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HELMINTH DIVERSITY IN TELEOST FISHES FROM THE AREA OF THE UKRAINIAN ANTARCTIC STATION "AKADEMIK VERNADSKY", ARGENTINE ISLANDS, WEST ANTARCTICA

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Helminth Diversity in Teleost Fishes from the Area of the Ukrainian Antarctic Station "Akademik Vernadsky", Argentine Islands, West Antarctica. Kuzmina, T. A., Dykyy, I. V., Salganskij, O. O., Lisitsyna, O. I., Korol, E. M., Kuzmin, Yu. I. — Monitoring studies of the species diversity in marine ecosystems provide important data on ecological changes caused by global warming and anthropogenic influence. The present work was aimed to analyze the species diversity of the helminths parasitic in teleost fishes inhabiting the area near the Ukrainian Antarctic Station "Akademik Vernadsky" (Galindez Island, Argentine Islands, West Antarctica). During April–January of 2014–2015 and 2019–2020, 156 specimens of six fish species (*Notothenia coriiceps, N. rossii, Chaenocephalus aceratus, Parachaenichthys charcoti, Trematomus bernacchii*, and *Harpagifer antarcticus*) were examined. Totally, 21,166 specimens of 31 helminth species were collected and assigned to five taxonomic groups: Monogenea (1 species), Digenea (10), Nematoda (5), Cestoda (4), and Acanthocephala (11). Twenty-six helminth species were found in *N. coriiceps*, 14 in *N. rossii*, 27 in *P. charcoti*, 23 in *Ch. aceratus*, 16 in *T. bernacchii*, and six in *H. antarcticus*. Larval stages of anisakid nematodes prevailed in the helminth community of *Ch. aceratus* (66 %) and *P. charcoti* (40 %), while other fish species were mostly infected with acanthocephalans, trematodes and cestodes. The present data on the species diversity of helminth communities can be used as a baseline for long-term monitoring studies of fish parasites in the region of the Argentine Islands.
Key words: Helminths, Acanthocephala, Nematoda, Cestoda, Trematoda, teleost fishes, Antarctica.

Introduction

Biodiversity in Antarctica and the Southern Ocean is much more extensive, ecologically diverse and biogeographically structured than it was previously thought (Chown et al., 2015). Moreover, the fauna of this region is highly endemic; recent estimates suggest that 50 to 97 % of Southern Ocean species in various taxonomic groups such as sponges, polychaetes, amphipods, molluscs, isopods, pantopods, and notothenioid fish are endemic (De Broyer et al., 2014). The fish fauna in the Southern Ocean around Antarctica is dominated by the perciform suborder Notothenioidei, which comprise up to 90 % of the fish biomass and about 77 % of fish species diversity (Near, 2009; Near et al., 2012). Notothenioidei is a group uniquely adapted to the cold environment being endemic for the Antarctic and sub-Antarctic regions (Eastman, 1991; Near, 2009).

Parasite fauna of Antarctic fishes presently includes about 250 species found in more than 142 species of hosts (Oğuz et al., 2015). Several economically valuable members of the family Nototheniidae — the Antarctic toothfish *Dissostichus mawsoni* Norman, 1937, the Patagonian toothfish *Dissostichus eleginoides* Smitt, 1898, the humped rockcod *Gobionotothen gibberifrons* Lönnberg, 1905, etc., were the subjects of a variety of parasitological studies (Parukhin & Lyadov, 1982; Brickle et al., 2005; Gordeev & Sokolov, 2016); while unexploited families have so far been rarely a focus of the research (Münster et al., 2017; Kvach & Kuzmina, 2020). Likewise, parasites of main benthic and demersal fishes: *Notothenia coriiceps* Richardson, 1844, *Trematomus newnesi* Boulenger, 1902, *T. bernacchii* Boulenger, 1902, *Parachaenichthys charcoti* (Vaillant, 1906), *Lindbergichthys nudifrons* (Lönnberg, 1905), etc. which could be easily caught using simple fishing gear — rods and nets, were also investigated in several regions of Antarctica (Wojciechowska, 1993; Zdzitowiecki, 1979, 1987, 2001; Zdzitowiecki & White, 1996; Zdzitowiecki & Laskowski, 2004; Laskowski & Zdzitowiecki, 2005; Laskowski et al., 2007; 2012; Palm et al., 2007; Kuzmina et al., 2020). Most of the parasitological studies were focused on the description of new helminth species from Antarctic fish or single parasite taxa e.g. Digenea, Cestoda, Nematoda, or Acanthocephala (Zdzitowiecki, 1983, 1986, 1987, 1991, 1997 a, b, 1998, 2002, 2003; Zdzitowiecki & White, 1992; Rocka & Zdzitowiecki, 1998; Rocka, 2003, 2004, 2006, 2017; Sokolov & Gordeev, 2016; Sokolov et al., 2016, 2019; Laskowski & Zdzitowiecki, 2017). Nowadays, populational and ecological studies of parasites of various Antarctic vertebrates and marine fishes, in particular, are the most promising direction of parasitological studies in Antarctica (MacKenzi, 2017; Kvach & Kuzmina, 2020). Complex studies of changes in species diversity and the structure of parasite communities provide the monitoring of global ecological and anthropogenic changes in marine ecosystems that are pronounced in the polar regions of the Arctic and Antarctic (Clarke et al., 2007; Chown et al., 2015; Klimpel et al., 2017).

Metazoan parasites of various taxonomic groups are known as one of the most sensitive indicators of the state of ecosystems, especially in the marine environment (Mouritsen & Poulin, 2002; Hudson et al., 2006; Poulin & Mouritsen, 2006; Poulin, 2006). This is primarily associated with their complex life cycles, which involve various species of invertebrates and vertebrates as intermediate, paratenic and definitive hosts. The decrease in the species diversity of parasite communities has been noted as an important indicator of ecological changes in marine ecosystems (Khan & Thulin, 1991; Daszak et al., 2001; Barnes & Peck, 2008). Therefore, the acquisition of new data on the species diversity of the parasite fauna in Antarctic teleost fish species is important for monitoring the marine ecosystems in this region. Comparative analysis of modern data on fish parasite communities with data collected in previous decades allows revealing the main trends in the marine ecosystems changes.

For more than 100 years of parasitological studies of Antarctica, the main part of researches on the parasites of Antarctic fish has been carried out in West Antarctica (MacKenzie, 2017). In the region of the Argentine Islands near the Ukrainian Antarctic station (UAS) "Akademik Vernadsky", parasitological studies were performed only in 2002 (Zdzitowiecki & Laskowski, 2004; Laskowski & Zdzitowiecki, 2005). In 2004–2005, some collections of helminths from various fish species were carried out; however, only fish leeches were studied in details (Utevsky, 2007). Later, the parasitological studies in 2014–2015 revealed some changes in the structure of the helminth community of the most common fish species, *Notothenia coriiceps* (Kuzmina et al., 2020); however, the insufficient amount of data did not allow associating these changes with the state of the coastal ecosystem of Galindez Island. Therefore, parasitological studies of various teleost fish species in the Argentine Islands area were continued to collect a sufficient amount of data for a comprehensive analysis of the impact of climatic and anthropogenic changes on the marine ecosystems of the region. This work was aimed to analyze the modern data on the species diversity of helminth fauna of main species of teleost fish inhabiting the region of the UAS "Akademik Vernadsky", Argentine Islands, and West Antarctica.

Material and methods

Field studies and material collection were carried out in April 2014–January 2015 and in April 2019–January 2020 during the 19th and 24th Ukrainian Antarctic expeditions to the UAS "Akademik Vernadsky"on Galindez Island, Argentine Islands, West Antarctica (65°15′ S, 64°16′ W). Totally, 156 specimens of six fish species from the Order Perciformes, namely Antarctic black rockcod *Notothenia coriiceps* Richardson, 1844, marbled rockcod *N. rossii* Richardson, 1844, blackfin icefish *Chaenocephalus aceratus* (Lönnberg, 1906), Antarctic dragonfish *Parachaenichthys charcoti* (Vaillant, 1906), emerald rockcod *Trematomus bernacchii* Bou-

Table 1. Parameters of samples and number of helminths collected from six species of teleost fishes off the area of the UAS "Akademik Vernadsky", Argentine Islands, West Antarctica

Fish species	Number	Weight, gram	Size of fish*, cm	Number of helminths collected	
				No. specimens	No. species
Notothenia coriiceps	125	165–1,233	21.5–44.5	11,277	28
Notothenia rossii	3	173–696	24.0–38.5	769	14
Parachaenichtys charcoti	15	490–943	42.0–52.0	4,005	26
Trematomus bernacchii	6	89–197	18.5–27.5	266	16
Chaenocephalus aceratus	6	673–1,484	47.0–60.0	4,830	23
Harpagifer antarcticus	1	21	10.8	19	6
Total:	156			21,166	30

*Size of fish mean the total body length.

lenger, 1902, and Antarctic spiny plunderfish *Harpagifer antarcticus* Nybelin, 1947 were examined (table 1). The fishes were caught using a fishing rod off the shore of Galindez Island at depths from 10 to 30 m. All fishes collected were immediately transported to the laboratory, measured and examined using the standard parasitological techniques (see Zdzitowiecki & Laskowski, 2004; Weber & Govett, 2009). The fishes were processed on the same day they were caught; all precautions were followed to prevent confusion of the parasites between fish specimens.

Parasites were collected manually from the body cavity, stomach, intestine, liver and mesentery; all ectoparasites were carefully collected from the fish body and gills. All helminths were washed in saline and fixed in 70 % ethanol. Acanthocephalans were kept in tap water for 30 min to 3 hours for proboscis evagination prior to their fixation in 70 % ethanol. Helminths belonging to main taxonomic groups (monogeneans, nematodes, cestodes, trematodes and acanthocephalans) were counted, fixed and stored separately. Identification of the parasites was performed in the laboratory of the Department of Parasitology, I. I. Schmalhausen Institute of Zoology in Kyiv, Ukraine, using the Zeiss Axio Imager M1 compound microscope equipped with DIC optics and a digital imaging system. Prior to identification, all nematodes, cestodes and trematodes were clarified in lactophenol (25 % lactic acid, 25 % phenol, 25 % glycerin, and 25 % distilled water); acanthocephalans were studied on temporary total mounts in the Berlese medium (Swan, 1936; Kuzmina et al., 2020).

Identification of nematodes was performed according to Mozgovoy (1951) and Rocka (1999, 2017); cestodes were identified according to Wojciechowska (1993) and Rocka (2003, 2017); trematodes were identified according to Zdzitowiecki (1996), Zdzitowiecki and Cielecka (1997 a, b), Gibson et al. (2002), and Jones et al. (2005). Identification of acanthocephalans was performed according to Zdzitowiecki (1983, 1984 a, b, 1987, 1996) and Laskowski and Zdzitowiecki (2017). The helminth specimens were deposited in the Parasitological collection of the Department of Parasitology of the I. I. Schmalhausen Institute of Zoology NAS of Ukraine (Kyiv, Ukraine) and the Helminthological Collection of the Institute of Parasitology, Czech Academy of Sciences (České Budějovice, Czech Republic).

Data summaries and descriptive analyses were performed using Microsoft Excel and Paleontological Statistics Software (PAST v. 3.0) (Hammer et al., 2001). The prevalence, mean abundance, means and median intensity were calculated for each helminth species following the definitions of Bush et al. (1997). The species richness in the helminth community estimated using Chao1 and bootstrap methods were calculated using the PRIMER 6 software (Clarke & Gorley, 2006). The Sørensen similarity index was used to compare the helminth species composition in separate fish hosts. The results were visualised by the cluster analysis in the PRIMER 6 software.

Results

All fish specimens examined were infected with helminths; each fish individual harboured from 3 to 21 helminth species and from 9 to 1418 helminth specimens. In total, 21,166 specimens of helminths were collected and assigned to 31 species belonging to five taxonomic groups: Monogenea (1 species), Digenea (10), Nematoda (5), Cestoda (4), and Acanthocephala (11) (table 2). Host specificity of the helminth species to their fish hosts was estimated as low, for most species were found in several fish hosts. Five species (nematodes *Pseudoterranova* sp. and *Contracaecum* sp., acanthocephalans *Corynosoma evae, C. pseudohamanni*, and *Metacanthocephalus rennicki*) were registered in all six fish species; three species of trematodes and two species of acanthocephalans were found in five fish species; four helminth species were found in four fish species (table 2).

Table 2. Helminth species found in six teleost fish species in coastal waters of the Galindez Island (Argentine Islands, West Antarctica). Parameters of fish infection: P — prevalence, I — mean intensity with range (minimum–maximum)

N	Helminth species P, %	*N. coriiceps* (n = 140)		*N. rossii* (n= 3)		*P. charcoti* (n = 15)		*Ch. aceratus* (n = 6)		*T. bernacchii* (n = 6)		*H. ant-arcti-cus* (n = 1)
		I (min–max)	P*	I (min–max)	P, %	I (min–max)	P, %	I (min–max)	P, %	I (min–max)	+/—**	
	PLATYHELMINTHES: MONOGENEA											
1.	*Pseudobenedenia nototheniae* Johnston,1931	36,8	6.7 (1–42)	1/3	1	–	–	–	–	–	–	–
	PLATYHELMINTHES: TREMATODA											
2.	*Elytrophalloides oatesi* (Leiper et Atkinson, 1914)	43.2	5.6 (1–36)	2/3	62.0 (28–96)	40.0	22.8 (1–71)	100.0	12.4 (1–48)	50.0	6.3 (1–66)	–
3.	*Genolinea bowersi* (Leiper et Atkinson, 1914)	68.0	10.1 (1–42)	2/3	30.5 (3–58)	53.3	27.7 (1–113)	100.0	23.2 (1–69)	50.0	5.0 (2–7)	+
4.	*Glomericirrus macrouri* (Gaevskaja, 1973)	–	–	–	–	6.7	2	16.7	1	33.3	1.5 (1–2)	–
5.	*Lecithaster macrocotyle* Szidat et Graefe, 1967	2.4	2.0 (1–3)	–	–	13.3	2.0 (1–3)	33.3	6.0 (4–8)	16.7	1	–
6.	*Lepidapedon garrardi* (Leiper et Atkinson, 1914)	7.2	1.4 (1–3)	–	–	6.7	1	–	–	–	–	–
7.	*Macvicaria georgiana* (Kovaljova et Gaevskaya,1974)	80.8	25.2 (1–122)	1/3	1	–	–	66.7	3.8 (1–9)	–	–	–
8.	*Macvicaria pennelli* (Leiper & Atkinson, 1914)	–	–	–	–	73.3	5.6 (1–19)	–	–	–	–	–
9.	*Neolebouria georgiensis* Gibson, 1976	4.8	2.8 (1–7)	1/3	1	93.3	70.0 (4–222)	83.3	34.0 (2–115)	–	–	–
10.	*Lecitophallum* sp.	–	–	–	–	6.7	2	–		–	–	–
11.	*Derogenes johnstoni* Prudhoe et Bray, 1973	4.0	1.8 (1–5)	1/3	15	6.7	1	16.7	1	33.3	2.5 (1–4)	–
	PLATYHELMINTHES: CESTODA											
12.	*Diphyllobothrium* sp.	78.4	11.1 (1–58)	–	–	46.7	10.3 (1–33)	100.0	36.0 (8–75)	100.0	15.0 (2–41)	–
13.	Monolocular metacestode	11.2	1.5 (1–4)	–	–	13.3	1.0 (1–1)	50.0	1.0 (1–1)	–	–	–
14.	Bilocular metacestode	34.4	2.3 (1–8)	–	–	80.0	8.8 (1–26)	50.0	5.7 (1–14)	–	–	–

Continied Table 2.

15.	Trilocular metacestode	13.6	1.4 (1–3)	–	–	40.0	1.2 (1–2)	–	–	–	–	–
	NEMATODA: CHROMADOREA											
16.	*Ascarophis nototheniae* Johnston et Mawson, 1945	9.6	12.4 (1–49)	–	–	33.3	18.0 (1–39)	66.7	36.3 (14–65)	66.7	4.9 (1–8)	–
17.	*Dichelyne fraseri* (Baylis, 1929)	5.6	1.3 (1–3)	–	–	–	–	–	–	–	–	–
18.	*Anisakis* sp.	4.8	1.5 (1–2)	–	–	13.3	1.0 (1–1)	16.7	1	16.7	1	–
19.	*Contracaecum* sp.	40.0	5.1 (1–31)	2/3	23.0 (9–37)	100.0	43.3 (2–280)	100.0	308.5 (1–701)	66.7	2.5 (1–5)	+
20.	*Pseudoterranova* sp.	96.0	14.2 (1–74)	3/3	11.0 (2–21)	100.0	57.7 (13–178)	100.0	185.5 (59–403)	66.7	3.8 (2–8)	+
	ACANTHOCEPHALA: PALAEACANTHOCEPHALA											
21.	*Aspersentis megarhynchus* (Linstow, 1892) = syn. *A. austrinus* Van Cleave, 1929	11.2	4.0 (1–17)	1/3	1	–	–	–	–	–	–	–
22.	*Corynosoma bullosum* (Linstow, 1892)	–	–	–	–	33.3	2.8 (1–6)	66.7	2.5 (2–3)	–	–	–
23.	*C. evae* Zdzitowiecki, 1984	15.2	5.2 (1–13)	3/3	5.7 (1–13)	26.7	5.5 (2–8)	83.3	16.4 (7–51)	66.7	5.0 (1–17)	+
24.	*C. hamanni* (Linstow, 1892)	3.2	5.0 (1–14)	–	–	20.0	7.3 (1–18)	50.0	15.7 (4–26)	16.7	1	–
25.	*C. pseudohamanni* Zdzitowiecki, 1983	37.6	26.8 (1–138)	3/3	128.7(38–244)	86.7	20.9 (1–89)	83.3	146.2 (80–301)	100.0	8.5 (1–16)	+
26.	*C. shackletoni* Zdzitowiecki, 1978	8.8	1.2 (1–2)	–	–	–	–	16.7	1	–	–	–
27.	*Echinorhynchus petrotschenkoi* (Rodjuk, 1984)	–	–	–	–	13.3	1.0 (1–1)	–	–	–	–	–
28.	*Metacanthocephalus dalmori* Zdzitowiecki, 1983	39.2	4.7 (1–33)	–	–	73.3	1.0 (1–1)	16.7	1	–	–	–
29.	*M. campbelli* (Leiper & Atkinson, 1914)	30.4	3.4 (1–14)	3/3	2.0 (1–3)	66.7	5.5 (1–18)	66.7	4.3 (1–7)	66.7	2.5 (1–6)	–
30.	*M. johnstoni* Zdzitowiecki, 1983	83.2	10.4 (1–62)	3/3	15.7 (9–23)	73.3	6.2 (1–20)	66.7	5.5 (1–11)	33.3	2.5 (2–3)	–
31.	*M. rennicki* (Leiper & Atkinson, 1914)	85.6	9.3 (1–79)	2/3	15.0 (8–22)	93.3	17.3 (2–78)	83.3	10.4 (2–35)	50.0	1.0 (1–1)	+

*Prevalence is indicated as a number of infected specimens of 3 examined fishes.
**Presence (+) or absence (—) of the helminth species in HA host.

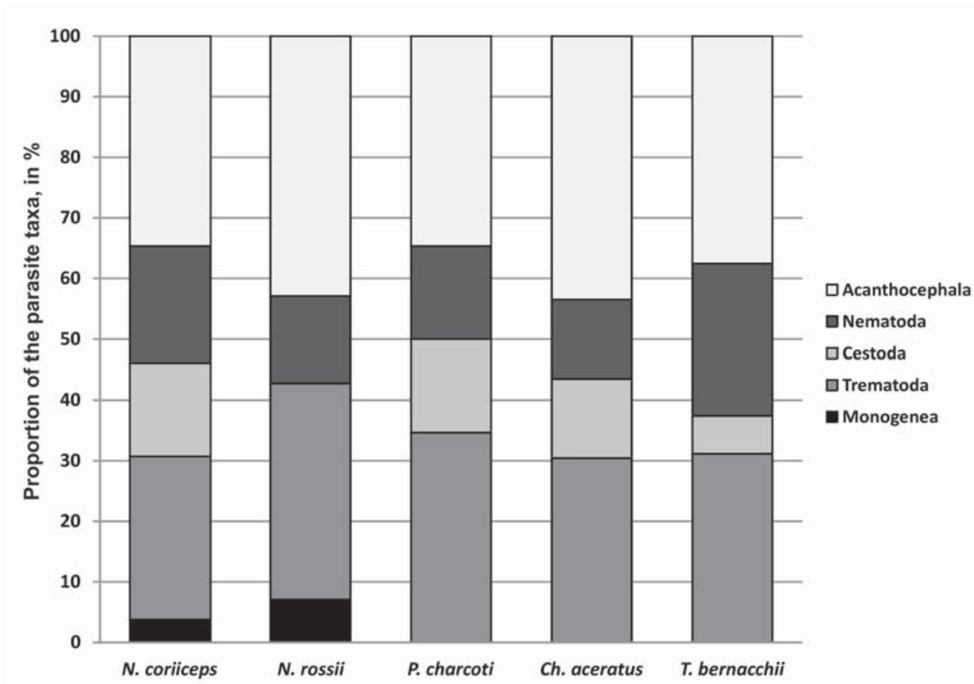

Fig. 1. Proportion (%) of five parasite taxa found in teleost fish off the area of the UAS "Akademik Vernadsky", Argentine Islands, West Antarctica.

In terms of species diversity, the proportion of separate parasite taxa varied in different fish species. Nevertheless, in all fish species studied, the largest numbers of species were recorded for acanthocephalans and digenean trematodes (fig. 1).

In term of the intensity of fish infection, nematodes prevailed in predacious fish species *Ch. aceratus* (up to 66 % of total helminth number) and *P. charcoti* (up to 40 %); while *N. coriiceps*, *N. rossii* and *T. bernacchii* which feed on macroalgae and benthic invertebrates (amphipods, isopods, euphausiids, polychaetes, molluscs) were infected mostly with acanthocephalans, trematodes and larval stages of cestodes (fig. 2).

Twenty-six helminth species were recorded in *N. coriiceps* (table 2). Eleven species including all cestodes, nematodes of the genera *Anisakis*, *Contracaecum* and *Pseudoterranova*, and acanthocephalans of the genus *Corynosoma* parasitize this fish host at their larval stages; therefore, *N. coriiceps* is considered to be a definitive host for 15 out of 26 helminth species recorded. In three specimens of the another species of the genus *Notothenia, N. rossii,* 14 helminth species were found, six of them parasitized this host on their larval stages (table 2). Thus, *N. rossii* is considered to be a definitive host for eight out of 14 helminth species recorded.

Twenty-seven helminth species were found in *P. charcoti* (table 2); it is considered to be a definitive host for 15 out of 27 helminth species recorded. In *Ch. aceratus*, 23 helminth species were found; the blackfin icefish is a definitive host of 13 out of 23 helminth species recorded. In *T. bernacchii,* 16 helminth species were found; the emerald rockcod is a definitive host for nine out of 16 helminth species. The smallest number of helminths was found in one examined specimen of *H. antarcticus*: six species of three taxonomic groups (table 2).

Three helminth species were first registered in separate teleost fishes: cercoids of monolocular metacestode were first found in *P. charcoti* and *Ch. aceratus*; monogenean *Derogenes johnstoni* was first recorded in *P. charcoti* and *Ch. aceratus*, and the larval stages of *Anisakis* sp. in *P. charcoti, Ch. aceratus* and *T. bernacchii*. All three helminth species were rather rare in all fish hosts, just single specimens of them were found in all infected fish individuals (table 2).

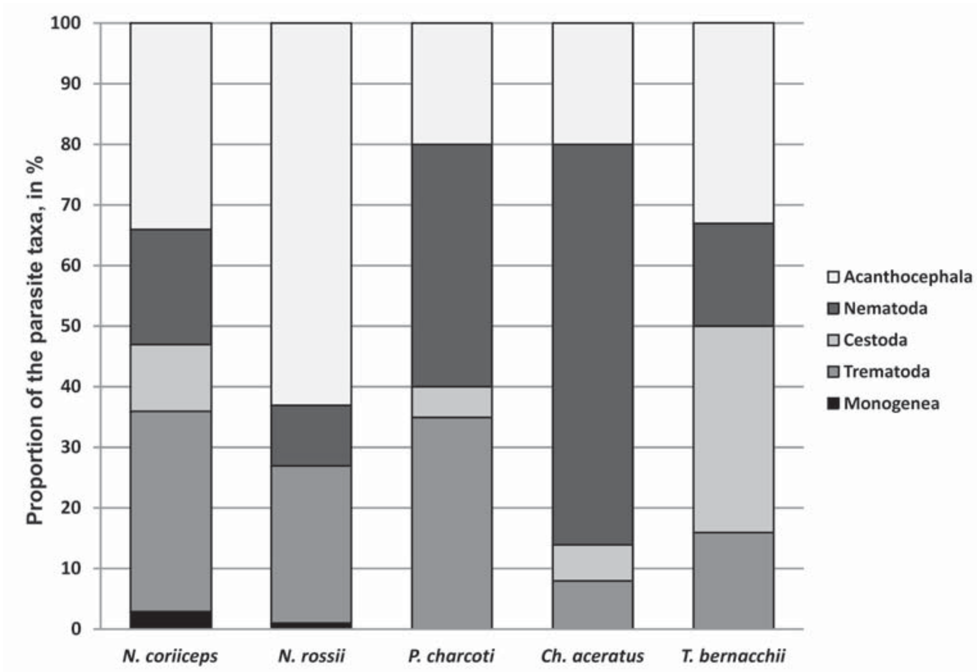

Fig. 2. Intensity of teleost fish infection off the area of the UAS "Akademik Vernadsky" by five parasite taxa (proportion of different parasite taxa is in %).

Proportion of helminth species parasitizing teleost fish species on larval stages was 42–44 %, while 56–58 % of helminths found in five fish species were adult parasites (fig. 3).

Data on the prevalence and intensity of infection of five teleost fish species with separate helminth species (see table 2) demonstrated that trematodes *E. oatesi, G. bowersi, Macvicaria* spp., larvae of *Diphyllobothrium* sp., nematodes from the genera *Contracaecum* and *Pseudoterranova* and acanthocephalans from the genera *Corynosoma* and *Metacanthocephalus* were prevalent in five fish species examined (parameters of *H. antarcticus* infection are not estimated).

We analyzed the species richness in the parasite communities from four fish species examined (table 3). Expectedly, larger host samples contained a comparatively larger number of helminth species. On the other hand, the helminth species richness in *P. charcoti* appeared to be similar to that in *N. coriiceps*, despite the difference in the sample size. The helminth species richness in *Ch. aceratus*, both observed and estimated, was higher than that in *T. bernacchii*, while the host sample size was the same. Even though the sample size of *Ch. aceratus* and *T. bernacchii* (n = 6) could not yield statistically significant estimation of the helminth species richness, it may be presumed that the richness is higher in the former host species. This observation is confirmed by the higher average species richness in the helminth infracommunities in *Ch. aceratus*, 13.7 vs. 8.3 (table 3). Besides, this parameter

Table 3. Parameters of the helminth species richness in separate fish species examined off the area of the UAS "Akademik Vernadsky", Argentine Islands, West Antarctica

Parameters of species richness	*N. coriiceps* (n = 140)	*P. charcoti* (n = 15)	*Ch. aceratus* (n = 6)	*T. bernacchii* (n = 6)
Observed number of species	26	27	23	16
Estimated species richness (Chao1 ± SD)	28 ± 2.6	28 ± 0.9	23 ± 9.5	16 ± 6.6
Estimated species richness (bootstrap)	29	29	25	17
Species richness in infracommunities: mean [median] (min–max)	9.0 [8] (3–15)	13.2 [13] (10–20)	13.8 [13.5] (8–20)	8.3 [8] (6–12)

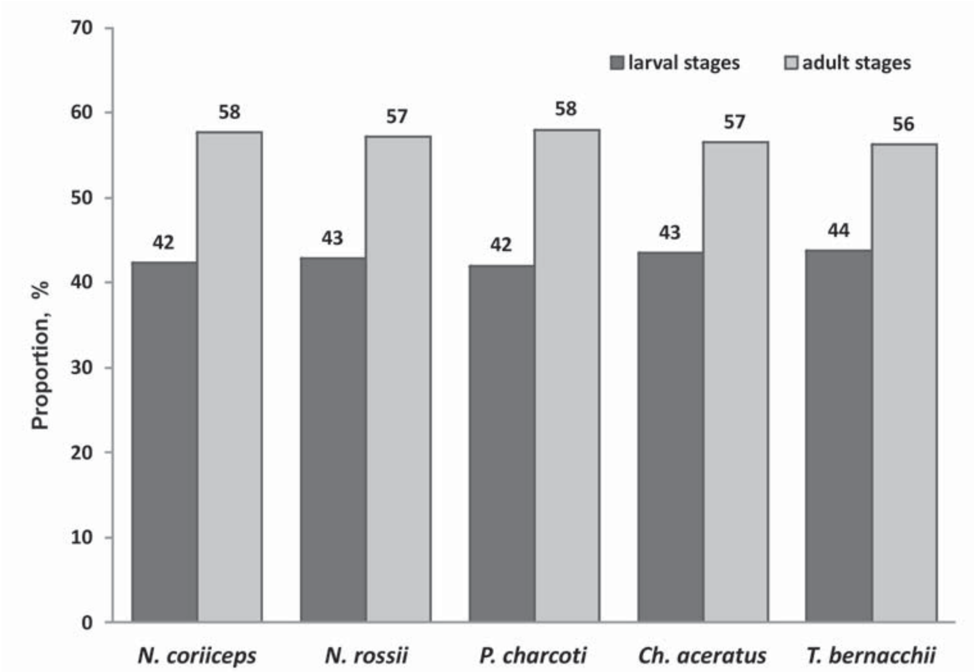

Fig. 3. Proportion (in %) of helminth species parasitize five Antarctic teleost fishes off the area of the UAS "Akademik Vernadsky" on larval and adult stages.

was higher in helminth infracommunities in *P. charcoti* (13.2) compared to those in *N. coriiceps* (9.0), though the species richness in the helminth component community was similar in two hosts.

Similarity of the helminth communities of five fish species examined, excluding a single specimen of *H. antarcticus*, was rather high; the Sørensen index between all samples was higher than 0.50. The maximum similarity was noted for helminth communities of *Ch. aceratus* and *P. charcoti* (Sørensen index = 0.88); the helminth community of *N. rossii* was the least similar to other host species (Sørensen index = 0.67). The cluster analysis confirmed the similarity of the helminth communities of *Ch. aceratus* and *P. charcoti* (fig. 4); the helminth community *N. coriiceps* was found to be the closest to the cluster of *Ch. aceratus* and *P. charcoti*.

Discussion

Our study provides new data on the species diversity of helminths parasitize the main teleost fish species in the region of Argentine Islands, West Antarctica; these data extend the list of helminth species to 31 species. In previous parasitological studies performed at the UAS "Akademik Vernadsky" in 2002, 21 species of helminths were found in teleost fishes, in particular, 21 in *N. coriiceps*, 14 in *T. bernacchii*, and seven in *H. antarcticus* (Zdzitowiecki & Laskowsky, 2004; Laskowsky & Zdzitowiecki, 2005). Any information on the parasite fauna of *N. rossii*, *P. charcoti*, and *Ch. aceratus* from the Argentine Islands area has not been published till now.

Species diversity of the helminth communities in teleost fish registered in our study was rather high: 27 helminth species were found in *P. charcoti*, 26 in *N. coriiceps*, and 23 in *Ch. aceratus* (table 2). The lower number of helminth species found in *N. rossii, T. bernacchii*, and *H. antarcticus* is apparently associated with a small number of specimens of each of these fish species examined in the present study. These three fish species are rare in the Argentine Islands region; in scientific catches in the waters of the UAS "Akademik Vernadsky" the proportions of these fish species were from 0.6 % to less than 10 % (Manilo,

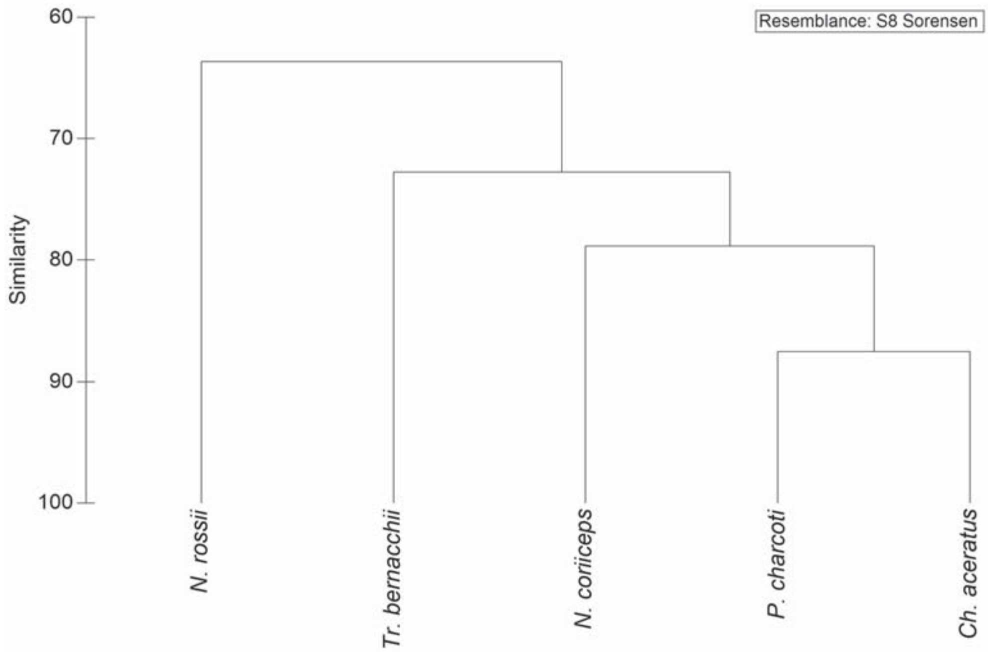

Fig. 4. Cluster analysis of the similarity between the helminth communities in five teleost fish species off the area of the UAS "Akademik Vernadsky", Argentine Islands, and West Antarctica.

2006; Veselskyy & Khoetskyy, 2018). Analysis of the published data on the parasites of these rare fish species from other regions of West Antarctica revealed that the number of specimens in samples studied by other researchers was also small, from single specimens to 10–15 specimens caught from one place (Zdzitowiecki, 2001; Laskowsky & Zdzitowiecki, 2005; Palm et al., 2007). Thus, our data on the helminth species diversity of teleost fishes collected in the present study are comparable with those from other regions of West Antarctica.

Of the five taxa of metazoan parasites found in Antarctic fishes in this study, the greatest species diversity was recorded for acanthocephalans (11 species) and digenean trematodes (10 species). The intensity of fish infection by different helminth taxa differed significantly. In the predatory blackfin icefish *Ch. aceratus*, nematodes accounted for 66 % of the total helminth number, with 95.4 % of them being larval stages of anisakid nematodes of the genera *Contracaecum* (58.4 %) and *Pseudoterranova* (37.0 %). These nematodes are parasites of pinnipeds; they use teleost fishes are their paratenic hosts (Mozgovoy, 1951; Palm et al., 1998; Anderson, 2000; Rocka, 2006). Other fish species feeding mostly on benthic invertebrates and macroalgae were mainly infected with acanthocephalans and trematodes which are transmitted via various species of amphipods, isopods, euphausiids and molluscs as their intermediate hosts.

In the present study, the helminth community of Antarctic rockcod *N. coriiceps* included 26 species from five taxonomic groups (monogeneans, trematodes, cestodes, nematodes and acanthocephalans). In the studies conducted at UAS "Akademik Vernadsky" in 2002, 21 helminth species were found in this fish species (Zdzitowiecki & Laskowsky, 2004). Previously, the helminth fauna of *N. coriiceps* was investigated in different regions of Antarctica. Twenty-two parasites species including 18 species of helminths were recorded in *N. coriiceps* in the Potter Cove of the King George Island (Palm et al., 1998); 27 helminth species were found in the Admiralty Bay region of the King George Island and South Shetland Islands (Zdzitowiecki & Laskowsky, 2004). In recent research in the Fildes Bay area near King George Island, 12 helminth species have been found (Muñoz & Rebolledo, 2019). Thus, of the 41 helminth species registered in total in *N. coriiceps* (see Oğuz et al., 2015), 63 % were found in the present study. This indicates a rather high helminth species richness in this fish species in the region of the Argentine Islands.

The second fish species of the genus *Notothenia*, *N. rossii*, is rare in the area of the Argentine Islands; its proportion in catches is about 1 % (Manilo, 2006; Veselskyy & Khoetskyy, 2018). Only 3 specimens of *N. rossii* were caught and examined in the present study; this number does not allow a reliable assessing of the main parameters of its infection with helminth. However, 14 species of helminths were found in the three studied specimens, which constitutes 41.2 % of the 34 helminths species previously recorded in *N. rossii* (Oğuz et al., 2015; Muñoz & Rebolledo, 2019). In East Antarctica, 19 helminth species of helminths were collected from 30 specimens of *N. rossii* (Parukhin, 1986); while in recent studies near King George Island, West Antarctica, only 13 species were recorded in this host (Muñoz & Rebolledo, 2019). We believe that more helminth species would be found in larger fish samples of *N. rossii* from the Argentine Islands area.

The highest species diversity was registered in Antarctic dragonfish *P. charcoti* — 27 species of helminths representing 93 % of the total helminth species number recorded in this fish species (Oğuz et al., 2015; Münster et al. 2017). Data on the helminth species richness in *P. charcoti* significantly differ in different studies performed in West Antarctica. Zdzitowiecki (2001) registered 18 species of helminths in the Antarctic dragonfish from the Bransfield Strait and Joinville shelf. In the studies conducted by Palm et al. (2007), and later by Münster et al. (2017) on the German research vessel Polarstern at the depth of 80–480 m and 100-300 m, each of the researchers found 11 species of helminths in *P. charcoti*; the total number of species detected and identified by these authors was 13. We believe that the greater species richness in the *P. charcoti* helminth community in our study is connected with comparatively higher diversity of invertebrates (crustaceans and molluscs) in the coastal waters near Galindez Island; these invertebrates are intermediate hosts of trematodes and acanthocephalans and participate in the transmission of these parasites in coastal ecosystems.

Twenty-three helminths species were recorded in six specimens of the blackfin icefish, *Ch. aceratus* in the present study; this number comprises 79 % of the total number of 29 species recorded in this host (Oğuz et al., 2015). The blackfin icefish were mainly infected with nematodes (66 % of the total helminth number), mostly with larval stages of anisakid nematodes of the genera *Contracaecum* and *Pseudoterranova* (see table 2). Various authors noted that Channichthyids, including blackfin icefish, occupy a key position in the life cycles of anisakids in the Antarctic (Kock, 1992; Oğuz et al., 2012; Kuhn et al., 2018); their definitive hosts are marine mammals (Weddel seal, Antarctic fur seal, etc.). Predacious *Ch. aceratus* feeds mostly on small pelagic fishes and krill; therefore it actively accumulates anisakid larvae as the paratenic host. High infection of *Ch. aceratus* by anisakid nematodes was also recorded in previous studies (Siegel, 1980; Palm et al., 2007; Rokicki et al., 2009; Oğuz et al., 2012).

In emerald rockcod, *T. bernacchii* 16 helminth species were recorded; this number corresponds to 64 % of a total of 25 species reported in this fish (Oğuz et al., 2015). From eight to 14 helminth species were recorded in the helminth community of *T. bernacchii* in separate studies previously (Moser & Cowen, 1991; Laskowski & Zdzitowiecki, 2005; Zdzitowiecki & Ozouf-Costaz, 2013); thus, our data indicate a rather high helminth species diversity in this fish species from the Argentine Islands region.

Only one specimen of rare demersal fish species *H. antarcticus*, was examined in the present study. Accordingly, six helminth species were found. This represents only 35 % of the 17 species recorded in this host (Zdzitowiecki & Zadrozny 1999; Oğuz et al., 2015). In the previous parasitological study of two *H. antarcticus* specimens from the Galindez Island area, seven helminth species were found (Laskowski & Zdzitowiecki, 2005). Also, seven helminth species were identified in ten specimens of this fish from the Fildes Bay of King George Island (Muñoz & Cartes, 2020). Earlier, Zdzitowiecki and Zadrozny (1999) identified 15–16 species and larval forms of helminths from 50 specimens of *H. antarcticus*. The material collected in our study does not allow us to perform any analysis of the parasite community; therefore, this fish species was excluded from the data analysis.

Analysis of the species richness in the helminth communities from four fish species represented by larger samples in the present study revealed the similarity of this parameter in the communities from *P. charcoti* and *N. coriiceps*, despite the difference in the sample size of these hosts. Also, a comparatively high helminth species richness was recorded in six specimens of the predatory fish *Ch. aceratus* (table 3). We assume that the higher species richness in the infracommunities of predatory fish species *Ch. aceratus* (13.8 species per host) and *P. charcoti* (13.2 species per host) is associated with the accumulation of helminths in predatory fishes due to their feeding on both invertebrate intermediate and fish paratenic hosts of helminths.

Comparison of the helminth species diversity in six fish species studied revealed very low host-specificity of the helminths; only the trematode *Macvicaria penelli* and the nematode *Dichelyne fraseri* were found each in one host species in our study. However, both these species were found in several Antarctic fishes in previos surveys (see Oğuz et al., 2015). In our study, five helminth species were recorded from all six fish hosts, five species — in 5 hosts, and 4 species — in 4 fish hosts (table 2). Low host specificity was previously reported for all groups of helminths of Antarctic fishes (Rocka, 2006, 2017; Faltýnková et al., 2017; Laskowski & Zdzitowiecki, 2017) except monogeneans (Klapper et al., 2017). We suppose that low host specificity in Antarctic helminths is associated both with a wide range of invertebrate species, which can be intermediate hosts of helminths (Rocka, 2006; Busch et al., 2012) as well as a wide variety of diets of the Antarctic fish species that includes various invertebrates and small fish species (McKenna, 1991; Reid et al., 2007; Kuhn et al., 2018; Barrera-Oro et al., 2019).

Comparison of the species composition of the helminth communities in five fish species examined in this study using the Sørensen index showed that even in a small number of examined individuals, the helminth communities of the predatory fish species *Ch. aceratus* and *P. charcoti* had the greatest similarity; the omnivorous species *N. coriiceps* was found to be the closest to them. The differences in the species composition of the helminth communities of *N. rossii* and *T. bernacchii* from other fish species observed in this study should be verified by investigation of large samples of these fish species.

As fish parasites are directly linked to the food chain in the Southern Ocean (Kuhn et al., 2018; Barrera-Oro et al., 2019), and the Antarctic bony fishes play an important role in the completion of life cycles of many helminth species as their definitive, intermediate and paratenic hosts (Palm et al., 1998; Rocka, 2006, 2017), the information on the species diversity of teleost fish parasites and its temporal and spatial changes can provide valuable information on ecology, trophic interactions and state of populations of various Antarctic vertebrates, including marine mammals and fish-eating birds in the Argentine Islands region. We believe that the current data on the species diversity of helminth communities of the main teleost fish species obtained in our study can be used as a baseline for further long-term monitoring studies of fish parasite communities and allow to estimate the changes in the marine ecosystems of West Antarctica.

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