduncum* (from the Gulf of Gdańsk), *Cystidicola farionis* (from the Curonian Lagoon and Lake Dąbie), *Pomphorhynchus laevis* (from Pomeranian Bay), and glochidia of Unionidae gen sp. (from the Oder River and Lake Dąbie). Three parasite species were dominant: *Proteocephalus longicollis*, *Hysterothylacium aduncum*, and *Ergasilus sieboldi* (all from Pomeranian Bay). All other parasites were subdominant, recedent, or subrecedent (Table 2).

Metacercariae of *Diplostomum* spp. were found in the eye lenses of smelt coming from all five surveys but were common only at three sites (GG, PB, OR). The prevalence ranged from 2.3% in Lake Dąbie to 34.3% in the Gulf of Gdańsk. The highest mean intensity of 8.07 parasites per infected fish was noted for Pomeranian Bay. A total of 301 specimens of *Diplostomum* spp. were found in the fish studied.

Metacercariae of *Posthodiplostomum cuticola* were detected at one site only (LD) and a single parasite specimen was found.

Adult tapeworms, *Proteocephalus longicollis*, occurred in the intestines of fish from all five surveys and the prevalence ranged from 7.0% in Pomeranian Bay to as much as 43.0% in Lake Dąbie. At the latter site, the mean intensity reached 9.15 tapeworms of this species per infected fish. As many as 101 specimens of *P. longicollis* were found in the most intensively infected fish. A total of 616 specimens of *P. longicollis* were found in all fish examined.

Adult tapeworms, *Eubothrium crassum*, were observed at two sites and the prevalence ranged from 1.6% in Pomeranian Bay to 5.9% in the Curonian Lagoon. The mean intensity of infection reached 1.5 in Pomeranian Bay and 1.33 in the Curonian Lagoon. A total of 12 parasite specimens were recovered from the fish studied.

Nematodes, *Hysterothylacium aduncum* (LRV + AD), were found during all five surveys with the prevalence ranging from 2.0% in the Oder River to 62.8% in the Curonian Lagoon. The mean intensity ranged from 1.17 in the Gulf of Gdańsk to 6.5 in the Curonian Lagoon. A total of 297 specimens of *H. aduncum* were observed in the fish examined. The adult form occurred in the intestine, while larval forms were on the liver, gonad, and in the gallbladder.

Adult nematodes, *Cystidicola farionis*, were found in swim bladders of smelt during almost all surveys, except for the fish from the Gulf of Gdańsk. The prevalence values ranged from 1.0% (OR) to 98.0% (CL). The mean intensity of infection ranged from 10.00 (Pomeranian Bay) to 145.68 (CL). A total of 10 450 specimens of *C. farionis* were found in the fish examined. Infected swim bladders were distinctly distended and the parasites were visible through the semi-translucent wall.

Adult acanthocephalans, *Pomphorhynchus laevis*, were found in 14 fish specimens from three surveys (GG, PB, LD), which totaled 54 parasite specimens. The highest prevalence (8.6%) was observed in fish from Pomeranian Bay.

A total of 29 juvenile specimens of the acanthocephalan, *Corynosoma semerme*, were observed in fish from the Curonian Lagoon, Pomeranian Bay, and the Oder River. The prevalence values did not exceed 2.0% (CL) and a single fish from OR harbored 27 *C. semerme*.

Glochidia of Unionidae gen sp. occurred at two sites only (OR and LD), where they were very common (72.5% and 100%, respectively). The mean intensity was very high (36.8 and 78.8, respectively). The total number of parasites found was 12 066.

[1] AD = adult, GL = glochidium, JUV = juvenile, LVR = larva

Table 2

Parasite species recovered from smelt, *Osmerus eperlanus*, from five estuary sites of major rivers of the southern Baltic Sea: principal infection parameters

Parasite species	Parameter	Study site				
		Curonian Lagoon	Gulf of Gdańsk	Pomeranian Bay	Oder River	Lake Dąbie
Diplostomum spp. MET	NFI	4	13	29	14	4
	P (%)	7.8	34.3	22.7	14.4	3.3
	Intensity	1-2	1-4	1-51	1-2	1-4
	Mean	1.25	1.85	8.07	1.71	2.25
	NP	5	24	234	24	14
	D	0.07	58.54	62.4	0.86	0.11
Posthodiplostomum cuticola MET	NFI					1
	P (%)					0.8
	Intensity					1
	Mean					1
	NP					1
	D					0.01
Eubothrium crassum	NFI	3		2		
	P (%)	5.9		1.6		
	Intensity	1-6		1-2		
	Mean	1.33		1.5		
	NP	10		3		
	D	0.13		0.80		
Proteocephalus longicollis	NFI	7	5	9	8	52
	P (%)	13.8	14.3	7.0	8.2	43.3
	Intensity	1-6	1-4	1-4	1-41	1-101
	Mean	3.29	1.8	2.11	11.13	9.15
	NP	23	9	19	89	476
	D	0.31	21.95	5.07	3.19	3.62
Eubothrium crassum	NFI	3		2		
	P (%)	5.9		1.6		
	Intensity	1-6		1-2		
	Mean	1.33		1.5		
	NP	10		3		
	D	0.13		0.80		
Cystidicola farionis	NFI	50		1	1	48
	P (%)	98.0		1.6	1.0	40.0
	Intensity	8-388		10	25	2-243
	Mean	145.68		10	25	65.2
	NP	7284		10	25	3131
	D	96.72		2.67	0.90	23.83
Hysterothylacium aduncum LRV + AD	NFI	32	6	11	2	45
	P (%)	62.8	17.4	8.6	2.0	37.5
	Intensity	1-42	1-2	1-8	1-2	1-2
	Mean	6.5	1.17	2.36	1.5	1.18
	NP	208	7	26	3	53
	D	2.76	17.07	6.93	0.11	0.40
Corynosoma semerme JUV	NFI	1		1	1	
	P (%)	2.0		1.6	1.0	
	Intensity	1		1	27	
	Mean	1		1	27	
	NP	1		1	27	
	D	0.01		0.27	0.97	
Pomphorhynchus laevis	NFI		1	11		2
	P (%)		2.9	8.6		1.7
	Intensity		1	1-15		1
	Mean		1	4.63		1
	NP		1	51		2
	D		2.44	13.6		0.02
Unionidae gen sp. GL	NFI				71	120
	P (%)				72.5	100.0
	Intensity				2-341	1-578
	Mean				36.76	78.8
	NP				2610	9456
	D				93.65	71.97
Ergasilus sieboldi	NFI			6	4	
	P (%)			4.7	4.1	
	Intensity			1-13	1-5	
	Mean			5.17	2.25	
	NP			31	9	
	D			8.27	0.32	
Argulus foliaceus	NFI					3
	P (%)					2.5
	Intensity					1
	Mean					1
	NP					3
	D					0.023
Piscicola geometra	NFI					2
	P (%)					1.7
	Intensity					1
	Mean					1
	NP					2
	D					0.015
Saprolegniaceae gen. sp.	NFI					3

NFI = number of fish infected, P = prevalence (percentage of hosts infected), Intensity = infection intensity range, Mean = mean intensity of infection (related to infected hosts only), NP = number of parasites found, D = coefficient of dominance, MET = metacercariae, LRV = larvae, AD = adult (also all species names without a label were adults), JUV = juvenile, GL = glochidia

Parasitic copepods, *Ergasilus sieboldi*, were found on gills of fish from two sites only (PB and OR), where their prevalence values were 4.7% and 4.1%, respectively. Only 40 *E. sieboldi* specimens were collected.

Leaches, *Piscicola geometra*, and fish lice, *Argulus foliaceus*, were observed in Lake Dąbie on two and three fish, respectively. Three fish from Lake Dąbie had small foci of a fungal infection (Saprolegniaceae gen sp.). The observed foci were not associated with any primary skin damage. Another fish from that site had unidentified small cysts on the gills. The cysts had amorphous structure with no resemblance to microsporidians, myxozoans, protozoans, or helminths.

The post-hoc test revealed significant differences in the number of *Diplostomum* metacercariae between the Curonian Lagoon and the Oder River and between Pomeranian Bay and the Oder River and Lake Dąbie. The number of those metacercariae was significantly higher in Pomeranian Bay than in the Curonian Lagoon, the Oder River, or Lake Dąbie. There were no significant differences between the numbers of this parasite between other sites ($P < 0.05$). The number of tapeworms, *Proteocephalus longicollis*, found in smelt was significantly higher in Lake Dąbie than at the other sites ($P < 0.05$). The number of nematodes, *Hysterothylacium aduncum*, recovered from their hosts from the Curonian Lagoon was statistically higher than at all other sites. Swim bladder nematodes, *Cystidicola farionis*, were significantly more numerous in smelt from the Curonian Lagoon and Lake Dąbie than in Pomeranian Bay and the Oder River ($P < 0.05$). There were no significant differences in the numbers of acanthocephalans, *Corynosoma semerme*, between the sampling sites ($P > 0.05$). *Pomphorhynchus laevis* were more numerous in Pomeranian Bay than in Lake Dąbie ($P < 0.1$), although apparently their number was higher in Pomeranian Bay than in the Gulf of Gdańsk. Tapeworms, *Eubothrium crassum*, were more numerous in smelt from the Curonian Lagoon than from Pomeranian Bay ($P < 0.05$).

Discussion

Although the above-mentioned excess of one hundred articles (traced by us) dealt with smelt parasites and listed more than 113 parasite "units" (i.e., usually species and/or higher taxa), the individual original papers reported on much smaller parasite assemblages. We would like to emphasize that the task of defining the exact number of relevant papers is virtually impossible because of confusion created by secondary reports and the "grey" literature items. It is equally difficult to count all parasite species because some "units" overlap – e.g., *Anodonta anatina*, *Anodonta* sp., glochodia Unionidae gen sp., etc. Moreover, the actual number changes after converting synonyms to valid names. Only the "leading" quarter of the analyzed literature (25 articles) described findings of six or more parasite species with four of these papers listing more than 20 parasite species (21-26). Ten papers covered between 10 and 16 parasite species, 36 papers reported 2-9 parasite species, and as many as 57 articles dealt with single parasite species only. Among the papers with the highest number of parasite species found, present-day Russia had 13 papers, Finland – 6, with 2 papers from Lithuania, and single papers from Germany, Ireland, Latvia, and the UK. The "leading" papers listed 96 out of 113 known smelt parasite "units" (i.e., species and/or higher taxa). For the reasons mentioned above, these "statistics" should not be treated literary and our intention was to show explicitly how many studies were done in Finland and Russia versus very few in the southern Baltic estuaries.

Among the most frequently found smelt parasites (based on the published sources), the most important ones were: *Cystidicola farionis* reported in 33 papers and *Proteocephalus longicollis* reported in 26 papers (with *Proteocephalus* sp. listed in additional 9 papers). Other "leading" species were: *Diphyllobothrium ditremum* (listed in 19 papers), *Corynosoma semerme* (17 papers), *Triaenophorus nodulosus* (15), *Diplostomum spathaceum* (Rudolphi, 1819) (13), *Ichthyosporidium hertwigi* (13), *Ergasilus sieboldi* (12), *Pseudoterranova decipiens* (12), *Hysterothylacium aduncum* (11), *Echinorhynchus salmonis* (10), *Ichthyocotylurus erraticus* (Rudolphi, 1809) (10), *Corynosoma strumosum* (8), and *Piscicola geometra* (7). Twenty-two species were reported in 3 to 6 papers, while the remaining 70 species/higher taxa were mentioned in one or two papers only.

Until recently, the parasite fauna of smelt in present-day Poland, reported in seven papers (listed in the Introduction), was represented by 8 species: *Anguillicoloides crassus* (Kuwahara, Niimi et Itagaki, 1974); *Corynosoma semerme*; *Cystidicola farionis*; *Ergasilus sieboldi*; *Eubothrium crassum*; *Hysterothylacium aduncum*; *Neoechinorhynchus rutili* (Müller, 1780); *Proteocephalus longicollis*. Parasite fauna of smelt in Lithuania, reported by Marre (1931) and Gecevičiūtė (1958), consisted of 14 species: *Caligus rapax* Milne Edwards, 1840; *Corynosoma semerme*; *Cystidicola farionis*; *Diphyllobothrium* sp.; *Diplostomum spathaceum*; *Ergasilus sieboldi*; *Eubothrium crassum*; *Hemiclepsis marginata* (O. F. Müller, 1774); *Hysterothylacium aduncum*; *Ichthyocotylurus variegatus* (Creplin, 1825). *Lepeophtheirus salmonis*

(Krøyer, 1837); *Piscicola geometra*; *Pomphorhynchus laevis* (Zoega in Müller, 1776); *Proteocephalus longicollis*. The validity of two Lithuanian records, reported from the Curonian Lagoon: *Caligus rapax* and *Lepeophtheirus salmonis* (reported by Marre 1931) is doubtful. The only known caligid copepod that tolerates low salinity is *Caligus lacustris* Steenstrup et Lütken, 1861. These misidentified records of Marre (1931) were repeated also by Voigt (1975, 1981a).

The findings of the presently reported study constitute a number of new faunistic records. There were two new host records for the smelt (*Posthodiplostomum cuticola* and Saprolegniaceae gen sp.), five new host records for Poland (*Diplostomum* spp., *Pomphorhynchus laevis*, *Piscicola geometra*, *Argulus foliaceus*, and Unionidae gen sp.), and two new host records for Lithuania (*Argulus foliaceus* and Unionidae gen sp.).

Niewiadomska (1984) sparked an ongoing discussion on the specific identity of diplostomulid metacercariae found in the eyes of fish. The majority of previous records of *Diplostomum* spp. metacercariae from smelt reported as *Diplostomum spathaceum* (see Petruševskij & Byhovskaâ (Pavlovskaâ) 1935; Novikova 1936; Baryševa & Bauer 1957; Gecevičiūtė 1958; Voigt 1981a; Jarling 1982; Rumâncev et al. 1984; Vismanis et al. 1984; Valtonen & Julkunen 1995; Doherty & McCarthy 2004; Kirjušina & Vismanis 2007; Mitenev et al. 2007; Valtonen et al. 2010) should now be considered as representing a collective species. Only a few recent papers reported those parasites as *Diplostomum* sp. (Ieško et al. 1983; Evseeva et al. 1999; Kirjušina & Vismanis 2007; Karvonen & Seppälä 2008). *Diplostomum* spp. metacercariae have not been reported in smelt from Poland.

Metacercariae of *Posthodiplostomum cuticola* have hitherto not been reported from the smelt. We found a single specimen of this species in a fish from Lake Dąbie. This digenean fluke does not seem to have a narrow host specificity, it is therefore surprising that none of the authors studying the smelt have observed this very characteristic and visible-to-the-naked-eye skin parasite, with the infection site marked by a concentration of melanin. The presently reported finding constitutes a new host record for the smelt.

Swim bladder nematodes, *Cystidicola farionis*, were officially described in 1798. We found three reports predating the official description (Artedi 1738 [based on second edition 1793]; Rolandson 1771; Acharius 1780). Authors of additional 31 publications reported it as well (Kessler 1868; Schneider 1900; 1902a,b; 1903; von Linstow 1906; Levander 1909[2]; Jääskeläinen 1917[2]; 1921[2]; Marre 1931; Petruševskij & Byhovskaâ (Pavlovskaâ) 1935; Novikova 1936; Baryševa & Bauer 1957; Gecevičiūtė 1958; Bauer & Nikolskaja 1962[2]; Järvekülg & Veldre 1963[1]; Voigt 1977; 1981a,b; 1994; Lysfjord 1981; Bagge & Hakkari 1982; Vismanis et al. 1984; Valtonen & Julkunen 1995; Valtonen et al. 2001; 2010; Żółtowska et al. 2001; Dziekońska-Rynko et al. 2003; Kirjušina & Vismanis 2007; Mitenev et al. 2007; Nelichik et al. 2014). In Poland, they were found by Żółtowska et al. (2001) and Dziekońska-Rynko et al. (2003). The reported prevalence values were usually very high, amounting to 100% (e.g., Schneider 1900; 1903; Levander 1909[1]; Baryševa & Bauer 1957; Voigt 1981), but sometimes rather low (e.g., 13%, Baryševa & Bauer 1957). In some studies, those nematodes were not found. Marre (1931) did not provide infection parameters, but he stated that *C. farionis* was the most common parasite of smelt in the Curonian Lagoon. Voigt (1977) observed that this nematode infected only smelt longer than 12 cm. Schneider (1903) found up to 267 *C. farionis* specimens in a single fish, while we recovered as many as 388 specimens in a fish from the Curonian Lagoon and 243 in a fish from Lake Dąbie.

The other most frequently found parasite was *Proteocephalus longicollis*. It was reported from many countries throughout the natural range of its host, from Ireland to northern Russia (Mühling 1898; Jääskeläinen 1917[2]; 1921[2]; Chlopina 1920; Marre 1931; Novikova 1936; Baryševa & Bauer 1957; Kogtewa 1957; Gecevičiūtė 1958; Willemse 1969; Rokicki 1975; Voigt 1981b; Bagge & Hakkari 1982; Jarling 1982; Rumâncev et al. 1984; Valtonen & Julkunen 1995; Anikieva 1998, 2010a,b; Evseeva et al. 1999; Valtonen et al. 2001; Doherty & McCarthy 2004; Kirjušina & Vismanis 2007; Mitenev et al. 2007). In Poland, it was reported only by Rokicki (1975) from the Gulf of Gdańsk, who noted the prevalence of 31.5% and the maximum infection intensity of 410.

The third important parasite, detected in this study, was nematode *Hysterothylacium aduncum*. It is a well-known marine anisakid species infecting many fish species. We found its larvae as well as adult forms in smelt from all five sites. This species was previously recorded in *O. eperlanus* by: Markowski (1933), Gecevičiūtė (1958), Rokicki (1975), Voigt (1977, 1981a,b, 1994), Jarling (1982), Vismanis et al. (1984), Valovaâ (1990), Munro et al. (1998), Doherty & McCarthy (2004), Kirjušina & Vismanis (2007). The most comprehensive and seasonal studies of this parasite in smelt were reported by Jarling (1982) from the Elbe River estuary and by Doherty & McCarthy (2004). The prevalence values determined by the above authors were 35.7%-85.7% and 10.3%-50%, respectively, and the

[2] According to Voigt 1975.

intensities were within 1-40 and 1-4.8, respectively. Gecevičiūtė (1958) reported the prevalence values of 66.6% in the smelt from Curonian Lagoon, while Rokicki (1975) determined the prevalence of 35% in the smelt from the Gulf of Gdańsk. In our studies, the parasite was present at all five sites and the prevalence ranged from 2.0% to 62.8%, with intensities within 1-42.

Glochidia of freshwater clams, representing the family Unionidae, are their infective stages with typically seasonal appearance on fish. After their association with the host, lasting from 3 days to 10 months, they leave the fish and resume free-living life stages (Piechocki 2009). They are small and semi-transparent and are often overlooked by fish parasitologists, especially those who focus on helminths only. Given the very high infection intensities, the time-consuming identification of individual glochidia basically prevents it from being performed. Moreover, the presence of smelt as migratory fish may not coincide with the availability of glochidia in the water. Therefore, those objectively ubiquitous temporary parasites were reported infrequently (see: Novikova 1936; Petrushevskii 1957; Rumâncev et al. 1984; Evseeva et al. 1999; Mitenev et al. 2007). Their identification is difficult and laborious and consequently only few authors attempt to assign them to a genus (Faussek 1895 and Voigt 1981a – as *Anodonta* sp.) or species level (Anders & Wiese 1993 – as *Anodonta anatina*). The latter authors published the most comprehensive study on unionid glochidia infecting the smelt. During a 2-year study they examined a total of over 40 000 *O. eperlanus* specimens from 30 stations in the German Wadden Sea. The overall prevalence was 0.2%, because the parasites were only observed in March and April with prevalence of 37% and 15%, respectively. It is worth noting that even though we recorded glochidia at two sites only (the Oder and Lake Dąbie), the prevalence values were the highest ever observed – 72.5% and 100%, respectively. We found as many as 578 glochidia on a single fish and the dominance values were the highest among all parasites we found. Other authors, studying smelt in Russia determined much lower (prevalence) values: 15% (Petrushevskii 1957), 5% (Rumâncev et al. 1984), 12% (Evseeva et al. 1999), and 5% (Mitenev et al. 2007). Glochidia on smelt have not been reported from the southern Baltic Sea estuaries. Their findings also constitute new records for smelt in Poland and Lithuania.

Although small copepods, *Ergasilus sieboldi*, are considered common parasites of freshwater fishes in Europe (Kozikowska 1975), they were infrequently reported by authors studying smelt (Chlopina 1920; Marre 1931; Novikova 1936; Leskien 1942; Jensen 1949; Baryševa & Bauer 1957; Kogtewa 1957; Kozikowska 1975; Bagge & Hakkari 1982; Evseeva et al. 1999; Kirjušina & Vismanis 2007; Mitenev et al. 2007). We believe this is partly because ectoparasites have never been the first priority of traditional faunistic parasitologists who preferred to study intestinal helminths rather than all parasite groups infecting other body parts. There is one reliable record of *E. sieboldi* from Poland by Kozikowska (1975), who provided a very comprehensive account on this parasitic copepod. Kozikowska (1975) studied smelt parasites from different lakes in Masuria and found prevalence values ranging from 14.6% to 33.3%. Marre (1931) reported 5% prevalence for smelt from the Curonian Lagoon. We found *E. sieboldi* in smelt from two sites only – Pomeranian Bay and the Oder River. The prevalence values were 4.7% and 4.1%, respectively, while the intensity of infection was 1-13.

One of the rarely reported parasites of smelt are tapeworms *Eubothrium crassum* (see Marre 1931; Rokicki 1975). Rokicki (1975) reported prevalence values of 5% and intensities of 1-2 for smelt from the Gulf of Gdańsk. We found this tapeworm at two sites only (Curonian Lagoon and Pomeranian Bay) and the prevalence values were 5.9% and 1.6%, respectively.

Pomphorhynchus laevis – a strongly pathogenic marine acanthocephalan, commonly occurring in flounder, where it perforates the intestine – in smelt it was reported in only three papers: Marre (1931), Jarling (1982), and Munro et al. (1998). We found it at three sites: the Gulf of Gdańsk, Pomeranian Bay, and Lake Dąbie, and the maximum prevalence value was 8.6%. This is a marine parasite, so its presence in Lake Dąbie gives clear evidence about the smelt migration route. The presently reported finding constitutes a new host record for smelt in Poland.

Encysted juveniles of *Corynosoma semerme* – a typical marine parasite, have been reported by many researchers (Rolandsson 1780; Forssell 1905; Jääskeläinen 1921[2]; Markowski 1933; Novikova 1936; Voore 1939; Baryševa & Bauer 1957; Gecevičiūtė 1958; Bauer & Nikolskaja 1962[2]; Rokicki 1975; Voigt 1977; 1981a,b; Timola 1980; Jarling 1982; Vismanis et al. 1984; Valtonen & Julkunen 1995; Kirjušina & Vismanis 2007; Valtonen et al. 2010). Jarling (1982), and Rokicki (1975) considered it as sporadically occurring. In the smelt from the Curonian lagoon, Gecevičiūtė (1958) reported the prevalence of 40%. We found *C. semerme* at three sites with low prevalence of up to 2%.

Leeches, *Piscicola geometra*, are typical freshwater opportunistic parasites, rarely reported from smelt (Marre 1931; Voigt 1977; Mitenëv & Karasëv 2005; Mitenev et al. 2007; Karasev et al. 2009; 2011). Marre

(1931) observed *Piscicola geometra* on smelt only during spawning time (as it was the case in the Gulf of Finland; Voigt 1981). We found it only in two fish from Lake Dąbie. This finding constitutes a new host record for smelt in Poland.

Fish lice, *Argulus foliaceus*, were previously reported by very few authors: Petruševskij & Byhovskaâ (Pavlovskaâ) (1935), Novikova (1936), Baryševa & Bauer (1957), Evseeva et al. (1999), and Kirjušina & Vismanis (2007). We found it only in three fish from Lake Dąbie. This finding constitutes a new host record for smelt in Poland and Lithuania. Our finding of Saprolegniaceae gen sp. constitutes a new host record.

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