



Changes in digenean infection of the Antarctic fish *Notothenia coriiceps* in Admiralty Bay, King George Island, over three decades

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Abstract: The infection of black rockcod, *Notothenia coriiceps*, with digeneans in Admiralty Bay (South Shetland Islands) within three months, from November 2007 to January 2008, is compared with the infection in the same three months in 1978/79, based on the examination of twenty fish collected in each month. Digenea found in 1978/1979 season were more numerous, and more diverse. Only five digenean species, *Macvicaria georgiana*, *Neolebouria antarctica*, *Lepidapedon garrardi*, *Genolinea bowersi* and *Lecithaster macrocotyle*, were recorded during both investigations, whereas three species, *Neolepidapedon trematomi*, *Elytrophalloides oatesi* and *Gonocerca phycidis*, only in 1978/79. *M. georgiana* was the dominant species in 1978/79 and sub-dominant in 2007/08. Other digeneans were found in *N. coriiceps* in 2007/08 invariably together with *M. georgiana*. *G. bowersi* was the sub-dominant species in 1978/79 and the most common species in 2007/2008. Infections with Digenea belonging to other species were much less intense. Of the three rare or common species in 1978/79, the two, *L. garrardi* and *L. macrocotyle*, occurred in both seasons, whereas *E. oatesi* occurred only in 1978/79. Three remaining species were sporadic or absent. The overall results therefore demonstrated that infections with almost all digenean species were less strong in 2007/08 than three decades earlier, in 1978/79. Only data on *M. georgiana*, *G. bowersi* and *L. garrardi* were statistically significant ($p < 0.05$). Data on the occurrence of 14 species of Digenea in *N. coriiceps* from South Shetland Islands, South Orkney Islands, South Georgia, Argentine Islands, Melchior Islands, Adelie Land and Heard Island are given.

Key words: Antarctic, Digenea, black rockcod, *Notothenia*, change of infection.

Introduction

Black rockcod, *Notothenia coriiceps* Richardson, 1844 (Nototheniidae), is an abundant predatory fish species occurring in sub-coastal circum-Antarctic waters (Gon and Heemstra 1990). Reports on the occurrence of digeneans in this host in

the environs of Adelie Land, in the West Antarctic, off South Georgia and in the Kerguelen subregion of Subantarctic were published by Szidat (1965), Prudhoe and Bray (1973), Zdzitowiecki (1987, 1988, 1997, 2001), Zdzitowiecki and White (1992), Zdzitowiecki *et al.* (1997, 1998), Palm *et al.* (1998), and Zdzitowiecki and Laskowski (2004). Extensive investigations were carried out in two localities in King George Island (South Shetland Islands) – in Admiralty Bay (Zdzitowiecki 1987, 1988) and in Potter Cove (Palm *et al.* 1998).

The report by Zdzitowiecki (1988) was based on the collection of parasites found during the whole year, from December 1978 to December 1979, in Admiralty Bay (King George Island, South Shetland Islands) near the *Arctowski* Station. Not less than 20 specimens of *N. coriiceps* were examined in each month; in total 248 specimens. The present investigation was carried out during three months at the same place, but 29 years later, from November 2007 to January 2008. These new data are compared with results of investigations in the same three months in 1978/79. Data on infections of *N. coriiceps* with acanthocephalans were previously published (Laskowski *et al.* 2012). The present paper contains data on the digenean infection of the same fish specimens.

Material and methods

Present investigations in Admiralty Bay were carried out during three months, from November 2007 to January 2008 near *Arctowski* Station (62°9' S, 58°28' W). Results are compared with those found during similar investigations in the same three months, November 1978, December 1978 and January 1979, so nearly three decades earlier. Twenty specimens of *Notothenia coriiceps* were caught in each month using a fishing rod or bottom net at a depth of 10–80 m (usually 10–50 m) at the shore of Admiralty Bay nearby the *Arctowski* Station. Standard lengths (S.L.) of fish examined in 1978/79 were 24.4–44.0 cm (mean 32.93 cm); of those examined in 2007/08 were 25.0–40.5 cm (mean 31.49 cm). In total 248 *N. coriiceps* were examined in 1978/79 (Zdzitowiecki 1988). Fresh fish were examined using a stereo-microscope. Digenea were found exclusively in the lumen of the stomach and intestine. Digenea were washed in a fresh water, killed by heat in this water, counted, fixed and stored in 70% ethanol (in 1978/79 with addition of 5% of glycerin). Taxonomic identifications were based on keys and descriptions published by Zdzitowiecki (1997). Most specimens were identified alive using a stereo-microscope. Some representative specimens of all digenean species and all doubtful ones were washed in fresh water, painted with carmine alum, washed again in fresh water, dehydrated in graded ethanol, cleared in benzyl alcohol and determined as temporary total mounts in clearing solution (benzyl alcohol) with a light microscope. Three indices of infection are given following Bush *et al.* (1997): prevalence – percent of infected fish, maximum intensity – the largest number of individuals of a particular

Table 1
Infection with Digenea of *Notothenia coriiceps* in Admiralty Bay in November–January 1978/79 and 2007/08 (n = 60 in each season). P – Prevalence, MI – Maximum intensity, MA – Mean abundance.

Parasite	1978/79			2007/08		
	P %	MI	MA	P %	MI	MA
<i>Macvicaria georgiana</i> (Kovaljova et Gaevskaya, 1974)	98	481	98.98	92	1157	74.60
<i>Neolebouria antarctica</i> (Szidat et Graefe, 1967)	2	1	0.02	2	1	0.02
<i>Lepidapedon garrardi</i> (Leiper et Atkinson, 1914)	28	12	0.90	7	2	0.08
<i>Neolepidapedon trematomi</i> Prudhoe et Bray, 1973	2	1	0.02	–	–	–
<i>Genolinea bowersi</i> (Leiper et Atkinson, 1914)	92	101	10.98	25	18	1.23
<i>Gonocerca phycidis</i> Manter, 1925	2	2	0.03	–	–	–
<i>Elytrophalloides oatesi</i> (Leiper et Atkinson, 1914)	17	12	0.53	–	–	–
<i>Lecithaster macrocotyle</i> Szidat et Graefe, 1967	7	2	0.08	2	1	0.02
Total	100	482	111.55	92*	1157	76.12

* – 8% (5 specimens) of fish examined in 2007/08 was not infected by digeneans.

parasite species in one host specimen, and mean abundance – mean number of parasite species among all members of a particular host species examined (Table 1). Data on the infection of the same fish specimens with Acanthocephala were given by Laskowski *et al.* (2012). The prevalence of infection was used for classification of each digenean species into different categories: dominant (95–100%), sub-dominant (50–95%), common (10–50%), rare (4–10%) and sporadic (below 4%).

Kolmogorov-Smirnov and Shapiro-Wilks' W test for distribution of variables data was performed. The Mann-Whitney U test was used to compare data on the levels of infection between two research seasons: 1978/79 and 2007/08. Statistical analysis was performed with the software package STATISTICA 6.1.

Results

Material from 1978/79 consists of 6693 digeneans belonging to eight species. Three species – *Genolinea bowersi* (Leiper et Atkinson, 1914), *Gonocerca phycidis* Manter, 1925 and *Elytrophalloides oatesi* (Leiper et Atkinson, 1914) were found in the stomachs. Five species – *Macvicaria georgiana* (Kovaljova et Gaevskaya, 1974), *Neolebouria antarctica* (Szidat et Graefe, 1967), *Lepidapedon garrardi* (Leiper et Atkinson, 1914), *Neolepidapedon trematomi* Prudhoe et Bray, 1973 and *Lecithaster macrocotyle* Szidat et Graefe, 1967 occurred in the lumen of the intestines. In total, 4567 digeneans of five species: *M. georgiana*, *N. antarctica*, *L. garrardi*, *G. bowersi* and *L. macrocotyle* were found in 2007/08. Three other species: *G. phycidis*, *E. oatesi* and *N. trematomi* present in *N. coriiceps* in 1978/79, were absent in 2007/08 (Table 1).

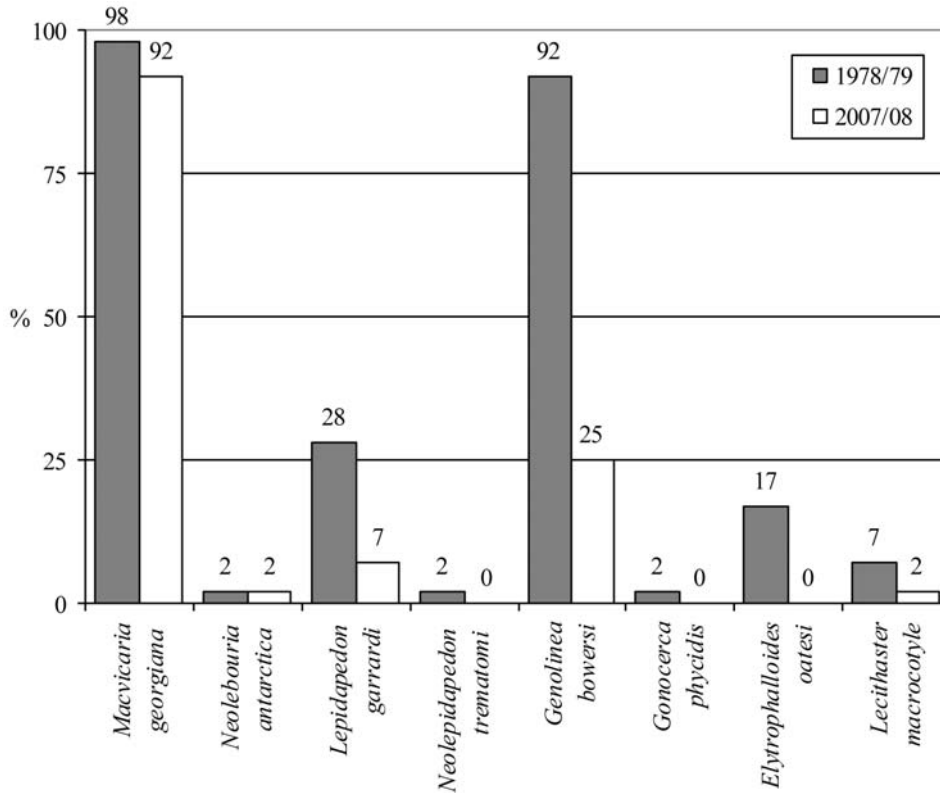


Fig. 1. Prevalence of infection of Digenea in *Notothenia coriiceps* in Admiralty Bay in 1978/79 and 2007/08.

Prevalence of three parasite species is shown in Fig. 1. *M. georgiana* was the dominant or sub-dominant species in both periods. This species was the most numerous – 88.7% of all digeneans in 1978/79 ($n = 5939$ worms) and 98% in 2007/08 ($n = 4476$ worms). Its prevalence was 98% in 1978/79 and 92% in 2007/08. Also MA was lower in 2007/08 (Table 1). Intensity of infection with this parasite exceeded 400 digeneans in some fish of both samples. However, the greatest intensity (1157) was found in one host specimen in December 2007. According to Zdzitowiecki (1988) *M. georgiana* occurred in 1978/79 less frequently during the Antarctic spring than in other seasons, just in the same months of investigations in 2007/08.

G. bowersi was the sub-dominant species in 1978/79 (prevalence 92%), but its prevalence in 2007/08 was almost four times smaller (25%). Infections with this parasite were less numerous than those with *M. georgiana* (101 in 1978/79 and only 18 in 2007/08); mean abundance was nine times smaller in 2007/08 than in 1978/79 (Table 1, Fig. 2). *M. georgiana* and *G. bowersi* were the only digenean species invariably occurring with mean abundance exceeding or equal to 1.0 (Table 1).

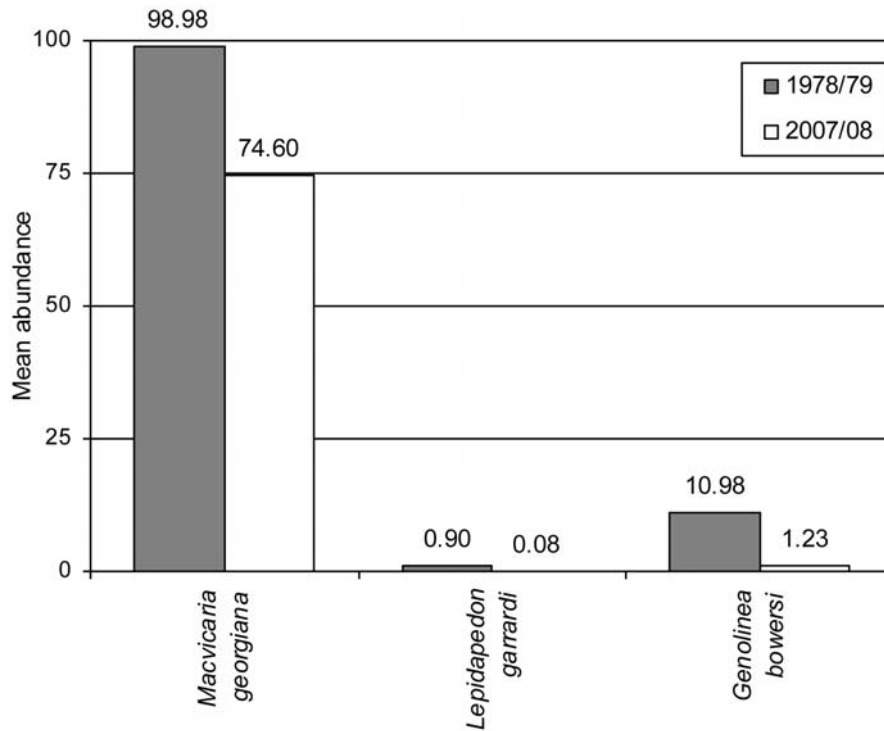


Fig. 2. Mean abundance of infection of three species of Digenea in *Notothenia coriiceps* in Admiralty Bay in 1978/79 and 2007/08.

Three species, *L. macrocotyle*, *E. oatesi* and *L. garrardi* occurred in low numbers in 1978/79 (prevalence 7%, 17% and 28%, respectively); *E. oatesi* was absent in 2007/08. This observation is peculiar as *E. oatesi* was abundant in blackfin icefish, *Chaenocephalus aceratus* Lönnberg, 1906 and *L. garrardi* in yellowfin notie, *Lindbergichthys nudifrons* (Lönnberg, 1905) caught together with *N. coriiceps* (unpublished data). Three remaining species – *N. antarctica*, *N. trematomi* and *G. phycidis* were sporadic in *N. coriiceps*, although abundant at the South Shetland Islands in other hosts, such as predators belonging to the families Nototheniidae, Bathydraconidae and Channichthyidae, e.g. *G. phycidis* in *Chaenocephalus aceratus*, *N. trematomi* in Antarctic toothfish, *Dissostichus mawsoni* Norman, 1937 and in striped rockcod, *Trematomus hansonii* Boulenger, 1902 (Zdzitowiecki 1988, 1991, 1997).

Except of *M. georgiana* and *G. bowersi* other digenean species were rare in *N. coriiceps* in Admiralty Bay. All analyzed data are not normally distributed (Kolmogorov-Smirnov and Shapiro-Wilks' W test). The Mann-Whitney U test was used to compare levels of infection data between two research seasons: 1978/79 and 2007/08. Changes in infection rates were statistically significant ($p < 0.05$) for three digenean species: *M. georgiana*, *G. bowersi*, and *L. garrardi* (Table 1, Fig. 2).

Discussion

Records of 14 species of digeneans in *N. coriiceps* in different areas are shown in Table 2. A check list of Digenea identified at the Adelie Land (East Antarctica) concerns nine species, *Macvicaria pennelli* (Leiper *et al.* 1914), *M. microtestis* Zdzitowiecki *et al.* 1997, *Neolebouria terranovaensis* Zdzitowiecki, Pisano *et al.* 1993, *Lepidapedon balgueriasi* Zdzitowiecki *et al.* 1997, *Lepidapedon garrardi*, *Genolinea bowersi*, *Derogenes johnstoni* Prudhoe *et al.* 1973, *Gonocerca phycidis* and *Elytrophalloides oatesi* (Zdzitowiecki 2001, Table 1). Dominant species were not observed. Three species, however, were sub-dominant: *N. terranovaensis* (prevalence 61.1%), *M. microtestis* (77.8%) and *G. bowersi* (72.2%). Other parasites were either common (four species) or rare (two species).

Only two digenean species – *Stenakron kerguelense* Prudhoe *et al.* 1973 and *Lecithaster australis* Prudhoe *et al.* 1973 (= *L. macrocotyle* Szidat *et al.* Graefe, 1967) were recorded in *N. coriiceps* at the Heard Island (Kerguelen subregion, Subantarctic) (Prudhoe and Bray 1973). Indices of infections were not given.

Three species – *Macvicaria georgiana* (as *Plagioporus pennelli* Leiper *et al.* 1914), *L. garrardi* (as *Lepocreadium trullaforme* Linton, 1940) and *N. antarctica* (as *Opegaster synodi* Manter, 1947) were found at the South Orkney Islands (Szidat 1965). Zdzitowiecki *et al.* (1997) recorded in this area *M. georgiana* (dominant species, prevalence 100%, mean abundance 72.17) and *G. bowersi* (sub-dominant species, prevalence 87%, mean abundance 3.91).

Only three *N. coriiceps* were examined in a fjord in South Georgia and four digenean species *M. georgiana* (as *M. pennelli*), *G. bowersi*, *E. oatesi* and *L. macrocotyle* were found (Zdzitowiecki and White 1992). Szidat (1965) reported the presence of three digenean species, *Genolinea bowersi* (as *Derogenes parvus* Szidat, 1950), *L. garrardi* (as *Lepocreadium trullaforme* Linton, 1940) and *M. georgiana* (as *Plagioporus pennelli*) in the environs of Melchior Islands. Indices of infection were not given.

Six species, the same as occurring in Admiralty Bay with exceptions of *N. trematomi* and *G. phycidis*, occurred at the Argentine Islands (Zdzitowiecki and Laskowski 2004). *M. georgiana* was almost the dominant species (94%) and *G. bowersi* the sub-dominant (74%). Three species were common – *E. oatesi* (47%), *N. antarctica* (30%) and *L. garrardi* (18%). *L. macrocotyle* was observed to be sporadic (1%).

According to Palm *et al.* (1998) two species were sub-dominant in Potter Cove (King George Island): *P. pennelli* (= *M. georgiana*) (74%) and *G. bowersi* (62%). Three other species – *L. garrardi*, *E. oatesi* and *G. phycidis* were rare or common (4%, 8% and 14%, respectively).

Taking into account all faunistic data, the dominant digenean species occurring in *N. coriiceps* in the West Antarctic is *M. georgiana* and the sub-dominant is *G. bowersi*. The only exceptions were the dominance of *E. oatesi* at South Georgia

Table 2
Records of Digenea in *Notothenia coriiceps* in various areas. S.S. – South Shetland Islands, S.O. – South Orkney Islands; S.G. – South Georgia; A.I. – Argentine Islands; M.I. – Melchior Islands (West Antarctic); A.L. – Adelie Land (East Antarctic); H.I. – Heard Island (Kerguelen subregion, Subantarctic).

Parasite	S.S.	S.O.	S.G.	A.I.	M.I.	A.L.	H.I.
<i>Macvicaria georgiana</i> (Kovaljova <i>et</i> Gaevskaya, 1974)	+	+	+	+	+		
<i>Macvicaria microtestis</i> Zdzitowiecki <i>et</i> Cielecka, 1997						+	
<i>Macvicaria pennelli</i> (Leiper <i>et</i> Atkinson, 1914)						+	
<i>Neolebouria antarctica</i> (Szidat <i>et</i> Graefe, 1967)	+	+		+			
<i>Neolebouria terranovaensis</i> Zdzitowiecki, Pisano <i>et</i> Vacchii, 1993						+	
<i>Stenakron kerguelense</i> Prudhoe <i>et</i> Bray, 1973							+
<i>Lepidapedon balgueriasi</i> Zdzitowiecki <i>et</i> Cielecka, 1997						+	
<i>Lepidapedon garrardi</i> (Leiper <i>et</i> Atkinson, 1914)	+	+		+	+	+	
<i>Neolepidapedon trematomi</i> Prudhoe <i>et</i> Bray, 1973	+						
<i>Genolinea bowersi</i> (Leiper <i>et</i> Atkinson, 1914)	+	+	+	+	+	+	
<i>Derogenes johnstoni</i> Prudhoe <i>et</i> Bray, 1973						+	
<i>Gonocerca phycidis</i> Manter, 1925	+					+	
<i>Elytrophalloides oatesi</i> (Leiper <i>et</i> Atkinson, 1914)	+		+	+		+	
<i>Lecithaster macrocotyle</i> Szidat <i>et</i> Graefe, 1967	+		+	+			+

(Zdzitowiecki and White 1992) and the strong infection with *N. antarctica* at the Argentine Islands (Zdzitowiecki and Laskowski 2004). None of the digenean species found at Adelie Land (East Antarctic) were dominant. However, the most numerous was *N. terranovaensis*, with a prevalence 61.1%, mean abundance of 8.11, and maximum intensity of 91 (Zdzitowiecki 2001). Indices of infections at Heard Island (Subantarctic) and the Melchior Islands (West Antarctic) were not given (Prudhoe and Bray 1973 and Szidat 1965). Data on the occurrence of digeneans in *N. coriiceps* at South Georgia were not sufficient for conclusions, but it should be noted that *E. oatesi* was the dominant parasite species present in other predatory fish including *Notothenia rossii* Richardson, 1844 (Zdzitowiecki 1991, Zdzitowiecki and White 1992).

Digenea found in 1978/79 season were more numerous and more diverse than in 2007/08. These results demonstrated that infections with almost all digenean species were less strong in 2007/08 than in 1978/79. The reverse situation occurred with the infection of *N. coriiceps* in Admiralty Bay with acanthocephalans of the order Echinorhynchida co-occurring with Digenea in the alimentary tract of fish, final hosts of both kinds of parasites (Laskowski *et al.* 2012). Digeneans were much more numerous with the mean abundance of 111.55 in 1978/79 and 76.12 in 2007/08, than echinorhynchids occurring in the same fish specimens with the mean abundance 35.35 in 1978/79 and 46.54 in 2007/08. Life cycles of Antarctic Digenea are poorly known. Zdzitowiecki (1997) suggested that probably all

digeneans maturing in Antarctic bony fishes use molluscs as hosts of parthenogenetic generations and various marine invertebrates (prey species for *N. coriiceps*) as intermediate host. Organic pollution from scientific station and vessels could change a composition of benthic invertebrates in shallow waters and reduce the amount of potential digenean intermediate host.

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References

- BUSH A.O., LAFFERTY K.D., LOTZ J.M. and SHOSTAK A.W. 1997. Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology* 83: 575–583.
- GON O. and HEEMSTRA P.C. 1990 (eds). *Fishes of the Southern Ocean*. J.L.B. Smith Institute of Ichthyology, Grahamstown: 462 pp.
- LASKOWSKI Z., KORCZAK-ABSHIRE M. and ZDZITOWIECKI K. 2012. Changes in acanthocephalan infection of the Antarctic fish (*Notothenia coriiceps*) in Admiralty Bay (King George Island) after 29 years from previous investigations. *Polish Polar Research* 33: 99–108.
- PALM H.W., REIMANN N., SPINDLER N. and PLÖTZ J. 1998. The role of the rock cod *Notothenia coriiceps* Richardson, 1844 in the life-cycle of Antarctic parasites. *Polar Biology* 19: 399–406.
- PRUDHOE S. and BRAY R.A. 1973. Digenetic trematodes from fishes. *B.A.N.Z.A.R.E. Reports, Series B* 8: 195–225.
- SZIDAT L. 1965. *Estudios sobre la fauna de parásitos de peces antárticos. I. Los parásitos de Notothenia neglecta Nybelin*. Servicio de Hidrografía Naval, Secretaria de Marina Republica Argentina, Publico H 910, Buenos Aires: 84 pp.
- ZDZITOWIECKI K. 1987. Digenetic trematodes from the alimentary tract of fishes off South Shetlands (Antarctic). *Acta Parasitologica Polonica* 32: 219–232.
- ZDZITOWIECKI K. 1988. Occurrence of digenetic trematodes in fishes of South Shetlands (Antarctic). *Acta Parasitologica Polonica* 33: 155–167.
- ZDZITOWIECKI K. 1991. Occurrence of digeneans in open sea fishes off the South Shetland Islands and South Georgia, and a list of fish digeneans in the Antarctic. *Polish Polar Research* 12: 55–72.
- ZDZITOWIECKI K. 1997. Antarctic Digenea parasites of fishes. In: J.H. Wägele and J. Sieg (eds) *Synopses of the Antarctic benthos*. Vol. 8. Koeltz Scientific Books, Koenigstein: 156 pp.
- ZDZITOWIECKI K. 2001. New data on the occurrence of fish endoparasitic worms off Adelie Land, Antarctica. *Polish Polar Research* 22: 159–165.
- ZDZITOWIECKI K. and LASKOWSKI Z. 2004. Helminths of an Antarctic fish, *Notothenia coriiceps*, from the Vernadsky Station (Western Antarctica) in comparison with Admiralty Bay (South Shetland Islands). *Helminthologia* 41: 201–207.
- ZDZITOWIECKI K. and WHITE M.G. 1992. Digenetic Trematoda infection of inshore fish at South Georgia. *Antarctic Science* 4: 51–55.
- ZDZITOWIECKI K., WHITE M.G. and ROCKA A. 1997. Digenetic, monogenetic and cestode infection of inshore fish at the South Orkney Islands. *Acta Parasitologica* 42: 18–22.
- ZDZITOWIECKI K., ROCKA A., PISANO E. and OZOUF-COSTAZ C. 1998. A list of fish parasitic worms collected off Adelie Land (Antarctic). *Acta Parasitologica* 43: 71–74.

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