

## Original papers

# Species richness and diversity of the parasites of two predatory fish species – perch (*Perca fluviatilis* Linnaeus, 1758) and zander (*Sander lucioperca* Linnaeus, 1758) from the Pomeranian Bay

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**ABSTRACT.** Pomeranian Bay as an ecotone is a transition zone between two different biocenoses, which is characterized by an increase in biodiversity and species density. Therefore, Pomeranian Bay is a destination of finding and reproductive migrations of fish from the rivers entered the area. The aim of the study was to compare parasitic fauna of two predatory fish species from the Pomeranian Bay, collected from the same fishing grounds at the same period. A total of 126 fish studied (53 perches and 73 zanders) were collected in the summer 2013. Parasitological examinations included: skin, fins, gills, vitreous humour and lens of the eye, mouth cavity, body cavity and internal organs. Apart from the prevalence and intensity of infection (mean, range) the parasite communities of both fish species were compared. European perch and zander were infected with parasites from five different taxonomic units. The most numerous parasites were *Diplostomum* spp. in European perch and *Bucephalus polymorphus* in zander. The prevalence of infection of European perch ranged from 5.7% (*Diphyllbothrium latum*) to 22.3% (*Diplostomum* spp.) and for zander from 1.4% (*Ancyrocephalus paradoxus*, *Hysterothylacium aduncum*) to 12.3% (*Bucephalus polymorphus*). Different composition of the parasitic fauna is likely due to the different biology of both fish species.

**Key words:** parasites, *Perca fluviatilis*, *Sander lucioperca*, Pomeranian Bay, Poland

## Introduction

Pomeranian Bay is located in the south-western Baltic Sea and belongs to the Oder estuary. The depth does not exceed 20 m, the area covers almost 6000 km<sup>2</sup> [1]. The main tributaries on Polish side are Oder, Parsęta and Rega rivers, and Piana and Wkra on the German side. Pomeranian Bay is characterized by variable hydro-chemical conditions caused by the interaction of marine and inland waters. Mainly caught fish, important for the local economy, are cod, herring, sprat, flat fish, brown trout, eel, roach, bream, European perch and zander [2].

European perch and zander (Percidae) are predatory fish that compete in the Szczecin Lagoon with each other for food, and also migrate to feeding grounds of Pomeranian Bay. The diet of both species consists of organisms inhabiting fresh and

brackish waters [3].

European perch is present in all types of lakes and brackish waters and belongs to the most common fish species in Poland. Adult European perch dwells in the lakes in the sublittoral and littoral zones. Research on the biology of this species showed that European perch fry swims and feeds in the summer months with the fry of zander, ruffe and cyprinids [3]. European perch is characterized by a large increase in the body length during the first year of life. At the SL (standard length) of approx. 15 cm they undergo from invertebrates to fish diet.

Parasitic fauna of European perch has been studied in Poland [e.g. 4–7] and in the world [e.g. 8–10], but these fish from the Szczecin Lagoon and Pomeranian Bay were investigated only by Pilecka-Rapacz [11] and Sobecka and Słomińska [12].

Zander inhabits the middle and lower course of large rivers, oligotrophic lakes and brackish waters of sea lagoons. It is a species of the pelagic zone. Those living in rivers and lakes, classified as the non-migratory fish. Zander of coastal marine waters migrate both for food and reproduction, therefore, they are considered the semi-migratory fish [13].

Parasitic fauna of zander in Poland has been studied in lakes [14], in the Gulf of Gdansk [15] and Szczecin Lagoon [11]. In Finland, the parasites of fry were examined, breed in reservoirs of various natural food resources [16]; in Turkey parasitic Metazoa of adult zander from Lake Siğircı was studied [17].

The aim of the study was to compare parasitic fauna of European perch and zander from the Pomeranian Bay, obtained from the same fishing grounds, at the same time.

## Materials and Methods

The study material (126 fishes: 53 perches, 73 zanders) was collected from the professional fishermen in the summer 2013, from the Pomeranian Bay (53°58'–53°72'N; 14°18'–14°23'E). Fish were caught using a bottom trawl at a depth of about 10 m. The smallest European perches and zanders were a by-catch during fishing of other fish species.

Fish were placed in styrofoam containers filled with ice and transported under such conditions to the laboratory. The average total length of European perch was 22.7 cm (10–34 cm), and zander 20.5 cm (7–58 cm); mean body weight was 208.2 g (10–560 g) and 374.2 g (3.2–1938 g), respectively. Age of fish was determined on the scale-reading and it amounted to an average of six years for European perch (2–12) and one year for zander (0–5).

Parasitological examinations included: skin, fins, gills, vitreous humour and lens of the eye, mouth cavity, body cavity and internal organs (stomach, intestine, liver, gall bladder, heart, kidneys, gonads and swim bladder). Parasitic communities were determined based on the location of the parasite in the fish, parasites were also divided into allogenic and autogenous species.

The prevalence, mean intensity, and the range of intensity of infection were calculated according to Pojmańska [18] and Bush et al. [19].

Dominance index was calculated according to the following formula [20]:  $D_i = n_i \times 100 / N$  [%]

where:  $n_i$  – total number of parasites of a particular species,  $N$  – total number of all parasites

The following scale was used to determine species dominance:

$D_i > 10\%$  – eudominants;  $5.01\% < D_i < 10\%$  – dominants;  $2.01\% < D_i < 5\%$  – subdominants;

$1.01\% < D_i < 2\%$  – recedents;  $D_i > 1\%$  – subrecedents

The following indicators characterizing parasite communities were calculated [21]:

1. Berger-Parker dominance index:  $d = n_{\max} / N$

where:  $n_{\max}$  – number of parasites of the most abundant species,  $N$  – total number of parasites in the sample

2. Shannon-Weaver species diversity index:  $H' = -\sum(p_i \times \ln p_i)$

where:  $p_i$  – number of parasites of the particular species/total number of parasites in the sample

3. Margalef index, specifying the relative species richness:  $M = S - 1 / \ln N$

where:  $S$  – number of species,  $N$  – total number of parasites in the sample

4. Simpson index, which is a measure of species diversity in the community:  $D = \sum n_i(n_i - 1) / (N(N - 1))$

where:  $n_i$  – total number of parasites of a particular species,  $N$  – total number of parasites in the sample

Two coefficients were also calculated to indicate the condition of the fish [22]:

1. Fulton coefficient according to the formula:  $K = 100 \times M / L^3$

where:  $M$  – total weight of fish (g),  $L$  – total length of fish (cm)

2. Clark coefficient according to the formula:  $C = 100 W / L^3$

where:  $W$  – gutted fish weight (g),  $L$  – SL body length (cm)

## Results

From the European perch examined, 165 parasites were collected, belonging to 5 species of 3 higher taxa: Digenea, Cestoda and Acanthocephala. The largest group were the digenean larvae, constituting a community of eye parasites (123 specimens), including: 109 *Diplostomum* spp. metacercariae (in the eye lens) and 14 *Tylodelphys clavata* metacercariae (Nordmann, 1832) (in the vitreous humour). The second group was the parasites community of the gastrointestinal tract, consisting of three species of helminths. Acanthocephalans *Echinorhynchus gadi* (Müller, 1776), (22 specimens) was observed in the midgut (18 helminths) and hindgut (4 specimens). Among the cestodes (20 parasites), 17 encysted *Triaenophorus nodulosus* (Pallas, 1781) was found in the liver and

Table 1. Infection parameters of *Perca fluviatilis* and *Sander lucioperca* from Pomeranian Bay

Host	Parasites	Prevalence [%]	Intensity			Number of parasites
			mean	range	SD	
<i>Perca fluviatilis</i> p. – 51.0	<i>Diplostomum</i> spp. (met.)	22.6	9.1	0-71	9.9	109
	<i>Tylodelphys clavata</i>	11.3	2.3	0-5	0.9	14
	<i>Triaenophorus nodulosus</i>	15.1	1.3	0-6	1.0	17
	<i>Diphyllobothrium latum</i>	5.7	1.0	0-1	0.2	3
	<i>Echinorhynchus gadi</i>	7.5	6.0	0-14	2.0	22
<i>Sander lucioperca</i> p. – 20.5	<i>Ancyrocephalus paradoxus</i>	1.4	5.0	0-3	0.6	5
	<i>Bucephalus polymorphus</i>	12.3	19.5	0-30	3.6	67
	<i>Bunodera luciopercae</i>	2.7	7.4	0-25	3.5	39
	<i>Hysterothylacium aduncum</i>	1.4	1.0	0-1	0.1	1
	<i>Achtheres percarum</i>	2.7	1.0	0-1	0.2	2

Abbreviations: SD – standard deviation; met. – metacercariae; p. – prevalence of all parasite species (%)

3 larvae of *Diphyllobothrium latum* (Linnaeus, 1758) in stomach. In total, 51% of the fish was infected.

*Diplostomum* spp. occurred with the highest prevalence, while *D. latum* with the lowest (Table 1). *Diplostomum* spp. also occurred with the highest intensity and mean intensity of infection. The lowest values of the above parameters was observed in the case of *D. latum*. Two of the three species of gastrointestinal parasites of European perch (*E. gadi* and *T. nodulosus*) were autogenic parasites. Other (*D. latum*, *Diplostomum* spp. and *T. clavata*) were allogenic parasites.

The highest dominance index of the European perch parasites was recorded for the digeneans

complex of the genus *Diplostomum*, and the lowest for *D. latum* (Table 2). The most common class of domination was eudominants (Table 2).

In the zanders studied, 114 parasites representing 5 species, including two belonging to Digenea (106 specimens), one to Monogenea (5 specimens), one to Nematoda (4 specimens) and one belonging to Crustacea (2 specimens) were detected. In total, parasites were recorded in 20.5% of the fish. The largest group, similarly as in the case of European perch, were Digenea (106 specimens) and these were *Bunodera luciopercae* (Müller, 1776) (39 specimens in pyloric appendages) and *Bucephalus polymorphus* (Baer, 1827) (67 specimens – 50 also in pyloric appendages, 11 in the foregut, 2 in the

Table 2. Dominance index (D) and class of domination

Host	Parasites	D [%]	Class of domination
<i>Perca fluviatilis</i>	<i>Diplostomum</i> spp.	66.1	eudominant
	<i>Tylodelphys clavata</i>	8.5	dominant
	<i>Triaenophorus nodulosus</i>	10.3	eudominant
	<i>Diphyllobothrium latum</i>	1.8	recedent
	<i>Echinorhynchus gadi</i>	13.3	eudominant
<i>Sander lucioperca</i>	<i>Ancyrocephalus paradoxus</i>	4.4	subdominant
	<i>Bucephalus polymorphus</i>	58.8	eudominant
	<i>Bunodera luciopercae</i>	34.2	eudominant
	<i>Hysterothylacium aduncum</i>	0.9	subrecedent
	<i>Achtheres percarum</i>	1.7	recedent

hindgut and 4 in the stomach). Monogenean *Ancyrocephalus paradoxus* (Creplin, 1839) was rare (5 specimens); 3 specimens in the second left gill arch and 2 in the third left gill arch was noted. *Achtheres percarum* (Nordmann, 1832) copepods were the least abundant (1 parasite on the first right gill arch and one on the second left gill arch). A single adult *Hysterothylacium aduncum* (Rudolphi, 1802) nematode was found in the zander foregut.

*Bucephalus polymorphus* in the largest number of fish were observed (Table 1), while *A. paradoxus* and *H. aduncum* in the lowest. The highest mean intensity of infection was observed in the case of *B. polymorphus*, the lowest for *H. aduncum* and *A. percarum*. *B. polymorphus* occurred with the highest range intensity of infection (up to 30 parasites in the fish) (Table 1). *Bucephalus polymorphus* constituted the largest attendance in the community of gastrointestinal parasites (62.6%). All parasites identified were autogenic. Two species of parasites belonged to eudominants, one to subdominants, one to recedents and one to subrecedents (Table 2).

Shannon-Weaver species diversity index, Simpson species richness index and Berger-Parker dominance index had higher values for European perch parasites (Table 3). Only the Margalef diversity index reached a higher value for zander parasites.

European perch examined were in good condition; the average values of Clark and Fulton coefficients were 1.17 and 1.4, respectively, while the values of the same coefficients for zander were significantly lower and amounted to 0.89 and 0.96, respectively (Table 3).

## Discussion

List of European perch parasites contains 69 species [23], of which 67 can be found in the Polish

Table 3. The indicators characteristics of the parasite community of the *Perca fluviatilis* and *Sander lucioperca*

Index	<i>P. fluviatilis</i>	<i>S. lucioperca</i>
Margalef	0.8	0.8
Simpson	0.5	0.5
Shannon-Weaver	1.5	0.9
Berger-Parker	21.8	13.4

coastal zone (estuaries of the Oder and Vistula rivers) [6]. The number of zander parasites is lower and includes 40 species [6].

The studied European perches and zanders from the Pomeranian Bay were infected with parasites from five different taxonomic units. This diversity may be due to the difference in the age of both species studied. Mean age of European perch investigated was 5 years, and in the case of zander it was one year; a large part of zander collected (40%) was the by-catch of age 0+ which probably explains their lower condition factor values. Food composition of zander and European perch was comparable prior to undergo to the fish diet, with the difference that the transition in zander occurs in the first year of life, while it is the third in European perch [3,13]. Digenea were most numerous in both species. In European perch those were species that actively colonize the host, as they accounted for 74.5% of all parasites, of which 66% were *Diplostomum* spp. metacercariae. These digeneans have been recorded in Polish waters in 40 species of fish, including zander [24], however, in the Pomeranian Bay zanders, metacercariae of these digeneans has not been found thus far. In addition, *Diplostomum* spp. have not been found in the European perch from the Pomeranian Bay, examined in the years 2002–2003 [12], which was probably due to the sampling period (winter, early spring and autumn months) and low water temperature. The number of *Diplostomum* spp. significantly decreases at low temperatures [25–27]. This is related to seasonal variations in the occurrence of *Lymnea stagnalis* (Linnaeus, 1758), the first intermediate host [28]. Regularity associated with a decrease in the intensity of *Diplostomum* spp. infection was also observed in European perch from the Vistula Lagoon studied in winter, when the percentage of infected fish was two times lower [4].

Metacercariae of *Diplostomum* spp. reached the highest infection parameters of all European perch parasites collected. They have been recorded in European perch already at the age 0+ [29]. They accumulate in the eye lens with the age of the fish, and their lifespan is about 200 days [30]. The relationship was noted between the body length of European perch and the presence of *Diplostomum* spp. metacercariae; as with the increasing length of the body (15 to 18 cm), the prevalence and mean intensity of infection decreases [31]. At the high intensity of infection, clouding of the lens, cornea



damage or even deterioration of vision may occur in fish [24]. For this reason, young fish infected with weaker vision swim near the surface or in the shallows, because of better visibility in those areas. This results in the elimination from the stock, because they become easy prey for fish-eating birds.

Another digeneans in European perch were metacercariae of *T. clavata*, which infected only 6 fish. These parasites prefer fresh water, as indicated by the study on parasitic fauna of European perch from the lake and the Baltic Sea coastal zone [5]. *Tylodelphys clavata* with *Diplostomum* spp. are the dominant species in the parasitic fauna of European perch in northern Poland [4,7,12,32], Finland [9] and Russia [10].

The largest group of parasites in the examined zanders were also Digenea, which accounted for 93% of all parasites, but these were species that infect the host by the oral route. *Bucephalus polymorphus* occurred with the highest prevalence (9 fish infected). They occurred with a similar prevalence (10%) in the summer in zander from the Szczecin Lagoon [12]; no evidence of this parasite was found in the autumn. The high prevalence of *B. polymorphus* is probably associated with a high abundance of *Dreissena polymorpha* (Pallas, 1771) in the waters of the Oder estuary [33], the first intermediate host [24], which number increases in the spring and summer season [34]. Zander are infected with metacercariae during feeding on infected cyprinids that come to the Pomeranian Bay from the Szczecin Lagoon.

In other studies, the authors indicated the most abundant presence of *B. polymorphus* in the autumn [4,15]; in zander from the Gulf of Gdańsk, the prevalence of this parasite was 95.3%, while in the summer only 20%. The prevalence of *B. polymorphus* in zander from the Vistula Lagoon in the autumn during the 90s ranged from 48 to 60%, while in the summer from 32 to 25% [4]. The difference in the incidence of infection in zander from the Vistula Lagoon and the Pomeranian Bay is the result of the differences in food consumed. The diet of zander from the Vistula Lagoon is mainly bream and roach [15], while these species in the stomachs of zanders from the Pomeranian Bay are of marginal importance.

The second most common parasite of zander was digenean *B. luciopercae*. The percentage of fish infected was lower than in Roztoka Odrzańska, where in the summer season, *B. luciopercae* was observed in 20% of the fish; it showed even higher

prevalence in the autumn [35]. The study of Rolbiecki and Rokicki [15] showed that in the length class 30.5–45 cm, infected zanders accounted for about 10%, and this percentage increased with the fish growth. In zanders from the Pomeranian Bay, *B. luciopercae* also occurred only in fish longer than 30 cm; they were not recorded in smaller fish, which accounted for the vast majority of the sample.

In the present study two species of cestodes were collected, both in the larval stage. *Triaenophorus nodulosus* is a parasite of predatory fish, in Poland it is also found in European perch in the mature and larval stage [36]. It is most abundant in both stages in the summer season [4,37]. In the European perch studied, 17 plerocercoids were recorded in 8 fish, and the prevalence and infection intensity were similar to those of the Vistula Lagoon (11.9%; 1–6) and the Lake Miedwie (12.5%; 1–4) [4,37]. Higher prevalence and intensity of infection are recorded in a typical freshwater reservoirs. This is indicated by the results of Wierzbicka et al. [5]. These authors have found two-fold lower prevalence of this parasite at the transition from fresh to the marine waters.

The second representative of cestodes in the parasitic fauna of European perch from the Pomeranian Bay was *D. latum*, of which three plerocercoids were found in three fish. In Poland, *D. latum* was recorded only in Lake Drużno where one plerocercoid was found in European perch, one in bream (*Abramis brama* L. 1758) and four in pike (*Esox lucius* L. 1758) [14]. However, in the years 2003 and 2005, from 4 to 10% of the fillets of European perch caught in Lake Geneva contained plerocercoids of this tapeworm [38]. Plerocercoids of *D. latum* identified by molecular analysis have also been found in European perch fillets from Switzerland, Poland, Estonia and Russia [39]. Identification of larvae of *Diphyllobothrium* is difficult, because their reproductive systems are not developed, specimens are similar to each other, and in the literature usually only adult forms are described [8]. In Szczecin Lagoon, we have recorded the occurrence of cestodes and determined only their genus – *Diphyllobothrium*; their prevalence was 12.73% [12].

*Achteres percarum* is a parasite occurring in both zander and European perch [40]. Significantly lower percentage of zander was infected in the Pomeranian Bay than in the Gulf of Gdańsk in the summer (90%) [15]. The mean intensity of infection was also considerably lower [4,15].

The only representative of Monogenea found in zander from the Pomeranian Bay was *A. paradoxus*. The prevalence was lower than in the Gulf of Gdańsk [15] and the Vistula Lagoon [4], where in summer it was 70% and 96%, respectively. However, the value of the mean intensity of infection of zander caught in the summer in the Gulf of Gdansk and the Vistula Lagoon was similar (4 and 8.2 parasites). *A. paradoxus* was found only in 9 cm long zanders studied.

The study of Rolbiecki [31] have shown a relationship between the size of the fish and intensity of parasitic infection, which have in their development cycle a free-living stage, actively seeking host. Larger fish with a large body area are an easier target to detect and colonize by the parasite, thus it explains the low values of the parameters characterizing zander infections by *A. paradoxus* and *A. percarum*.

One typical marine species has been identified in the parasitic fauna of European perch and zander from the Pomeranian Bay. In European perch it was acanthocephalan *E. gadi*. It is a parasite of marine and eustary fish; it also occurs in freshwater reservoirs, which are connected with the sea, but there it is found much less frequently than in fish from sea waters [5, 7]. It is related to the availability of amphipods, its intermediate hosts [41].

Nematode *H. aduncum* was the only one marine species found in zanders examined in the Vistula Lagoon, where only 1% of the fish was infected [4]. Zanders get infected with this parasite only in the brackish water [15]. Probably, this is connected with their migrations to the Pomeranian Bay. These migrations are of feeding nature, associated with the dispersion of smelt stocks in summer [41] – the main component of food of zander and one of the hosts of *H. aduncum*.

Parasites of both studied species of fish from the Pomeranian Bay were divided into 4 classes based on the dominance index values. Communities of European perch and zander parasites consisted of a small number of species. A greater dominance is visible in such communities, and the remaining classes are much smaller in number [22].

Margalef biodiversity index and Simpson species richness index had similar values for parasites of European perch and zander from the Pomeranian Bay. However, the Berger-Parker dominance index differed significantly, because despite the same number of species in parasitic fauna, one group of parasites (Digenea) was

significantly dominant in zander, while the number of all parasites recorded in the sample was low.

The value of Shannon-Weaver species diversity index was significantly higher for the community of European perch parasites. This is due to a significant difference between the percentage composition of the largest groups of parasites (in both cases these were digeneans), where in zander they constituted up to 93% of the sample, while 75% in European perch. In European perches from the Oder estuary, the Shannon-Weaver index (1.3) was at a similar level, because there digeneans also accounted for the majority of parasitic fauna of European perch (73.71%) [12].

The Berger-Parker dominance index was almost twice as high for parasite community of European perch. This indicated the proportion of the most abundant species in the studied community. The higher value of this index, the lower the diversity of the community. Its value describing the parasite community of the Oder estuary European perch in 2007 [12] was much higher, since there were 13 species of parasites recorded at that time.

Zander and European perch in European waters are characterized by high abundance and wide range. However, they do not compete with each other, because despite many similarities, they exhibit large differences in feeding. Zander is a night predator, feeding most intensively in low light or low water transparency. European perch often prey in schools consisted of fish of different sizes, and it is active during the day. It may become an easier target for cercariae seeking a host.

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