Basic epidemiological data on metazoan parasites of notothenioid fish off James Ross Island (Prince Gustav Channel, Weddell Sea), Antarctica

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Abstract
During the Czech Antarctic expedition 2014, 102 fish of six species (*Trematomus hansoni, T. bernacchii*, *T. newnesi*, *Notothenia coriiceps*, *Parachaenichthys charcoti*, *Pagothenia borchgrevinki*) were examined for parasites. The fish were caught in the Prince Gustav Channel (depth about 5–25 m) off the Johann Gregor Mendel Station on the James Ross Island. Altogether 7,925 metazoan parasites were found, which were identified to individual groups (usually classes). The most abundant were nematode larvae (prevalence 97.0 %, mean abundance 32.7 larvae/per fish), followed by acanthocephalans, especially larvae of species of *Corynosoma* (76.5%, 14.9) and monogeneans (77.5%, 13.0). Cestodes (Diphyllobothriidea, Tetraphyllidea) were represented by larval stages whereas trematodes only by adults. Our preliminary data may help in future studies on fish parasites in Antarctica because they indicate the most abundant groups of parasites occurring in notothenioid fish.

Key words: parasites, host, notothenioid fish, Weddell Sea, Prince Gustav Channel

DOI: 10.5817/CPR2015-1-5

Introduction

Bony fishes represent the most species-rich group of vertebrates in the Antarctic region (Rocka 2006, Cemal Oguz et al. 2012). Matschiner et al. (2015) mentioned that only several groups of teleost fishes have been able to successfully colonize the Antarctic waters. Although the Southern Ocean represents 10% of the world's ocean waters, it contains only 1% of the recorded species, with approximately 88%

Received May 25, 2015, *accepted* August 11, 2015.
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Acknowledgements: This study was supported by the Masaryk University and the Czech Science Foundation (project No. P505/12/G112). We are grateful to the staff of the Antarctic expedition 2014 in the Czech Antarctic Station "J. G. Mendel" in the James Ross Island for their help and support. We thank also Pavel Jurajda for fish collection, Zdeněk Stachoň for preparation of maps and Karel Janko for providing the photo of *Pagothenia borchgrevinki*.

of them endemic to Antarctica (Andriashev 1987). Less than 400 teleost fish species are known to occur in Antarctica (Eastman 2005), which is only a small proportion of worldwide diversity estimated to be about 28,000 species (Nelson 2006). The fish fauna in Antarctica is dominated by fishes of the Notothenioidea that comprises eight families, 43 genera and 122 species (Balushkin 2000, Eastman et Eakin 2000).

Antarctic fish parasites are diverse and the majority of them are endemic (Rocka 2006). A number of studies on the occurrence, distribution and biology of fish parasites in Antarctica have been published, with most attention paid to trematodes (*e.g.* Byrd 1963, Zdzitowiecki 1997, Rocka 2003, 2004, Mašová et Baruš 2013, Zdzitowiecki et Ozouf-Costaz 2013, Bray et al. 2014). Most Antarctic endoparasites have complex life cycles that include invertebrate and vertebrate hosts at various levels of the marine food chain. For anisakid nematodes and some cestodes, zooplankton serve as the first intermediate hosts and marine mammals or fish-eating birds as definitive hosts (Szostakowska et al. 2005, Mattiucci et Nascetti 2007). Fish are situated in the middle of the food chain and this position predisposes them to become an intermediate, paratenic or definitive hosts of parasites (Rocka 2006).

In 2014, notothenioid fish caught in the Prince Gustav Channel, northwestern Weddel Sea, were examined for metazoan parasites. Even though these parasites were not identified more specifically (in fact, most were classified only to the major parasite groups such as classes Trematoda or Monogenea), we present preliminary data on the proportion and basic epidemiological data on these groups of metazoan parasites in six species of notothenoids in the Prince Gustav Channel.

Material and Methods

Collecting fish and their parasites

Field investigations were carried out during the Czech Antarctic expedition from January to March 2014. Fishes were caught with rods and gill nets in several sites in the Prince Gustav Channel (63°47'58.37"S, 57°55'12.35"W; depth about 5–25 m; Fig. 1) off the Johann Gregor Mendel station on the James Ross Island. Total 102 specimens of six notothenioid fish species (14 specimens of *Notothenia coriiceps*, 30 *Trematomus bernacchii*, 32 *T. hansoni*, 23 *T. newnesi*, 2 *Parachaenichthys charcoti* and 1 *Pagothenia borchgrevinki*) were collected and examined for parasites during the expedition (Table 1). All these host fish were obtained and all were processed without any bycatch. Fish were individually sacrificed prior to dissection and standard (SL) and total lengths (TL, to the nearest 1 mm), total body weight (W, to the nearest 0.01 g) and wet weight of gonads and liver (to the nearest 0.01 g) were measured. Fish nomenclature is in concordance with FishBase (Froese et Pauly 2015). Fish were examined under a binocular microscope for the presence of metazoan parasites according to standard methods (Ergens et Lom 1970). Collected parasites were preserved in 4% formaldehyde solution or in 80% ethanol (Acanthocephala, Cestoda, Crustacea, Hirudinea, Nematoda, Trematoda), in a mixture of glycerine and ammonium picrate (Monogenea) and in a mixture of glycerine and alcohol (Nematoda). Parasites were identified using a light microscope Olympus BX 50 equipped with phase-contrast or differential interference contrast (DIC) optics and digital image analysis system (Motion Stream).

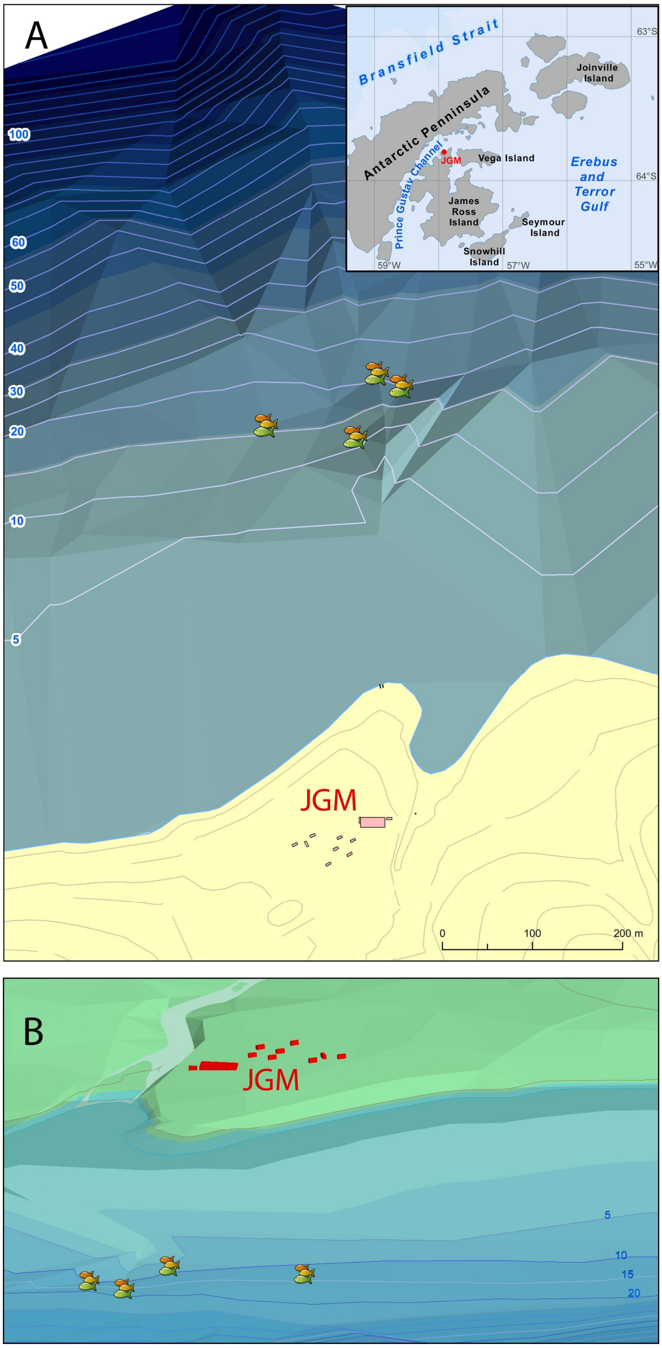


Fig. 1. Map of sampling area with marked localities (fish) with schematic visualization of depths: **A.** The view of on position of the station and localities from the above. **B.** View on position of localities and the station from the sea. (JGM - Johann Gregor Mendel Station).

Data analyses

Three indices of fish condition were calculated for each fish: (1) Fulton's condition factor: $K = W \times 10^5 / SL^3$; (2) hepatosomatic index: $HSI = W\ (liver) \times 10^2/W$; and (3) gonadosomatic index: $GSI = W\ (gonads) \times 10^2/W$, using W and weight of organs in grams and SL in millimetres. In some individuals, liver or gonads could not be weighed due to the constraints imposed by parasitological dissections or because the fish were juveniles. These individuals are not included in HSI or GSI analyses. Parasite infection was characterized according to Bush et al. (1997) for all fish of four species with the greatest abundance (*N. coriiceps, T. bernacchi*, *T. hansoni* and *T. newnesi*). The number of the other two fish species was not enough to provide adequate results. Kruskall-Wallis test was used to compare the size of individual fish species and Spearman correlation was used for evaluation the relationship between the size of the fish and number of parasites. All analyses were performed using Microsoft Office Excel 2010 for Windows and Statistica 12.0 for Windows.

Results

A total of 7,925 metazoan parasites were found in six species of notothenioid fishes: ectoparasites were represented by Monogenea (1,327), Crustacea (44) and Hirudinea (20); endoparasites: Nematoda – all larvae of the family Anisakidae (3,335), Acanthocephala (2,053) – adults (538, undetermined) and larvae belonging to more than one species of *Corynosoma* Lühe, 1904 (1,515), larvae of Cestoda (870) and adults of Trematoda (276); *see* Figs. 2, 3 and Table 1. Monogenea (both oviparous and viviparous) were located on gills, fins and, to a lesser extent, on the body surface (head area, the base of fins). Adult trematodes were present in anterior and posterior intestine, pyloric appendices and stomach. Larval cestodes were found in the intestinal lumen, pyloric appendices, stomach, liver, in the wall of digestive tract and in the body cavity. Larvae (cystacanths) of *Corynosoma* were found mostly in the body cavity and on the surface of internal organs. Adult acanthocephalans were found only in the intestine and pyloric appendices. Nematodes were found in the liver, intestine and in the wall of the digestive tract. All host individuals were infected with at least one parasite taxa (Table 2). Mean total parasite abundance across the hosts was 76. The most parasitized host was *Notothenia coriiceps* with the mean parasite abundance of 117. This value is influenced by the largest fish (SL = 375 mm) with the maximum total abundance 565, where cystacanths *Corynosoma* spp. dominated (339 larvae of *Corynosoma*). Larvae of *Corynosoma* spp. and Cestoda were found also in other individuals of *N. coriiceps*. The prevalence of cystacanths of *Corynosoma* spp. ranged from 39% in *T. newnesi* to 100% in *N. coriiceps*. The fish were also heavily infected with nematodes (prevalence 91 %, mean abundance 30), in *T. hansoni* and *T. newnesi* the prevalence was 100 %, whereas the infection was lowest in *N. coriiceps* (prevalence 71 %, mean abundance 5). There was significant difference in standard length (SL) of the four most abundant fish species (Kruskal-wallis test: $H_{(3,99)} = 53.94$, $P < 0.0001$) except *T. hansoni* and *T. bernacchii* that did not differ in size from each other (Fig. 4). The individuals of *N. coriiceps* were the largest, *T. newnesi* the smallest (Fig. 4). In all fish species, there was no significant correlation between the size of the fish and total number of parasites (*N. coriiceps*: $r_s = 0.17$, $P > 0.05$; *T. bernacchii*: $r_s = 0.22$, $P > 0.05$;

T. hansoni: $r_s = 0.16$, $P > 0.05$; *T. newnesi*: $r_s = 0.29$, $P > 0.05$). There was not statistically significant correlation between the number of ectoparasites (endoparasites) and size of the fish ($P < 0.05$) when dividing the parasites into groups 'endoparasites' and 'ectoparasites'. Only in *T. newnesi*, the correlation between fish size and number of endoparasites ($r_s = 0.42$, $P < 0.05$) and the number of nematodes ($r_s = 0.46$, $P < 0.05$) was significant (Fig. 5).

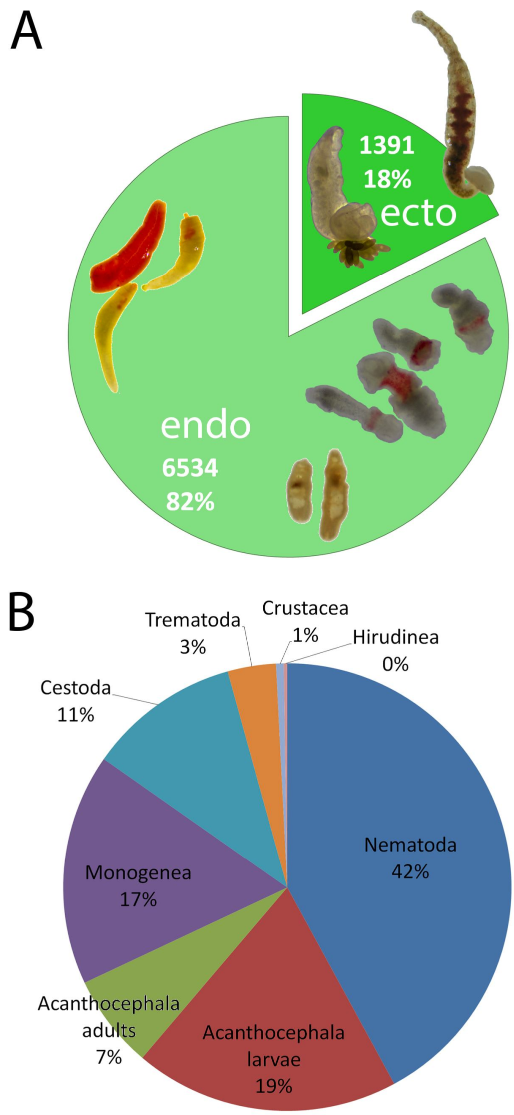
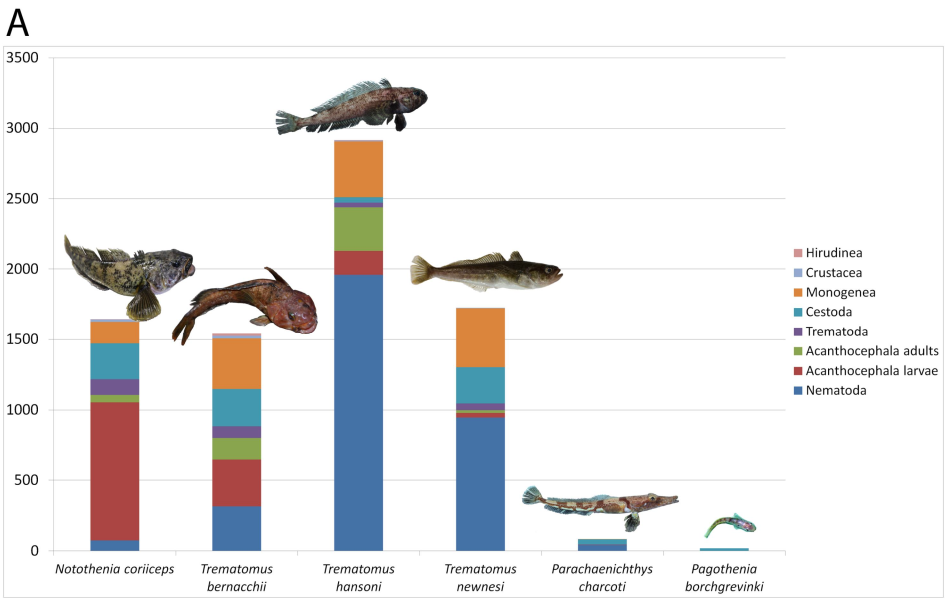


Fig. 2. A. The numbers and percentages of ectoparasites (ecto) and endoparasites (endo) infecting all examined fish. **B.** Percentage proportions of parasite groups infecting all examined fish.



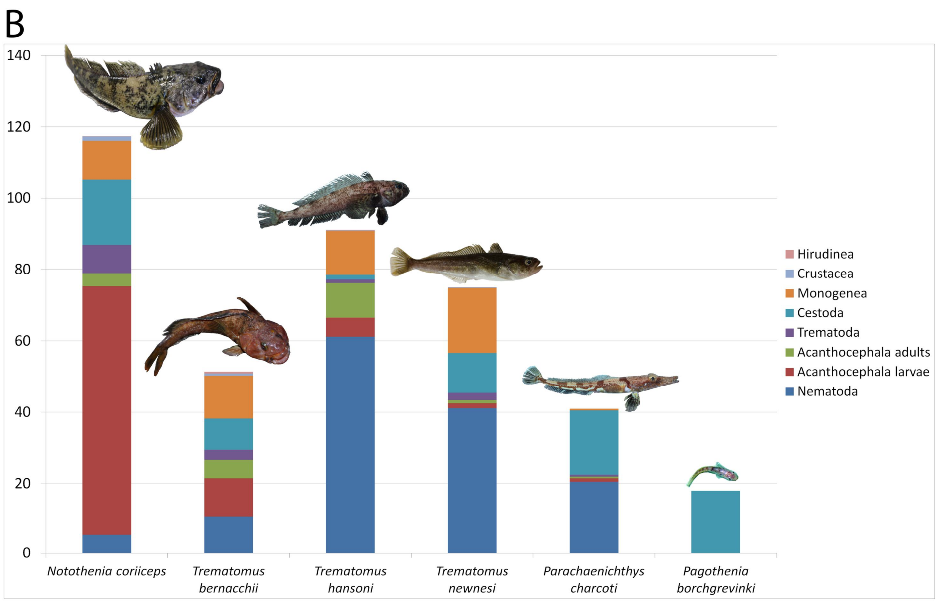


Fig. 3. A. Total numbers of parasites at single fish hosts. **B**. Mean parasite abundance per one fish host.

Host species	**Common name**	**N**	**SL ± SD**	**K ± SD**	**HSI ± SD**	**GSI ± SD**	**Food compostion**
Notothenia coriiceps	Black rockcod	14	228.4 ± 46.6	1.3 ± 0.2	2.7 ± 1.1	1.8 ± 1.6	amphipods, small fishes, macroalgae (Rhodophyta and Phaeophyta) [1]
Trematomus bernacchii	Emerald rockcod	30	167.1 ± 30.9	1.8 ± 0.2	1.6 ± 0.4	1.0 ± 1.0	polychaetes, gastropods, isopods, amphipods and few algae [2]
T. hansoni	Striped rockcod	32	154.2 ± 22.3	1.4 ± 0.1	1.6 ± 0.4	0.4 ± 0.1	small fishes, krill and other euphausiids, polychaetes, copepods, amphipods, isopods and small gastropods [2]
T. newnesi	Dusky rockcod	23	124.3 ± 18.9	1.3 ± 0.2	2.7 ± 1.1	1.8 ± 1.6	amphipods, polychaetes, gastropods, isopods, copepods, and euphausiids [2]
Parachaenichthys charcoti	Antarctic dragonfish	2	166.5 ± 72.8	1.2 ± 0.7	2.9	0.1	fish [2]
Pagothenia borchgrevinki	Bald notothen	1	115	1.7	3.2	1.0	copepods and krill [2]

Table 1. Number of fish examined (N), standard length (SL), Fulton's condition factor (K), hepatosomatic index (HSI) and gonadosomatic index (GSI) of sampled notothenioid fish. Food composition according Kamler (2003) [1] and Froese et Pauly (2015) [2].

	Total		Acanthocephala				Cestoda		Crustacea		Hirudinea		Monogenea		Nematoda		Trematoda	
Parasite stage	larvae & adults		larvae		adults		larvae		adults		adults		adults		larvae		adults	
Host species	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD	P [%]	MA ± SD
Notothenia coriiceps	100	117.4 ± 131.8	100	70.0 ± 82.1	85.7	3.6 ± 3.9	85.7	18.2 ± 39.8	21.4	1.2 ± 2.9	7.1	0.1 ± 0.3	50	11.0 ± 21.2	71.4	5.3 ± 8.4	71.4	8.0 ±10.5
Trematomus bernacchi	100	51.4 ± 32.3	90	11.0 ± 11.3	60	5.2 ± 12.5	80	8.8 ± 10.5	30	0.6 ± 1.3	30	0.5 ± 1.0	73.3	12.0 ± 18.9	93.3	10.5 ± 16.0	50	2.8 ± 5.5
T. hansoni	100	91.1 ± 55.5	75	5.3 ± 8.1	93.8	9.7 ± 9.7	53.1	1.3 ± 1.7	9.4	0.2 ± 0.5	6.3	0.1 ± 0.6	93.8	12.3 ± 7.6	100	61.2 ± 55.8	28.1	1.0 ± 4.2
T. newnesi	100	75.0 ± 69.2	39.1	1.4 ± 3.1	30.4	0.9 ± 2.2	95.7	11.2 ± 10.4	8.7	0.1 ±0.5	-	-	69.6	18.2 ± 41.3	100	41.1 ± 29.0	60.9	2.0 ± 4.6

Table 2. Prevalence (P) and mean abundance (MA) of each parasite taxon of four fish species.

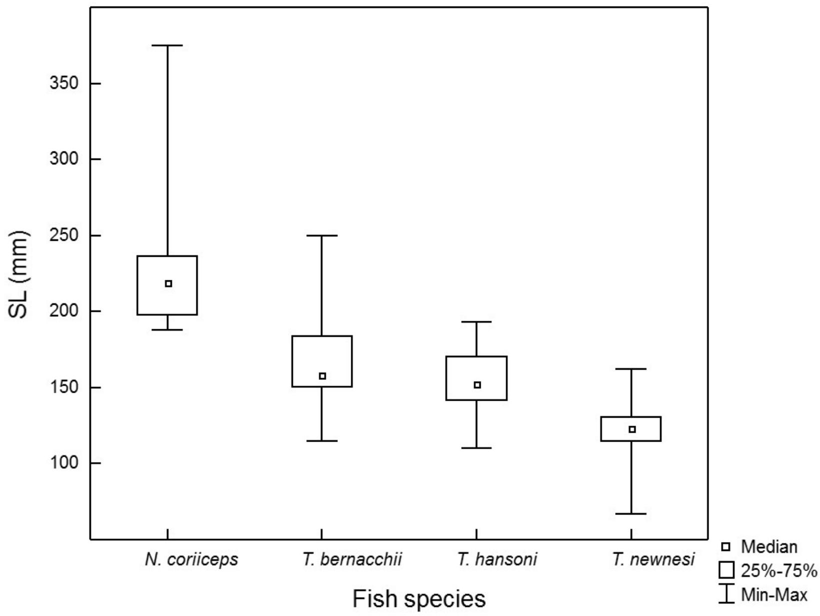


Fig. 4. The comparison of size of four most abundant fish species (*Notothenia coriiceps*, *Trematomus bernacchii*, *T. hansoni* and *T. newnesi*). There were significant differences in standard length (SL) among species except *T. bernacchii* and *T. hansoni* (Kruskal-wallis test: $H_{(3,99)}$ = 53.94, $P < 0.0001$).

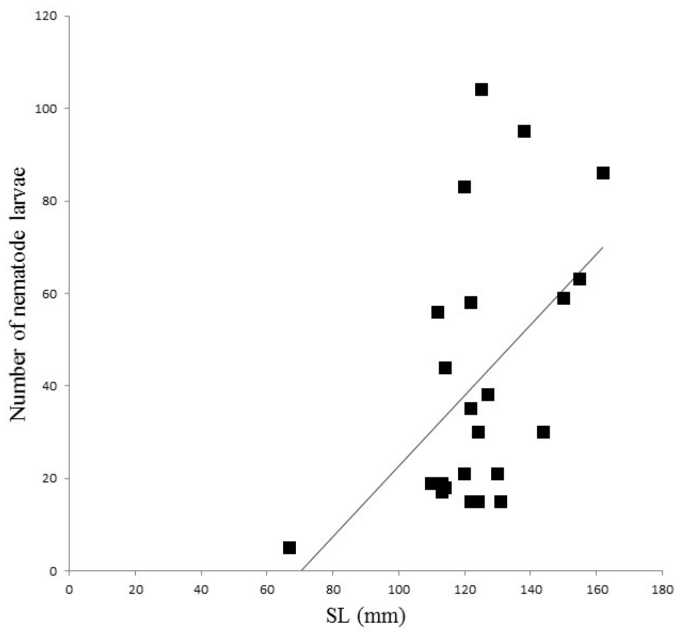


Fig. 5. Spearman correlation between size of the fish (SL) and number of nematode larvae in *Trematomus newnesi* ($r_s = 0.46$, $P < 0.05$).

Discussion

Notothenioid fish are dominant fish fauna in the South Ocean and our preliminary results indicate that their parasite fauna is abundant. Our research on fish parasites was held in the northwestern Weddell Sea in the Prince Gustav Channel for the first time. All taxa of major groups of fish parasites were present in the six fish species examined and there were no fish specimen without parasites. Previous investigations of fish parasites in the Weddell Sea were performed by *e.g.* Zdzitowiecki (1996), Rocka et Zdzitowiecki (1998), Rocka (2002) and Zdzitowiecki (2002 a, b). Palm et al. (1998) studied parasites of *Notothenia coriiceps* in Potter Cove, King George Island (the opposite side of the Antarctic Peninsula than the study area) and found high parasite diversity. In accordance with our study, the fish were infected with parasites from all parasite taxa, acanthocephalan adults and larvae and adult trematodes dominated. All endoparasites found have indirect life cycles where two or more host species are needed. Parasites found in fish as larvae (Nematoda, Cestoda, *Corynosoma* spp.) use the fish as intermediate or paratenic host (Palm et al. 1998, Rocka 2006). For the completion of their life cycles, the fish has to be eaten by the following intermediate or definitive host, *e.g.* fish-eating birds or mammals. In contrast, for Trematoda and part of Acanthocephala that were found in fish as adults, the fish serve as definitive host. The most abundant parasites in our study were nematodes, all of them belonging to the Anisakidae. Anisakid larvae are widespread and abundant in bony fishes in the whole Antarctica (Rocka 2004). Antarctic bony fishes serve as second intermediate and paratenic hosts for them (Palm et al. 1998). Their prevalence in our specimens of *T. hansoni* and *T. newnesi* was 100%. The most heavily infected fish species was *Notothenia coriiceps*, which may correspond to the size (biggest from all host species). Individual fish species differed considerably in the composition and quantity of parasites. This aspect probably corresponds to the different ecological niche of each fish species.

Generally, attention has not been paid to ectoparasites as much as to endoparasites (*e.g.* Zdzitowiecki et Laskowski 2004, Rocka 2006, Santoro et al. 2013, Zdzitowiecki et Ozouf-Costaz 2013). In Palm et al. (1998), only one species of Monogenea was found in *N. coriiceps*, although in our study, there were at least two species of these ectoparasites (both viviparous and oviparous) in this fish species. In other fish species, the prevalence and abundance of Monogenea were even higher and in *T. hansoni*, prevalence reached almost 94%. There was no significant correlation between the size of the host fish and the number of parasites, but parasites of major groups were pooled. Although this trend has been often documented in variety of fish and parasites (*e.g.* Guégan et al. 1992, Muñoz et al. 2007), some other studies did not confirm this relationship (Jarkovský et al. 2004, Gonzáles et Poulin 2005). The increasing number of parasites in larger fish is explained by the accumulation of parasites in fish throughout its life, but this accumulation in host is not possible in all parasite groups and the correlation could be different in ectoparasites and endoparasites. In our case, the correlation between the size of the fish and the number of endoparasites (especially the number of nematodes) was significant only in *T. newnesi* only (Fig. 5).

Conclusion

Our data indicate that fish parasites off the James Ross Island form abundant group of organisms. For them, notothenioid fish are appropriate hosts because of their central position in the Antarctic food chain that enables the parasites to successfully pass and finish their life cycles. However, specific identification of parasites is necessary for completion of the study and evaluation the diversity and possible effects of Antarctic parasites on trophic relationship of their fish hosts.

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