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HELMINTHS OF ANTARCTIC ROCKCOD *NOTOTHENIA CORIICEPS* (PERCIFORMES, NOTOTHENIIDAE) FROM THE AKADEMIK VERNADSKY STATION AREA (ARGENTINE ISLANDS, WEST ANTARCTICA): NEW DATA ON THE PARASITE COMMUNITY

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Helminths of Antarctic Rockcod *Notothenia coriiceps* (Perciformes, Nototheniidae) from the Akademik Vernadsky Station Area (Argentine Islands, West Antarctica): New Data on the Parasite Community. Kuzmina, T. A., Salganskij, O. O., Lisitsyna, O. I., Korol, E. M. — The aim of our study was to update the information on taxonomic diversity and structure of the parasite community of Antarctic rockcod, *Notothenia coriiceps* in the coastal water off the Argentine Islands (Wilhelm Archipelago, Graham Land, West Antarctica). The material for this study was collected in 2014–2015 at the Ukrainian Antarctic station "Akademik Vernadsky". More than 8,500 specimens of parasites from 106 host specimens were collected and identified. All fishes were found to be infected with helminths; 25 helminth species were identified. Acanthocephalans were recorded in 93.4 % of hosts; eight species of acanthocephalans (*Metacanthocephalus rennicki, M. johnstoni, M. campbelli, M. dalmori, Aspersentis megarhynchus, Corynosoma hamanni, C. pseudohamanni*, and *C. evae*) were found. Nematodes were found in 96.2 % of fishes; larval stages of *Pseudoterranova* sp., *Contraceacum* sp., *Anisakis* sp. and adults *Ascarophis nototheniae* and *Dichelyne fraseri* were identified. Trematodes were found in 94.3 % of fishes; seven species (*Macvicaria georgiana, Neolebouria antarctica, Lepidapedon garrardi, Genolinea bowersi, Elytrophalloides oatesi, Lecithaster macrocotyle, Derogenes johnstoni*) were identified. Larval stages of cestodes (*Diphyllobothrium* sp. and tetraphyllidean metacestodes) and the monogenean species *Pseudobenedenia nototheniae* were found. Our studies revealed significant changes in the structure of the parasite community of *N. coriiceps* during the last decade.

Key words: *Notothenia coriiceps,* helminths, Acanthocephala, Nematoda, Cestoda, Trematoda, Antarctica.

Introduction

The Antarctic black rockcod, *Notothenia coriiceps* Richardson, 1844 previously referred to as *Notothenia neglecta* (Nybelin) is the dominant inshore demersal fish in waters off the west Antarctic Peninsula, including the South Shetland Islands (Casaux et al., 1990; Iken at al., 1997; Near, 2009). *Notothenia coriiceps* has a circum-Antarctic distribution. This species was recorded at sites in the western Ross Sea, the Weddell Sea, the Western Antarctic Peninsula, near the islands of the Scotia Arc to South Georgia, the Balleny Islands, and the sub-Antarctic islands of the Indian Ocean sector (Eastman, 1993; Barrera-Oro, 2002; Barrera-Oro and Marschoff, 2007). In the coastal waters of the Argentine Islands and in the area close to the Ukrainian Antarctic Station (UAS) "Akademik Vernadsky", *N. coriiceps* is the most abundant species of fish; its proportion in fish catches ranged from 51.2 % up to 95.4 % (Manilo, 2006). As the black rockcod is a non-commercial fish species in contrast to other nototheniids, such as *Notothenia rossii* Richardson, 1844, *Dissostichus mawsoni* Norman, 1937, and *Gobionotothen gibberifions* (Lönnberg, 1905), the stock of *N. coriiceps* does not show the tendency of decline during the last decades (Barrera-Oro et al., 2000; Barrera-Oro and Marschoff, 2007; Near, 2009). Therefore, this fish species can be used as an indicator species for monitoring ecological and environmental changes in the Antarctic coastal ecosystems.

Notothenia coriiceps is an important component of diets of many piscivorous birds and seals (Barrera-Oro, 2002; Casaux and Barrera-Oro, 2006, 2013; Casaux et al., 2011). Therefore, this species is included in complex life cycles of various parasites (Palm et al., 1998; Rocka, 2006). The first studies of the helminths parasitizing black rockcod were published by Linstow (1892) and Ralliet and Henry (1907), who studied nematodes and acanthocephalans in fish from Antarctica including South Georgia. Later, several separate studies on nematodes, cestodes, acanthocephalans and digenetic trematodes of *N. coriiceps* were performed on limited samples collected in various parts of the Southern Ocean around Antarctica (Johnston, 1937, 1938; Johnston and Best, 1937; Johnston and Mawson, 1945; Szidat, 1965; Prudhoe, 1969; Prudhoe and Bray, 1973). The broad list of *N. coriiceps* parasites that included 19 species was published by Zdzitowiecki et al. (1998) and Zdzitowiecki (2001). In the area of the UAS "Akademik Vernadsky", the studies of helminths from *N. coriiceps* were carried out in February–March 2002 by the researchers from the W. Stefansky Institute of Parasitology (Poland); in total, 21 species of helminths were found in the black rockcod in this area (Zdzitowiecki and Laskowski, 2004; Laskowski and Zdzitowiecki, 2005). Also, several species of ectoparasitic fish leeches were reported in *N. coriiceps* in this area (Utevsky, 2007). Since then, comprehensive collections and examination of the parasites of marine fishes including *N. coriiceps* have not been carried out in the water off the Argentine Islands.

In 2014–2015, during the 19th Ukrainian Antarctic expedition, extensive parasitological studies of various fish species including *N. coriiceps* were carried out. Helminths from different taxa have been collected weekly for 10 months. The aims of the present study were to update the information on the parasites of the Antarctic black rockcod off the Galindez Island near the UAS "Akademik Vernadsky", and to investigate possible changes in species diversity and structure of the helminth community in *N. coriiceps* during the last decade as a possible reflection of ecological changes in the shore ecosystem of the Argentine Islands.

Material and methods

Field studies and material collection were carried out in April 2014–February 2015 during the 19th Ukrainian Antarctic expedition to the UAS "Akademik Vernadsky" on the Galindez Island, Argentine Islands (65˚15' S, 64˚16' W). Totally, 106 individuals of *N.* coriiceps were caught using a fishing rod off the shore of the 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 and Laskowski, 2004; Weber and Govett, 2009). The standard length of the fishes ranged from 21.5 cm to 44.5 cm (average 32.9 ± 6.1 cm); four specimens of fish were not measured. In the laboratory, all fishes were examined on the same day they were caught. Five to 18 fishes were collected and examined monthly.

Parasites were collected manually from the skin, body cavity, stomach, intestine, liver and mesentery. All parasites were washed in saline (0.9 % NaCl) 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 ethanol. Helminths belonging to main taxonomic groups (nematodes, cestodes, trematodes, monogeneans and acanthocephalans) were counted and stored separately. Identification of the parasites was performed in the laboratory of the Department of Parasitology, I. I. Schmalhausen Institute of Zoology NAS of Ukraine in Kyiv, using a 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). Identification of nematodes was performed according to Mozgovoj (1953) and Rocka (1999); cestodes were identified according to Wojciechowska (1993); trematodes were identified according to Zdzitowiecki (1979), Zdzitowiecki and Cielecka (1997). Morphology of acanthocephalans was studied on temporary total mounts in the Berlese medium; some specimens were stained with iron acetocarmine and permanently mounted in Canada balsam. Identification of acanthocephalans was performed according to Zdzitowiecki (1983, 1984 a, b, 1987); identification of monogeneans was performed according to the description by Suydam (1972). Totally, 8,398 specimens of parasites were collected and identified; among them 1,513 specimens of nematodes, 883 specimens of cestodes, 3,368 specimens of trematodes, 192 specimens of monogeneans and 2,442 specimens of acanthocephalans. Additionally, 7,597 tissue cysts containing cystacanths of acanthocephalans were collected from the fish body cavity. As the cysts were fixed in 70 % ethanol, we could extract and identify cystacants from just about 13 % of cysts collected; extractions and identification of most cystacanths were not performed. All helminth specimens were deposited in the Parasitological collection of the Department of Parasitology of the I. I. Schmalhausen Institute of Zoology NAS of Ukraine.

Data summaries and descriptive analyses were performed using the Microsoft Excel and Paleontological Statistics Software (PAST v. 3.0) (Hammer et al., 2001). The Kruskal–Wallis test was used to analyze the differences in helminth infections of *N. coriiceps* of different size groups and during different seasons. The proportion of the helminth species in the parasite community was calculated as the ratio (in %) of the number of specimens of a certain species to the total number of helminths collected.

Results

1. Helminths of *N. coriiceps*

All fishes examined (100 %) were found to be infected with at least one species of helminths. Totally, 25 species of helminths were found in *N. coriiceps* near the UAS "Akademik Vernadsky" in 2014–2015 (table 1). Five main taxonomic groups of helminths were documented in *N. coriiceps*: one species of Monogenea, seven species of Trematoda, larvae of several species of Cestoda and Nematoda, two species of Nematoda, and eight species of Acanthocephala. Nematodes (prevalence 96.2 %), trematodes (prevalence 94.3 %) and acanthocephalans (prevalence 93.4 %) were the most common groups of helminths found (table 1).

One monogenean species, *Pseudobenedenia nototheniae* Johnston, 1931 was found on the skin of *N. coriiceps* with the prevalence of 31.4 % and the intensity from 1 to 42 specimens per fish (mean intensity 5.7; median intensity 3). As every fish was placed in a separate container and was dissected 2–5 of hours after it had been caught, we assume that all monogeneans from every fish have been collected.

Trematodes were registered in 94.3 % of *N. coriiceps* with the intensity from 1 to 127 (mean intensity 33.7; median intensity 23.5) specimens per fish with a mean abundance of 33.77. Seven species of trematodes from the families Opecoelidae Ozaki, 1925, Lepidapedidae Yamaguti, 1958, Hemiuridae Looss, 1899, Lecithasteridae Odhner, 1905, and Derogenidae Nicoll, 1910 were collected from the gastrointestinal tract of *N. coriiceps*. *Macvicaria georgiana* (prevalence 87.7 %) was dominant and the most abundant species of trematodes; two other species, *Genolinea bowersi* and *Elytrophalloides oatesi* were found in 69.8 % and 41.5 % of fishes, respectively (table 1), while four other species were registered in less than 10 % of fishes examined. The number of species of trematodes increased with the size of the fish; smaller rockcod individuals were infected with 4 species of trematodes, while larger specimens were infected with 6 specimens (table 2).

Cestodes were registered in 86.8 % of *N. coriiceps* with the intensity from 1 to 55 (mean intensity 9.6; median intensity 6.5) specimens per fish and with a mean abundance of 8.33. All cestodes registered in *N. coriiceps* intestine were larval forms (plerocercoids); some plerocercoids were in encapsulated cysts in the stomach wall and in the body cavity. Plerocercoids of diphyllobothriid cestodes (family Diphyllobothriidae Lühe, 1910), which are primarily parasites of marine mammals, were the dominant group of cestodes found in *N. coriiceps*; they were registered in 75.5 % of fishes with the intensity up to 49 specimens per host (mean intensity 9.4; median intensity 6). Three morphological forms of cercoids of tetraphyllidean cestodes (order Tetraphyllidea Carus, 1863), parasites of the Chondrichthyes — rays and sharks, were registered. They represented a mixed group of species and were divided into three groups based on their morphology: monolocular metacestodes (found in 12.3 % of fishes), bilocular metacestodes (in 28.3 %) and trilocular metacestodes (in 13.2 %) (table 1). Bilocular metacestodes belonged to at least four morphological forms

Table 1. Helminth species and parameters of infection of *Notothenia coriiceps* in the waters surrounding the Ukrainian Antarctic station "Akademik Vernadsky" in 2014–2015

	Helminths	Prevalence, % average	Intensity			Mean abundance
			average	min–max	median	
	Phylum: PLATYHELMINTHES Class: MONOGENEA					
1	*Pseudobenedenia nototheniae* Johnston,1931	31.4	5.7	1–42	3	1.81
	Phylum: PLATYHELMINTHES Class: TREMATODA	94.3	33.7	1–127	23.5	31.77
2	*Macvicaria georgiana* (Kovaljova et Gaevskaya, 1974)	87.7	26.7	1–122	16	23.45
3	*Neolebouria antarctica* (Szidat et Graefe, 1967)	5.7	2.8	1–7	1	0.16
4	*Lepidapedon garrardi* (Leiper et Atkinson, 1914)	8.5	1.4	1–3	1	0.12
5	*Genolinea bowersi* (Leiper et Atkinson, 1914)	69.8	9.4	1–37	7	6.54
6	*Elytrophalloides oatesi* (Leiper et Atkinson, 1914)	41.5	3.5	1–19	2	1.43
7	*Lecithaster macrocotyle* Szidat et Graefe, 1967	0.9	1	1	1	0.01
8	*Derogenes johnstoni* Prudhoe et Bray, 1973	3.8	1	1	1	0.04
	Phylum: PLATYHELMINTHES Class: CESTODA	86.8	9.6	1–55	6.5	8.33
9	*Diphyllobothrium* sp.	75.5	9.4	1–49	6	7.09
10	*Metacestode monolocular*	13.2	1.5	1–4	1	0.20
11	*Metacestode bilocular*	38.6	2.2	1–7	1.5	0.87
12	*Metacestode trilocular*	15.1	1.4	1–3	1	0.22
	Phylum: NEMATODA Class: CHROMADOREA	96.2	14.8	1–52	13	14.27
13	*Ascarophis nototheniae* Johnston et Mawson,1945	10.4	12.6	1–49	3	0.31
14	*Pseudoterranova* sp.	95.3	12.6	1–47	10	12.04
15	*Anisakis* sp.	1.9	2	2	2	0.04
16	*Contracaecum* sp.	31.1	2.8	1–17	2	0.89
17	*Dichelyne fraseri* (Baylis, 1929)	4.7	1.4	1–3	1	0.07
	Phylum: ACANTHOCEPHALA Class: PALAEACANTHOCEPHALA	93.4	24.7	1–106	17	23.04
18	*Metacanthocephalus rennicki* (Leiper & Atkinson, 1914)	86.8	9.9	1–79	5.5	8.63
19	*Metacanthocephalus johnstoni* Zdzitowiecki, 1983	88.7	11.2	1–62	8	9.93
20	*Metacanthocephalus campbelli* (Leiper & Atkinson, 1914)	31.1	3.7	1–14	2	1.15
21	*Metacanthocephalus dalmori* Zdzitowiecki, 1983	45.3	4.8	1–33	2	2.15
22	*Aspersentis megarhynchus* (Linstow, 1892)	13.2	4.0	1–17	2	0.53
23	*Corynosoma pseudohamanni* Zdzitowiecki, 1983	ND		ND		ND
24	*Corynosoma hamanni* (Linstow, 1892)	ND		ND		ND
25	*Corynosoma evae* Zdzitowiecki, 1984	ND		ND		ND

ND — not complete data.

(see Wojcechowska, 1993); however we could not identify these specimens using only morphology. Prevalence and abundance of cestodes increased with the size of the fishes; larger specimens of *N. coriiceps* were significantly more infected with *Diphyllobothrium* sp. as well as with bilocular and trilocular metacestodes (table 2).

Nematodes were documented in 96.2 % of *N. coriiceps* with intensity from 1 to 52 (mean intensity 14.8; median intensity 13) specimens per fish and with mean abundance of 14.27. Most of the nematodes found in the body cavity, liver and in the stomach wall of *N. coriiceps* were larval forms of three genera: *Pseudoterranova* Mozgovoi, 1951, *Contracaecum* Railliet & Henry, 1912 and *Anisakis* Dujardin, 1845. Larvae of *Pseudoterranova* sp. were dominant; they were found mostly in the liver and the body cavity of 95.3 % of fishes examined. Larvae of *Contracaecum* sp. were registered in 31.1 % of fishes. Both genera, *Pseudoterranova* and

Contracaecum, are common parasites of pinnipeds (seals) which are abundant in the waters around the UAS "Akademik Vernadsky". Nematodes of the genus *Anisakis* are parasites of whales which are quite rare in waters near the UAS. Two species of nematodes, *Ascarophis nototheniae* Johnston et Mawson, 1945 and *Dichelyne fraseri* (Baylis, 1929), which are common parasites of teleost fishes were found in the intestines of 10.4 % and 4.7 % of *N. coriiceps*, respectively (table 1).

Acanthocephalans were registered in 93.4 % of *N. coriiceps* with intensity from 1 to 106 (mean intensity 24.7; median intensity 17) specimens per fish and with mean abundance of 23.04. Eight species of acanthocephalans from two orders: Echinorhynchida Southwell et Macfie, 1925, parasites of teleost fishes, and Polymorphida Petrochenko, 1956, parasites

Table 2. Distribution of helminths found in *Notothenia coriiceps* according to host size; prevalence (P) and mean abundance (A)

	Helminth species	Size groups of fish, cm									
		21.5–24.9		25.0–29.9		30.0–34.9		35.0–39.9		40.0–43.5	
		P, %	A	P, %	A	P, %	A	P, %	A	P, %	A
	Phylum: PLATYHELMINTHES Class: MONOGENEA										
1	*Pseudobenedenia nototheniae*	15.4	0.85	21.7	0.39	32.4	1.24	42.1	2.37	46.2	5.69
	Class: TREMATODA	100.0	18.07	86.9	27.78	97.1	26.15	94.7	36.42	100.0	61.31
2	*Macvicaria georgiana*	92.3	12.46	82.6	23.48	85.3	19.18	89.5	24.00	100	48.77
3	*Neolebouria antarctica*	7.7	0.46	4.4	0.04	2.3	0.03	5.3	0.05	15.4	0.62
4	*Lepidapedon garrardi*	—	—	8.7	0.13	14.7	0.24	5.3	0.05	7.7	0.08
5	*Genolinea bowersi*	61.5	3.62	65.2	3.52	73.5	5.24	68.4	10.63	76.2	10.38
6	*Elytrophalloides oatesi*	53.9	3.62	26.1	0.52	38.4	1.38	47.4	1.63	46.2	1.46
7	*Lecithaster macrocotyle*	—	—	—	—	—	—	—	—	7.7	0.08
8	*Derogenes johnstoni*	—	—	8.7	0.09	2.9	0.03	5.3	0.05	—	—
	Class: CESTODA	69.2	3.46	95.7	4.39	85.3	10.65	94.7	10.37	84.6	11.69
9	*Diphyllobothrium* sp.	38.5	1.92	52.2	3.17	73.5	8.88	78.9	8.00	84.6	9.62
10	*Metacestode monolocular*	23.1	0.31	4.4	0.04	14.7	0.15	15.8	0.47	7.7	0.08
11	*Metacestode bilocular*	33.8	0.38	34.8	0.57	29.4	0.74	42.1	0.21	69.2	1.38
12	*Metacestode trilocular*	7.7	0.08	13.0	0.13	17.7	0.21	5.3	0.05	23.1	0.62
	Phylum: NEMATODA Class: CHROMADOREA	100.0	12.76	91.3	9.30	97.1	15.06	100.0	21.05	100.0	14.08
13	*Ascarophis nototheniae*	30.8	6.08	8.7	0.26	11.8	1.56	—	—	7.7	0.08
14	*Pseudoterranova* sp.	92.3	6.92	91.3	8.39	97.1	15.06	100.0	18.37	100.0	13.31
15	*Anisakis* sp.	7.7	0.20	—	—	—	—	5.3	0.11	—	—
16	*Contracaecum* sp.	7.7	0.2	26.1	0.65	20.6	0.44	63.2	2.58	46.2	0.69
17	*Dichelyne fraseri*	—	—	4.3	0.04	5.9	0.06	5.3	0.06	7.7	0.08
	Phylum: ACANTHOCEPHALA Class: PALAEACANTHOCEPHALA	92.3	24.84	95.7	24.95	97.1	20.12	94.7	27.79	100.0	25.08
1.	*Metacanthocephalus rennicki*	92.3	11.50	95.7	10.96	79.4	6.08	94.7	8.21	92.3	11.23
19	*Metacanthocephalus johnstoni*	92.3	11.58	95.7	10.13	91.2	10.11	89.5	12.63	84.6	7.31
20	*Metacanthocephalus campbelli*	23.1	0.62	26.1	0.77	23.5	0.61	36.8	2.05	61.5	2.77
21	*Metacanthocephalus dalmori*	38.5	1.31	39.1	1.08	47.1	2.44	63.2	3.58	46.2	2.69
22	*Aspersentis megarhynchus*	15.4	0.38	21.7	1.39	5.9	0.06	15.8	0.42	15.4	0.69
23	*Corynosoma pseudohamanni*					ND					
24	*Corynosoma hamanni*					ND					
25	*Corynosoma evae*					ND					
	TOTAL:	100.0	59.15	100.0	66.43	100.0	71.97	100.0	95.63	100.0	112.15
	Number of species	19		23		21		21		21	

ND — not complete data

of birds and mammals, were found (table 1). Five echinorhynchid species parasitized the lumen of the intestine of *N. coriiceps*; polymorphid acanthocephalans from the genus *Corynosoma* Lühe, 1904 were found at the stage of cystacanth. Two species from the genus *Metacanthocephalus* Yamaguti, 1959: *M. johnstoni* Zdzitowiecki, 1983 and *M. rennicki* (Leiper & Atkinson, 1914) were the most prevalent; they were found in 86.8 % and 88.7 % of examined hosts, respectively. Species from the genus *Corynosoma* are parasites of pinnipeds (seals) or sea birds (cormorants, penguins). In this study, *C. pseudohamanni* Zdzitowiecki, 1983 was found in the intestines of 27.4 % of fishes examined with intensity from 1 to 6 specimens; *C. hamanni* (Linstow, 1892) and *C. evae* Zdzitowiecki, 1984 were found in 0.9 % of fishes each with a mean intensity of 2 specimens. In this study, *C. evae* was first documented in *N. coriiceps*. However, these data are not completed, because most *Corynosoma* specimens were found in *Notothenia coriiceps* in cysts and, therefore, were not identified to species level. The species of *Corynosoma* use various marine fishes as the paratenic hosts (Petrochenko, 1958); these acanthocephalans usually parasitize the mesentery and body cavity of teleost fishes at the stage of cystacanth and are rarely found in the intestine.

Cysts containing acanthocephalans from the genus *Corynosoma* were collected in 100 % of *N. coriiceps* individuals in our study. Larval stages (cystacanths) of *C. pseudohamanni*, *C. hamanni* and *C. evae* were found. However, we could extract and identify cystacanths from approximately 13 % of cysts collected; all other cysts were not identified because of impossibility to extract intact cystacanths from the cysts fixed in ethanol.

2. Structure of the parasite community

Analysis of the structure of the parasite community of Antarctic rockcod according to the prevalence of separate species revealed that all helminth species could be assigned to five groups: dominant (prevalence 80.1–100 %), subdominant (prevalence 50.1–80 %), background (prevalence 20.1–50 %), rare (prevalence 1–20 %), and occasional (prevalence < 1 %) species. Dominant and subdominant species also were found to be the most abundant — together those species composed 87.4 % of the total number of helminths collected; mean intensity of *N. coriiceps* infection with those species also was comparatively high (fig. 1). Acanthocephalans from the genus *Corynosoma* were not included in the analysis because most of these species parasitize *N. coriiceps* as tissue cysts.

Prevalence and intensity of infection of *N. coriiceps* by helminths varied between fishes of different size groups. Fishes of large size were found to be more infected with most of the helminths comparing to smaller individuals (table 2). Differences in the abundance of helminth infection between fishes of five size groups were statistically significant (Kruskal–Wallis test; $H = 19.79$, $p = 0.0005$). Analysis of differences in abundance for separate taxonomic groups of helminths revealed significant differences in *N. coriiceps* infection with nematodes (Kruskal–Wallis test; $H = 17.3$; $p = 0.0017$), cestodes (Kruskal–Wallis test; $H = 15.45$; $p = 0.0038$) and trematodes (Kruskal–Wallis test; $H = 13.92$; $p = 0.0076$). Differences in infection with acanthocephalans were insignificant (Kruskal–Wallis test; $p > 0.05$); the test was not applied to the infection with monogeneans because of their low prevalence.

The number of tissue cysts containing cystacanths of acanthocephalans was found to increase significantly with the size and, respectively, with the age of the fish due to their accumulation. On average, from 54.7 to 104.5 cysts per one host were found in fishes of five size groups (fig. 2).

Prevalence and abundance of *N. coriiceps* infection by helminths varied between the seasons (table 3). More species of helminths (21) were found in rockcods in warmer seasons (September–November and December–January); fewer species were found in colder seasons — April–May (18) and June–August (19). Similar trends were observed for the number of cysts found in *N. coriiceps* body cavity: 53.3 cysts/fish in April–May,

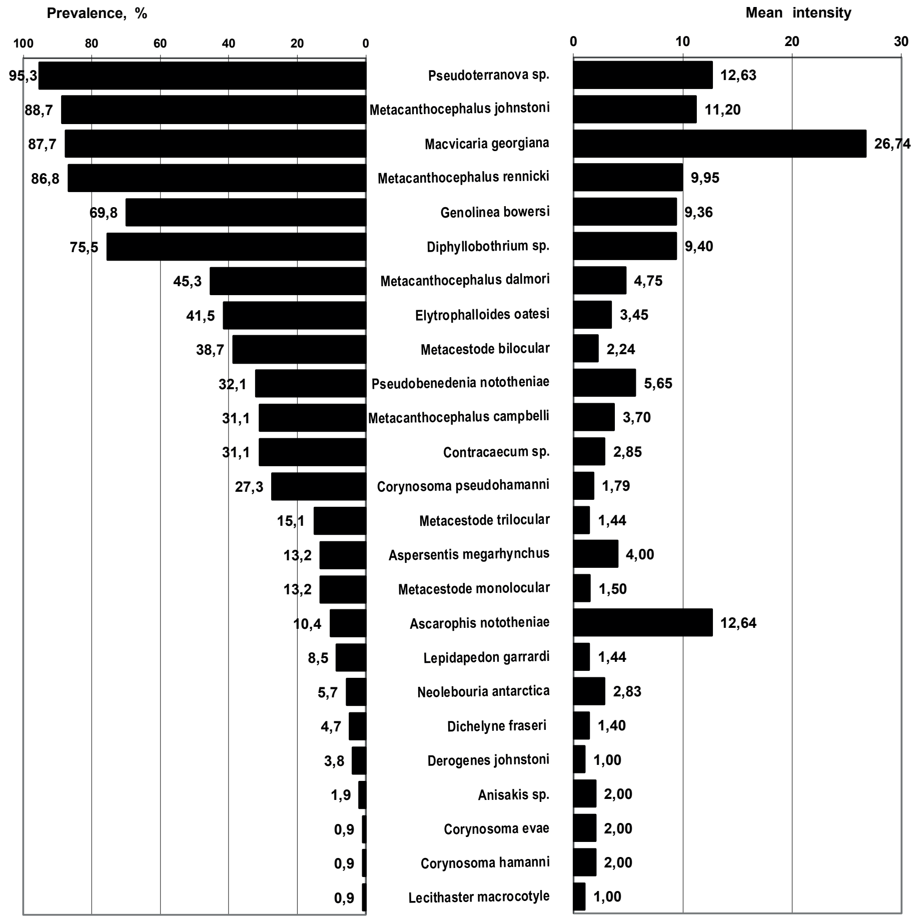

Fig. 1. Prevalence (in %) and mean intensity of helminth species found in *Notothenia coriiceps* in the waters surrounding the Ukrainian Antarctic station "Akademik Vernadsky" in 2014–2015.

78.1 cysts/fish in June–August, 81.3 cysts/fish in September–November and 88.8 cysts/fish in December–January. However, these differences appeared to be statistically insignificant (Kruskal–Wallis test; $p > 0.05$).

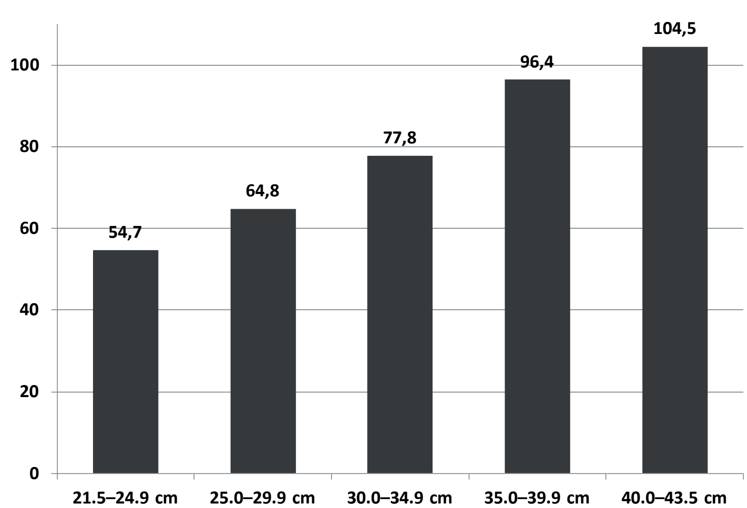

Fig. 2. Average number of cysts of *Corynosoma* spp. in the body cavity of *Notothenia coriiceps* of five size groups.

Table 3. Prevalence (P) and mean abundance (A) of helminths found in *Notothenia coriiceps* in different seasons of 2014–2015 in the waters surrounding the Ukrainian Antarctic station "Akademik Vernadsky"

Helminths	April–May (n = 13)		June–August (n = 29)		September–November (n = 35)		December–February (n = 29)	
	P, %	A	P, %	A	P, %	A	P, %	A
Monogenea	4.7	0.27	4.7	0.23	13.2	0.38	9.4	0.93
Trematoda	10.4	1.84	26.4	5.05	31.1	11.13	26.4	13.75
Cestoda	8.5	0.49	22.6	2.93	31.1	2.76	24.5	2.14
Nematoda	12.3	1.23	25.5	5.36	33.9	3.47	24.5	3.43
Acanthocephala	10.4	3.53	26.4	6.67	32.1	8.73	24.6	1.13
Number of species	18		19		21		21	

3. Changes in the parasite community during the last decade

Analysis of our data on the parasites of *N. coriiceps* collected in 2014–2015 and the data collected in 2002 (Zdzitowiecki and Laskowski, 2004) revealed 28 helminth species parasitizing the rockcod in the waters near UAS (table 4). Three species of acanthocephalans, namely *Corynosoma bullosum* (Linstow, 1892), *C. arctocephali* Zdzitowiecki, 1984, and *C. shackletoni* Zdzitowiecki, 1978 were not found in our study; while the trematode *Derogenes johnstoni* Prudhoe et Bray, 1973, nematodes *Dichelyne fraseri* (Baylis, 1929) and *Anisakis* sp., three species of acanthocephalans (*M. rennicki*, *M. campbelli* and *C. evae*) and monolocular metacestode larvae were found in *N. coriiceps* in 2014–2015 and not documented in 2002.

We observed significant changes in the prevalence and abundance of *N. coriiceps* infection with separate species of helminths comparing the data from 2002 (Zdzitowiecki and Laskowski, 2004) and 2014–2015. The prevalence of the trematode *Neolebouria antarctica* (Szidat et Graefe, 1967) decreased from 30 % in 2002 to 5.7 %, and its abundance decreased from 9.00 to 0.16; the prevalence of bilocular metacestode decreased from 74 % to 38.6 %, and its abundance decreased from 14.23 to 0.87. Changes in the prevalence and abundance of other species such as trematode *Lepidapedon garrardi* (Leiper et Atkinson, 1914), cestode *Diphyllobothrium* sp., nematodes *Pseudoterranova* sp. and *A. nototheniae*, and acanthocephalan *Aspersentis megarhynchus* (Linstow, 1892) were less dramatic (table 4).

Discussion

The results of our study present current information describing the parasite fauna of Antarctic rockcod *N. coriiceps* in the area of the UAS "Akademik Vernadsky", Argentine Islands in 2014–2015. This study also documents the changes in the parasite community of *N. coriiceps* over the last decade. Despite numerous discrete studies addressing various groups of parasites of *N. coriiceps* conducted for more than 100 years (Linstow, 1882; Ralliet and Henry, 1907; Johnston, 1937, 1938; Johnston and Best, 1937; Szidat, 1965; Prudhoe and Bray, 1973, etc.), only a few comprehensive researches on the taxonomic structure of its parasite community have been published (Szidat, 1965; Palm et al., 1998; Zdzitowiecki et al., 1998; Zdzitowiecki, 2001; Zdzitowiecki and Laskowski, 2004). Most of these studies were carried out in the areas of South Shetland Islands, South Georgia as well as on the Argentine Islands. Twenty-one species of helminths of 5 taxonomic groups were previously found to parasitize *N. coriiceps* near the "Akademik Vernadsky" UAS (Zdzitowiecki and Laskowski, 2004); acanthocephalans (*Corynosoma pseudohamanni, Metacanthocephalus johnstoni*) and trematodes (*Macvicaria georgiana* and *Genolinea bowersi*) were the dominant species. The results of our study increased the list of the helminths by 7 species; thus presently 28 helminth species are known to parasitize *N. coriiceps* in this area (tables 1 and 4).

Table 4. Prevalence (P) and mean abundance (A) of helminths found in *Notothenia coriiceps* in the waters surrounding the Ukrainian Antarctic station "Akademik Vernadsky" in 2014–2015 and in 2002

	Helminth species P, %	In 2014–2015 (our data)		In 2002 (Zdzitowiecki and Laskowski, 2004)	
		P, %	A	P, %	A
	MONOGENEA				
1	*Pseudobenedenia nototheniae*	31.4	1.81	20	0.82
	TREMATODA				
2	*Macvicaria georgiana*	87.7	23.45	94	29.45
3	*Neolebouria antarctica*	5.7	0.16	30	9.00
4	*Lepidapedon garrardi*	8.5	0.12	18	0.35
5	*Genolinea bowersi*	69.8	6.54	74	5.96
6	*Elytrophalloides oatesi*	41.5	1.43	47	2.49
7	*Lecithaster macrocotyle*	0.9	0.01	1	0.01
8	*Derogenes johnstoni*	3.8	0.04	—	—
	CESTODA				
9	*Diphyllobothrium* sp.	75.5	7.09	22	0.87
10	*Metacestode monolocular*	13.2	0.20	—	—
11	*Metacestode bilocular*	38.6	0.87	74	14.23
12	*Metacestode trilocular*	15.1	0.22	8	0.11
	NEMATODA				
13	*Ascarophis nototheniae*	10.4	0.31	2	0.02
14	*Pseudoterranova* sp.	95.3	12.04	67	4.55
15	*Anisakis* sp.	1.9	0.04	—	—
16	*Contracaecum* sp.	31.1	0.89	30	1.16
17	*Dichelyne fraseri*	4.7	0.07	—	—
	ACANTHOCEPHALA				
18	*Metacanthocephalus rennicki*	86.8	8.63	—	—
19	*M. johnstoni*	88.7	9.93	74	3.61
20	*M. campbelli*	31.1	1.15	—	—
21	*M. dalmori*	45.3	2.15	47	1.38
22	*Aspersentis megarhynchus*	13.2	0.53	2	0.16
23	*Corynosoma pseudohamanni*	ND	ND	99	78.70
24	*C. hamanni*	ND	ND	19	0.43
25	*C. evae*	ND	ND	—	—
26	*C. bullosum*	—	—	3	0.03
27	*C. arctocephali*	—	—	44	0.98
28	*C. shackletoni*	—	—	4	0.05

ND — not complete data.

According to our data (2014–2015), nematodes (prevalence 96.2 %), digenean trematodes (94.3 %) and acanthocephalans (93.4 %) were the dominant groups of parasites of *N.coriiceps*; other groups of helminths, namely cestodes (prevalence 86.8 %) and monogeneans (31.4 %), were less abundant. Since we used the same techniques to collect the helminths, our data on the prevalence and intensity of the main groups of helminths were generally comparable with the results of Zdzitowiecki and Laskowski (2004). In our study, however, we did not use the "artificial digestion" of the acanthocephalan cysts in a water solution of pepsin and hydrochloric acid; therefore most cystacanths of *Corynosoma* spp. were impossible to extract from the cysts fixed in 70 % ethanol and identify to the species level. Consequentially, three species of acanthocephalans from the genus *Corynosoma* (*C. arctocephali, C. bullosum* and *C. shackletoni*) are not reported in our study; therefore, we cannot compare our data on prevalence and intensity of *Corynosoma* spp. with the results of Zdzitowiecki and Laskowski (2004). Despite this, we found a rare acanthocephalan species *C. evae*, which previously was not recorded in *N. coriiceps*.

The analysis of the differences in *N. coriiceps* infection depending on fish size and season revealed that abundance of most helminths increased with the size of fish. Significant increasing of the number of tissue cysts in large fishes also was documented. Since various marine fishes are the paratenic hosts for *Corynosoma* species which parasitize marine mammals and birds, cysts with cystacanths accumulate in the fish body cavity (Petrochenko, 1958) which increases the intensity of infection of their definitive hosts. According to our data, the differences in helminth abundance connected with four calendar seasons (spring, summer, autumn and winter) were not statistically significant. In our opinion, seasonal ecological differences in the coastal marine ecosystems of the Argentine Islands are not directly related to calendar months. Therefore, we believe that more parasitological data collected monthly over several years, as well as meteorological and hydrological data, are necessary to reliably detect the seasonal changes in the parasite community of Antarctic rockcod in future.

Comparison of our results in 2014–2015 with the data published by Zdzitowiecki and Laskowski (2004) revealed substantial differences in prevalence and abundance of *N.coriiceps* infection with trematodes *Neolebouria antarctica* and *Lepidapedon garrardi*. Infection of *N. coriiceps* with other trematode species near the UAS area has also decreased over 12 years, but not so significantly. We also recorded a decrease in the infection of *N. coriiceps* with the larval stages of cestodes «metacestode bilocular» (see table 3). Decreasing infection of *N. coriiceps* by digenean trematodes over the last decades was observed in other areas of West Antarctica (Laskowski et al., 2014). As these parasites have complex life-cycles and various species of molluscs, marine invertebrates and fishes serve as their intermediate and paratenic hosts. Climatic change in marine ecosystems and changes in water salinity connected with melting polar ice (Silvano et al., 2018), as well as anthropogenic pollution of the ocean in recent decades, could have substantially changed the composition of benthic invertebrates in coastal ecosystems and reduced the number of intermediate hosts (Zdzitowiecki, 1997; Laskowski et al., 2014).

Compared to the data of Zdzitowiecki and Laskowski (2004), we observed a significant increase in *N. coriiceps* infection with larval stages of the cestode *Diphyllobothrium* sp. We assume that increase in the population of pinniped definitive hosts (Weddell seals, Leopard seals, Crabeater seals, etc.) in the vicinity of the "Akademik Vernadsky" Station may account for the increase in rockcod infection by these diphyllobothriid cestodes. The differences in the prevalence of the nematode *Ascarophis nototheniae* and the acanthocephalan *Aspersentis megarhynchus* compared to the data of Zdzitowiecki and Laskowski (2004) could be connected with the seasonal changes in fish infection. Zdzitowiecki and Laskowski collected their material in February–March, 2002, while in our study the peak of fish infection with these helminths was in June–September. Further collections of helminths throughout the year are necessary to elucidate the dynamics of the Antarctic rockcod infection by all these groups of parasites.

The results of our work provide the initial parasitological data for the establishment of long-term monitoring studies at the UAS "Akademik Vernadsky". Environmental changes caused by global warming and anthropogenic factors are observed in terrestrial and marine ecosystems around the world (Vaughan et al., 2003; Clarke et al., 2007; Klimpel et al., 2017). Metazoan parasites (nematodes, cestodes, trematodes, etc.) are known as one of the most sensitive indicators of the state of ecosystems, especially in the marine environment (Mouritsen and Poulin 2002; Poulin and Mouritsen, 2006). Therefore, long-term monitoring studies of the species diversity and structure of parasite communities in fish are necessary to analyze the ecological changes in the marine ecosystems of the Antarctic shelf and to predict the rate and direction of these changes over the coming decades.

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