Sci Parasitol 13(3):119-128, September 2012
ISSN 1582-1366

ORIGINAL RESEARCH ARTICLE

Ecto and endoparasites of some fishes from the Antarctic Region

Mehmet Cemal Oguz[1], Richard A. Heckmann[2]✉, C.H. Christina Cheng[3], Atif El-Naggar[4], Yahya Tepe[5]

1 – Ataturk University, Faculty of Science, Department of Biology, 25240, Erzurum, Turkey.

2 – Brigham Young University, Department of Biology, Provo, Utah 84602, USA.

3 – University of Illinois at Urbana-Champaign, Department of Animal Biology School of Integrative Biology, 515 Morrill Hall, 505 South, Goodwin Ave. Urbana, IL 61801, USA.

4 – Ain Shams University, Cairo, Egypt. Brigham Young University, Provo, Utah 84602, USA.

5 – Ataturk University, Faculty of Science, Department of Biology, 25240, Erzurum, Turkey.

Correspondence: Tel. 801-422-2495, Fax 801-422-0090, E-mail richard_heckmann@byu.edu

Abstract. Parasites from 14 species of Antarctic fishes representing three (3) Notothenoid families and the unrelated Zoarcidae and Liparidae yielded symbiotic species in five major parasite groups. The fish were collected between mid-July and September 2008 from offshore sites near Palmer Station, Antarctica. Fourteen *Pseudobenedenia notothinae* were found on *Dissotiches mawsoni* attached to the gills and body surface of the host. Seven *Diphyllobothrium* sp. were present in the lumen of the intestine of *Lycenchelys* sp. Fourteen species of Antarctic fishes harbored varying numbers of *Hysterothylacium (Contracaecum) aduncum* a common nematode of fishes. Seven *Eubrachiella antarctica* were attached to the skin of *Chaenocephallus aceratus* collected near Low Island. Five *Eubrachiella gaini*, were attached to the body surface of *C. aceratus.* One leech was found on both *Cryodraco antarticus* and *Chionodraco rastrosinosus.* This hirudinean was attached to the skin of the host. Specific locations for the collected fish are listed along with pertinent research articles. Each parasite is represented by SEM figures.

Keywords: Antarctic Fishes; Parasites; Host-Parasite Relationship.

Received 25/05/2012. Accepted 25/09/2012.

Introduction

The Antarctic region has been considered as one of the most interesting areas for biological research for many years. There have been numerous articles published concerning the strange and highly evolved fish species in this region (Kock et al., 1984; Gon and Heemstra, 1990; Eastman and Clarke, 1998; Eastman, 2000). The Antarctic is a continent, twice the size of Australia with an expanse of ocean surrounding the landmass. There are numerous Islands and Bays in the Antarctic, most covered with ice 12 months of the year. The area has approximately 45,000,000^2 km of area. The dominant fauna, including fish, inhabits the water of the adjacent continental shelf rather than the landmass. Ice is a common characteristic of these waters. There have been many published records of surveys of the parasites of fishes and aquatic mammals in the continental shelf waters (Hargis and Dillon, 1968; Siegel, 1980; Hoogesteger and White, 1981; Zdzitowiecki et al., 1997; Rhode et al., 1998; Zdzitowiecki and Laskowski, 2004; Rocka, 2006).

Many of these studies have been completed on specific fish as hosts for various parasites (Szidat, 1965; Kock and Möller, 1977; Parukhin and Lyadov, 1981; Sosinski and Janusz, 1986; Gaevskaya et al., 1990; Palm et al., 1994; Palm et al., 1998; Zdzitowiecki et al., 1998; Janusz and Sosinski, 1999; Zdzitowiecki, 2001a; 2001b; Brickle et al., 2005; Laskowski et al., 2007; Bielecki et al., 2008).

It is important to study and understand the parasites of the Antarctic fauna. Antarctic vertebrates, including fish, are definitive hosts of internal parasitic worms belonging to four helminth groups: Digenea, Cestoda, Nematoda and Acanthocephala, as well as protozoan parasites. Leeches and copepods have also been reported on these fish hosts. The most species rich group of Antarctic vertebrates are bony fishes. They play an important role in the completion of life cycles of many helminth species, serving as definitive, intermediate and paratenic hosts.

Sub-regions of the Arctic and Antarctic have shown the most rapid rates of warming in recent years. Substantial environmental impacts of climate change show profound regional differences both within and between the polar regions. The impacts of the climate change in the polar regions over the next 100 years will exceed the impacts forecast for many other regions and will produce feedbacks that will have globally significant consequences. However, the complexity of response in biological and human systems means that future impacts remain very difficult to predict (Eastman, 2000; Brickle et al., 2006).

This change will be reflected on the ichthyofauna in the region and their parasitic symbionts. Most of the research on fish parasites in this region has been on helminths (Rocka, 2006; Bielecki et al., 2008; and others). There have been few studies related to the protozoan parasites. The present study expands on the known data and is especially important due to the unique regions where fish were examined. Overall, the fauna of Monogenea and Copepoda of Antarctic fish is much poorer than that of lower latitudes of the region. As an example there are fewer species of Gyrodactylidae relative to other Monogenea in the lower latitudes than at higher northern latitudes. Abundance and species richness of Acanthocephala are relatively high (Rohde et al., 1998).

The aim of this study is to determine the parasite species in the hosts collected from these Antarctic Peninsula waters.

Materials and methods

Examination

Specimens of 14 Antarctic fish species were captured between mid-July and September 2008 either from ship trawls and traps onboard the R/V Laurence M. Gould in offshore sites, or from traps or handlines in Arthur Harbor outside Palmer Station, Antarctica. The 14 fish species represent five families – three Antarctic notothenioid families, and the unrelated Zoarcidae and Liparidae. The collected species are: *Chaenocephalus aceratus* (juvenile and adult) (Lönnberg, 1906), *Chionodraco rastrospinosus* (De Witt and Hureau, 1979), *Cryodraco antarcticus* (Dollo, 1900), *Dissostichus mawsoni* (Norman, 1937), *Lepidontothen nudifrons* (Lönnberg, 1905), *Lepidontothen Iarseni* (Lönnberg, 1905), *Lepidonotothen squamifrons* (Gunther, 1880), *Liparis* sp. (Scipoli 1777), *Lycenchelys nigripalatum* (DeWitt and Hureau, 1979), *Notothenia corriiceps* (Richardson, 1844), *Trematomus bernacchii* (Boulenger, 1902), *Trematomus scotti* (Boulenger, 1907), and *Vomeridens infuscipinnis* (DeWitt, 1964).

Locations for the fish are listed in table 1 (name and location by degrees and minutes).

Table 1. Summary of parasites (helminths) found during the 2008 sample of antarctic fishes

Parasite	Location	Number	Host	Location (degrees-minutes)	Parasite Group
Pseudobenedenia nototheniae	Gills & body surface	14	*Dissotichus mawsoni*	Paradise bay 63 27S; 62 50 W	Monogenea
Diphyllobothrium sp.	Intestine	7	*Lycenchelys* sp.	Paradise bay 63 27 S; 62 50W	Cestoda
Hysterothylacium aduncum (Contracaecum)	Intestine, Liver, Abdominal cavity	Many	*Parachaenichthys charcoti*	Snow island 62 55 S; 61 21 W	Nematoda
			Vomeridens infuscipinnis	Dallman bay 64 08 S; 62 45 W	
			Chaenocephalus aceratus	Low island 63 27 S; 62 50 W	
			Cryodraco antarcticus	Gerlache Strait 64 44 S; 63 01 W	
			Chinodraco rastrospinosus	Hugo island 64 48 S; 65 23 W	
			Lepidonotothen nudifrons	Low island 63 27 S; 62 50 W	
			Lepidonotothen larseni	Dallman bay 64 08 S; 62 45 W	
			Lepidonotothen squamifrons	Dallman bay 64 08 S; 62 45 W	
			Trematomus bernacchii	Paradise bay 63 27 S; 62 50 W	
			Trematomus scotti	Gerlache strait 64 44 S; 63 01 W	
			Notothenia corriceps	Arthur harbor 64 46 S; 64 06 W	
			Lycenchelys nigripalatum	Low island 63 27 S; 62 50 W	
			Lycenchelys sp.	Paradise bay 63 27 S; 62 50 W	
			Liparis sp.	Low island 63 27 S; 62 50 W	
Eubrachiella antartica	Skin integument	7	*Chaenocephalus aceratus*	Low island 63 27 S; 62 50 W	Crustacea
Eubrachiella gaini	Skin integument	5	*Chaenocephalus aceratus*	Low island 63 27 S; 62 50 W	Crustacea
Leech	Skin	1	*Cryodraco antarctica*	Gerlache Strait 64 44 S; 63 01 W	Hirudinea
		1	*Chinodraco rastrosinosus*	Hugo island 64 48 S; 65 23 W	

The fish were collected at water depths between 10 and 500 m depending on location and species. The specimens were dissected and parasites were collected and preserved in 70% or 90% ethanol alcohol either onboard of R/V LM Gould, or at Palmer Station. The preserved parasites were returned to the US and examined in detail for species identification at the second author's laboratory.

Electron Optics

Select specimens were preserved for scanning electron microscopy (SEM) to help species identification. For SEM, a few specimens of the collected parasites previously fixed in 70% ethanol were placed in Critical Point Dry (CPD) baskets and dehydrated using an ethyl alcohol (ETOH) series of 95% and 100% for at least 10 minutes per soak followed by critical point drying (Lee, 1992). Samples were then mounted on SEM sample mounts, gold coated and observed with a scanning electron microscope (FEI X L30 ESEMFEG). Digital images of the structures and parasites were obtained and stored using digital imaging software attached to a computer (figures 1 to 22).

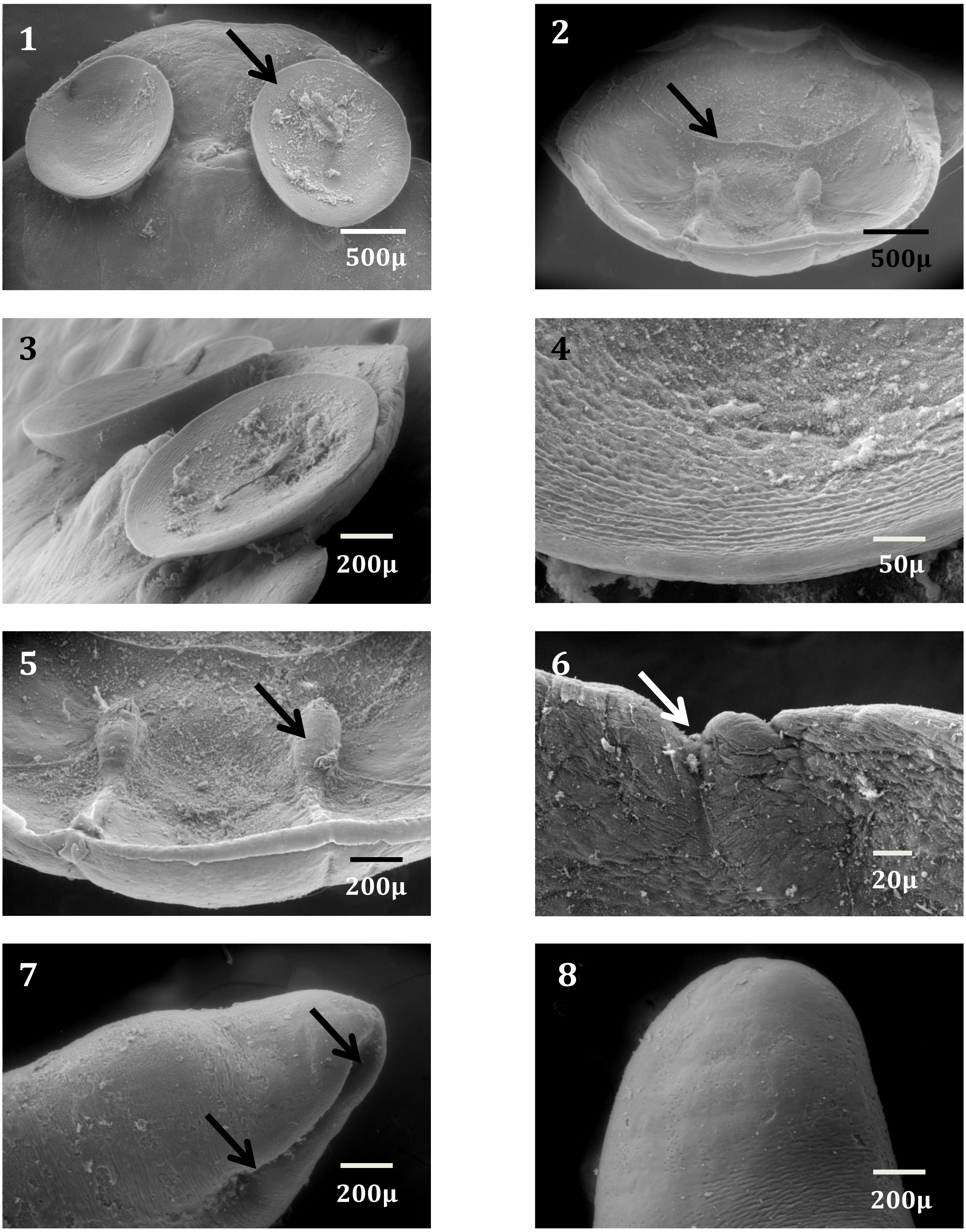
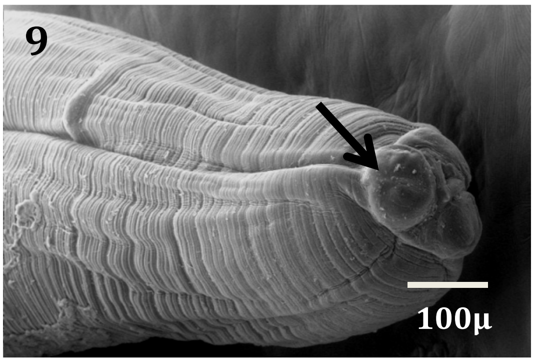
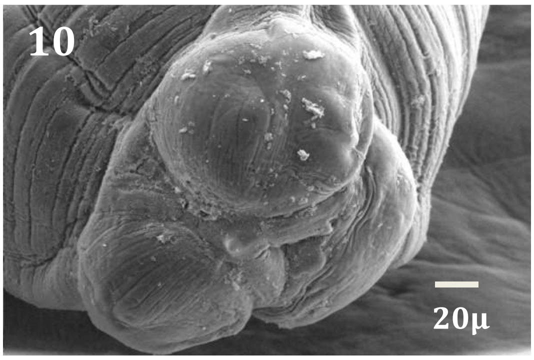
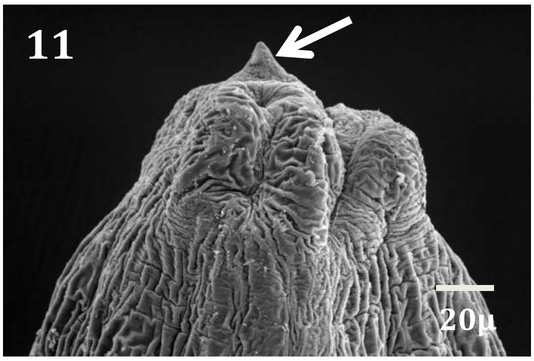
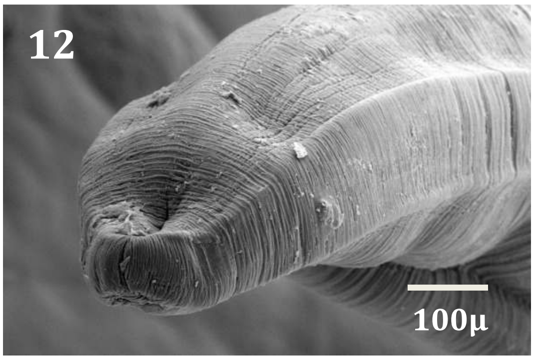


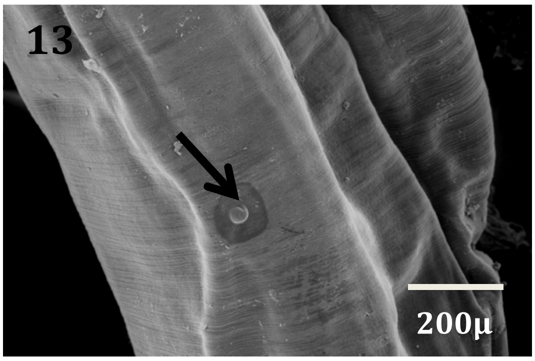
Figure 1. Ventral surface of *Pseudobenedenia nototheniae,* an SEM, showing the ventral suckers for the prohapter used for attaching to the host fish. The anterior adhesive organ with 2 suckers (arrow). **Figure 2.** Ventral surface, posterior region of *P. nototheniae* showing the major anchor and hooks (arrows). The outer fimbriated edge is also visible for the opisthohaptor. Figure 5 is a higher magnification of the area. **Figure 3.** Lateral view of the paired anterior suckers for *P. nototheniae* used for attaching to the fish host. **Figure 4.** Higher magnification of one of the suckers displaying a series of annulations. *P. nototheniae.* **Figure 5.** Higher magnification of the prohapter of *P. nototheniae* showing the scalloped edge and 3 pair of anchors. **Figure 6.** Dorsal surface of *P. nototheniae* showing the genital opening of the female reproductive system (arrow). **Figure 7.** *Diphyllobothrium* sp. plerocercoid showing the “ear-like” bothria (arrows). **Figure 8.** *Diphyllobothrium* sp. plerocercoid with no proglottids, posterior end.

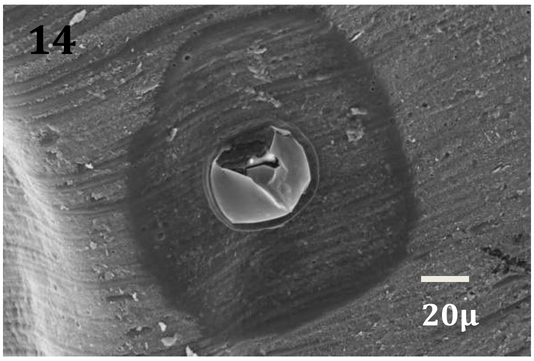


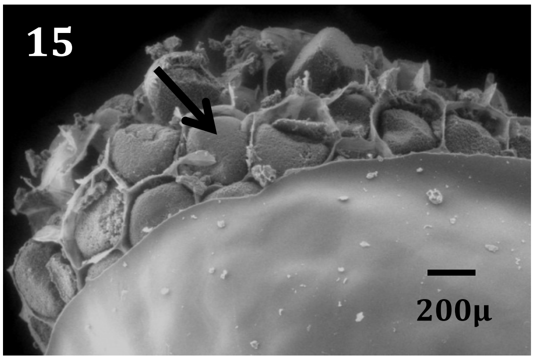












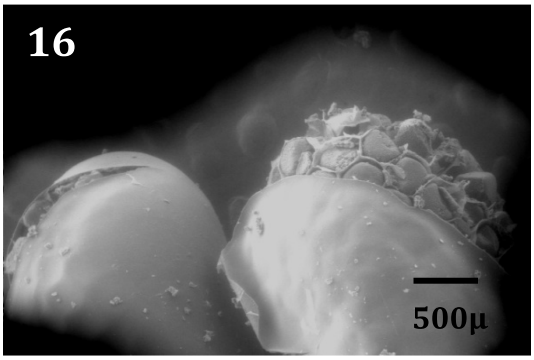
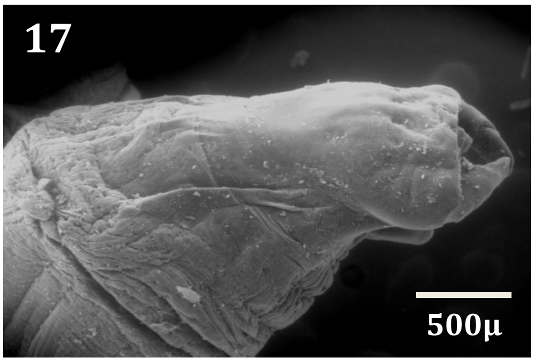
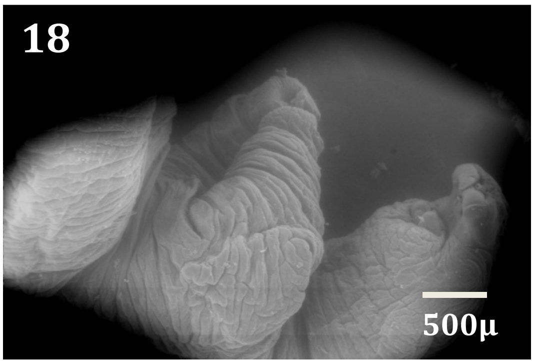
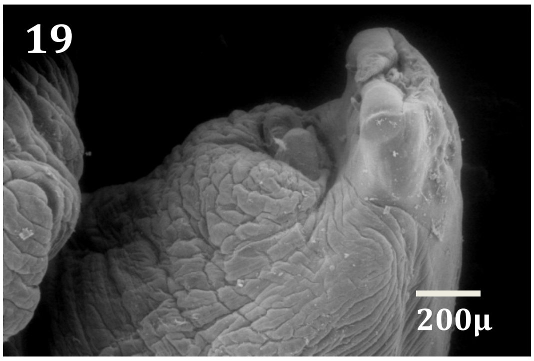


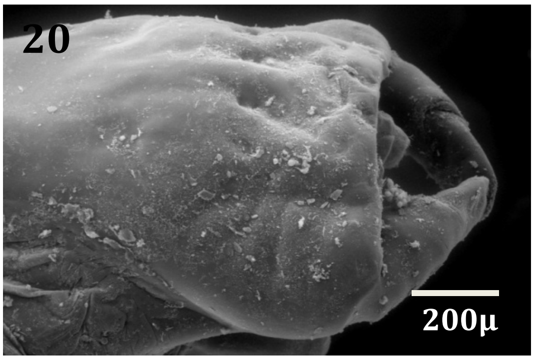
Figure 9. Lateral view of the nematode *Hysterothylacium aduncum* displaying the characteristics 3 lips surrounding the buccal cavity (arrow). Note the body annulations. **Figure 10.** "En face" or frontal view of the buccal cavity of *H. aduncum* showing the 3 lips and the opening (mouth) of the oral cavity. Note the unequal size of the lips. **Figure 11.** Posterior region of *H. aduncum* with the terminal spine (arrow). **Figure 12.** Posterior end of *H. aduncum*. The anal orifice is visible. **Figure 13.** The vulva opening (arrow) of the female nematode reproductive system (arrow). This is located near the posterior end of the round worm. **Figure 14.** Higher magnification of vulva opening of the female nematode, *H. aduncum.* **Figure 15.** Eggs (arrow) and egg sacs of the female *Eubrachiella antarctica.* **Figure 16.** Egg sacs of the female *E. antarctica.*

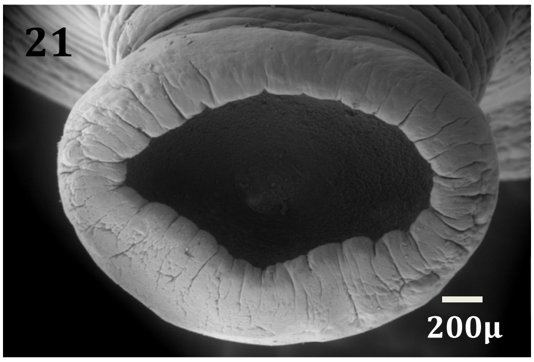
Sci Parasitol 13(3):119-128, September 2012
ISSN 1582-1366











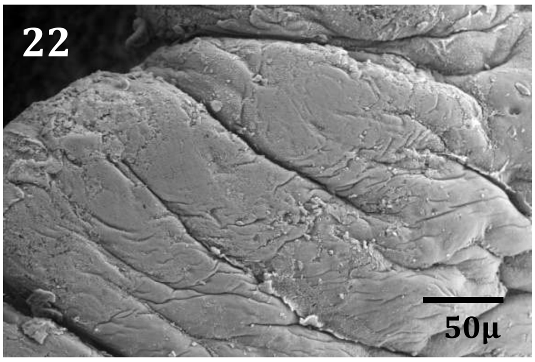


Figure 17. Appendages of *E. antarctica.* **Figure 18.** Body region of *E. antarctica.*
Figure 19. Appendages and body regions of *Eubrachiella gaini.* **Figure 20.** Appendages and body of *E. gaini.*
Figure 21. The oral sucker of a leech found attached to the host fish. Note the muscular lips of the sucker.
Figure 22. The body of the leech showing prominent annulations and segments.

Results

The examination of the collected Antarctic fishes yielded the following parasites with number listed: 14 *Pseudobenodenia notothinae* (Johnston, 1931), 7 *Diphyllobothrium* sp. (Cobbold, 1858), 180 *Hysterothylacium aduncum* (Ward and Magath, 1917), 7 *Eubrachiella antarctica* (dark) (Quidor, 1906), 5 *Eubrachiella gaini* (white) (Quidor, 1912) and Hirudinae sp. Parasites are deposited at the second author's lab at Brigham Young University, Provo, Utah. Parasites and host relationships are presented in table 1.

A brief summary of the observed parasites follows with reference figures (see table 1):

Monogenea: Platyhelminthes (Flatworm) (figures 1 to 6)

- *Pseudobenedenia nototheniae* (Johnston, 1931) Ectoparasite (skin)
- Host: *Dissotichus mawsoni,* depth of the host 120-150m
- Number collected: 14

Cestoda: Platyhelminthes (Tapeworm) (figures 7 and 8)

- *Diphyllobothrium* sp. (Cobbold, 1858) Endoparasite (lumen of Intestine)
- Host: *Lycenchelys* sp., depth of host, not available.
- Number collected: 7

Nematoda: Nematoda (Roundworm) (figures 9 to 14)
- *Hysterothylaceum: (Contracaecum)*
- *Contracaecum: (Hysterothylaceum) aduncum* (Ralliet and Henry, 1912: Ward and Magath, 1917) Endoparasite (lumen of intestine, mesenteries, abdominal cavity, liver)
- Host: (number of parasites and depth of host).
- *Parachaenichthys charcoti* (44; 10-330 m)
- *Vomeridens infuscipinnis* (12; 10-330m)
- *Chanocephalus aceratus*(26; 10-330 m)
- *Cryodraco antarcticus* (17; 10-330m)
- *Chionodraco rastrospinosus* (10; 10-330m)
- *Lepidonotothen nudifrons* (5; 10-330m)
- *Lepidonotothen squamifrons* (3; 10-330m)
- *Lepidonotothen larseni* (7; 10-330m)
- *Trematomus bernacchii* (12; 10-330m)
- *Trematomus scotti* (26; 10-330m)
- *Notothenia corriceps* (3; 10-330m)
- *Lycenchelys nigripalatum* (3; 10-330m)
- *Liparis* sp. (5; 10-330m)
- *Lycenchelys* sp. (7; 10-330m)

Crustacea: Arthropoda (copepods) (figures 15 to 20)
- *Eubrachiella antartica* (Quidor, 1906) Ectoparasite (skin, integument) (figures 15 to 18)
- Host: *Chaenocephalus aceratus:* depth of host, 500 m
- Number collected: 7
- *Eubrachiella gaini* (Quidar, 1912) Ectoparasite (skin, integument) (figures 19 and 20)
- Host: *Chaenocephalus aceratus.* Depth of host, 90-100m
- Number collected: 5

Hirudinea: Annelida (leeches) (figures 21 and 22)
- *Hirudinea* sp. (Lamarck, 1818) Ectoparasite (skin, integument)
- Host: *Cryodraco antarcticus:* depth of Host; 90-100m
- Number of Parasites: 1
- *Chinodraco rastrosinosus:* depth of host, 90-100m
- Number collected: 1 and 1

Figures 1 to 6 represent scans of the monogenean *Pseudobenedenia nototheniae. P. notothenia* is a large ectoparasite that attaches to the body surface (gills, integument) of the fish host. Figures 1 and 2 represent the ventral surface of the parasite showing the opisthohapter and prohapter *P. notothenia* has two prominent suckers used for host attachment representing the adhesive organ (figures 3 and 4). The opisthaptor (figure 2) of *P. notothenia*has a prominent anchor and hooks with an outer fimbriated edge. Figure 5 is a higher magnification of the anchors and hooks for the monogenean. Figure 6 shows the genital pore from the dorsal side.

The plerocercoid stage of *Diphyllobothrium* sp. is displayed by figures 7 and 8. The prominent ear-like bothria are present for figure 7 with the beginning of proglottid foundation posterior to the head end. The posterior region of the cestode is shown by figure 8.

The nematode *H. aduncum* for the anterior oral region has 3 prominent lips with a central mouth (figures 9, 10, 11). The lips are unequal in size and represent a characteristic of the ascarid nematodes. There are body annulations along the length of the nematode (figure 9). The posterior region of *H. aduncum* is represented by figure 12 with a characteristic anal orifice. The opening (vulva) for the female reproductive system is represented by Figures 13 and 14. This opening (vulva) is approximately 1/3 from the posterior end of the roundworm.

The parasitic copepod, *Eubrachiella* is represented by 2 species, *antarctica* (figures 15 to 18) and *gaini* (figures 19 and 20). Note the prominent egg sacs and eggs (figures 15 and 16) and the highly modified appendages (figures 17, 19, and 20). This arthropod is highly modified for a parasitic life.

Figure 21 and 22 represent the leech found during this study. Note the muscular oral opening (figure 21) and the body segments and annulations (figure 22).

Discussion and conclusions

Full surveys of all parasites (Johnston, 1931; Kagei and Watanuki, 1975; Hoogesteger and White, 1981; Bielecki et al., 2008) and specific studies either centered on the host (Gibson, 1976; Gaevakaya et al., 1990; Palm et al., 1998; Eastman, 2000; Walter et al., 2002; Laskowski et al., 2007) or on the parasite (Graefe, 1968; Kock and Möller, 1977; Holloway and Spence, 1980; Zdzitowiecki, 1990; 1996; 1999; 2001; Wojciechowska, 1991; Zdzitowiecki et al., 1993; 1998; Wojciechowska et al., 1994; Zdzitowiecki and Pisano, 1996; Janusz and Sosinski, 1999; Palm, 1999). Rocka and Zdzitowiecki (1998) and Rocka (2003; 2004) have published a series of articles on groups of parasites in Antarctic fishes.

P. nototheniae is found in various notothenioid fishes caught in different Antarctic regions (Lutnicka and Zdzitowiecki, 1984). In this study *P. nototheniae* (figures 1 to 6) was found in *Dissostichus mawsoni* and the authors in other published papers who studied that parasite also found it in notothenioid fishes This monogenean is a common member of the parasitofauna of Antarctic fishes (Hargis and Dillon, 1968; Rhode et al., 1998; Brickle et al., 2005; 2006).

Diphyllobothium sp. (figures 7 and 8) is widely distributed in man and fish-eating mammals, particularly of northern regions of Europe, Asia and North America. Plerocercoids parasitize numerous freshwater and migratory fishes. *Diphyllobothrium* was found in *Lycenchelys* sp. (Zoarchidae) in the present study. However, some authors who studied in the Antarctic region determined the parasite and plerocercoids in fishes which belong to Notothenidae, Channichthyidae and Bathydraconidae families (Szidat, 1965; Kock et al., 1984; Wojciechowska et al., 1991; Zdzitowiecki et al., 1997; Zdzitowiecki et al., 1998; Palm et al., 1998; Zdzitowiecki, 2001a; 2001b; Laskowski et al., 2007). Figures 7 and 8 represent the SEM studies of this tapeworm.

One of the most common parasites for this study was an intestinal lumen dwelling nematode; *Hysterothylacium aduncum (Contracaecum). H. aduncum* is a parasite not only of marine fish throughout most of the world but also of fish in some brackish water areas (Fagerholm, 1982). We obtained 180 *H. aduncum* from 14 fish species which belong to Notothenidae, Bathydraconidae, Channichthyidae, Liparidae and Zoarchidae families. According to authors who previously studied the region, *H. aduncum* is a common parasite in the Antarctica (Siegel, 1980; Hoogesteger and White, 1981; Kock et al., 1984; Brickle et al., 2005). *H. aduncum* is represented by SEM figures 9 to 14.

The parasite copepod *Eubrachiella antarctica* (figures 15 to 18)of the family Lernaeopodidae has been one of the external parasites more frequently occurring on the Antarctic fishes (Janusz and Sosinski, 1999). We found 7 individual *E. antarctica* on the skin of *Chaenocephalus aceratus.* According to previous studies infection rates for the parasite which were found on *Chaenoceohalus aceratus* is 56.7% in South Shetland (Kock and Möller, 1977), 77.2% in Elephant Island (Siegel, 1980), 96% in the Shelf of the Scotia Sea (Siegel, 1980). Furthermore the rate of occurrence of this parasite on the same host is 0.4% in buccal cavity and 3% on skin (Siegel, 1980).

Five individual *Eubrachiella gaini* (figures 19 and 20) were obtained on the skin of *Chaenocephalus aceratus.* It is understood from previous studies which were performed in Antarctica that *Eubrachiella gaini* were generally distributed in the Channichthyidae family. Occurrence rates for the parasite on the fish hosts are; *Chaenocephalus aceratus* 34% in Elephant Island, 29.7% in South Shetland Island, 2% South Georgia and the highest infection rate is 36.6% in *Champsocephalus gunnari* (South Shetland Island) (Sosinski and Janusz, 1986).

Other researchers reporting on this copepod include: Kock and Moller (1977); Ho and Takeuchi (1996); Rhode et al. (1998); Janusz and Sosinski (1999); Brickle et al. (2006). Copepods are common ectoparasites of fish. SEM figures are included for this ectoparasite (figures 15 to 20).

Only one Hirudinean parasite was obtained from *Cyrodraco antarcticus* and *Chionodraco* *rastrospinosus,* but it was not possible to determine species with one specimen. The SEM figures show the oral region and body of the leech (figures 21 and 22). Previous articles pertaining to leeches of Antarctic fishes include the following: Szidat (1965); Parukhin and Lyadov (1981); Rhode et al. (1998). This study has added to the literature pertaining to parasites of Antarctic fishes and further work should be completed for this problem. The protozoan parasites require research to complete parasite surveys.

Acknowledgements

The authors wish to thank Michael Standing and John Gardner from the Electron Optics Laboratory, Brigham Young Univeristy for their professional help and assistance in the preparation of the scanning electron micrographs.

References

Bielecki A., Rokicka M., Ropelewska E., Dziekonska-Rynko J. 2008. Leeches (Hirudinida: Piscicolidae). Parasites of Antarctic fish from Channichthyidae family. Wiad Parazytol. 54:345-348.

Brickle P., MacKenzie K., Pick A. 2005. Parasites of the Patagonian toothfish, *Dissostichus eleginoides* Smitt, 1989, in different parts of the Subantarctic. Polar Biol. 28:663-671.

Brickle P., Mackenzie K., Pick A. 2006. Variations in the parasite fauna of the Patagonian toothfish *(Dissostichus eleginoides* Smitt, 1898), with length, season, and depth of habitat around the Falkland Islands. J. Parasitol. 93:282-291.

Eastman J.T. 2000. Antarctic notothenioid fishes as subjects for research in evolutionary biology. Antarct. Sci. 12:276-287.

Eastman J.T., Clarke A. 1998. A comparison of adaptive radiations of Antarctic fish with those of non-Antarctic fish. *In:* Prisco G.D., Pisano E., Clarke A. (Eds.), Fishes of Antarctica. A biological review. Springer Verlag, Italia, pp. 3-26.

Fagerholm H.P. 1982. Parasites of fish in Finland. 6. Nematodes. Acta Academia, Aboensis, Ser. B. 1-128.

Gaevskaya A.V., Kovaljova A.A., Parukhin A.M. 1990. Peculiarities and formation of parasitofauna of the Patagonian toothfish *Dissostichus eleginoides.* Biologiya Morya 4:23-28 [In Russian].

Gibson D.I. 1976. Monogenea and Digenea from fishes. Discovery Reports 36:179-266.

Gon O., Heemstra P.C. 1990. Fishes of the Southern Ocean. J.L.B. Smith Institute of Ichthyology Grahamstown.

Graefe G. 1968. *Paramonostomum antarcticum* n. sp. (Trematoda: Notocotylidae) und Beobachtungen zur Larvenetwicklung in der Antarktis. Z. Parasitenkd. 30:207-232.

Hargis W.J.Jr., Dillon W.A. 1968. Helminth parasites of Antarctic vertebrates. Part IV. Monogenetic trematodes from Antarctic fishes: the superfamily Capsaloidea Price, 1936. Proceedings of the Biological Society of Washington 81:403-412.

Ho J., Takeuchi L. 1996. Systematic status of *Eubrachiella*, a genus of Copepoda parasitic on antarctic teleosts. Polar Biol. 9:169-177.

Holloway H.L., Spence J.A. 1980. Ecology of animal parasites in McMurdo Sound, Antarctica. Comp. Physiol. Ecol. 5:262-284.

Hoogesteger J.N., White M.G. 1981. Notes on parasite infestation of Inshore fish at Signy Island, South Orkney Islands. Brit. Antarct. Surv. B. 54:23-31.

Janusz J., Sosiński J. 1999. *Eubrachiella antarctica* (Quidor, 1906) (Copepoda)-levels of infection in selected fish species of the family Nototheniidae. Acta Ichthyol. Piscat. 29:43-52.

Johnston T.H. 1931. New trematodes from Subantarctic and Antarctic. Austr. J. Exper. Biol. Med. Sc. 8:91-98.

Kagei N., Watanuki T. 1975. On the parasites of fishes from the Antarctic Ocean. Antarct. Res. 54:84-93.

Kock K.H., Möller H. 1977. On the occurrence of the parasitic copepod *Eubrachiella antarctica* on some Antarctic fish. Arch. Fisch. Wiss. 28:149-156.

Kock K.H., Schneppenheim S., Siegel V. 1984. A contribution to the fish fauna of the Weddell sea. Arch. Fisch. Wiss. 34:103-120.

Laskowski Z., Rocka A., Zdzitowiecki K., Ozouf-Costaz C. 2007. Occurrence of endoparasitic worms in dusky notothen, *Trematomus newnesi* (Actinopterygii Nototheniidae) at Adèlie Land, Antarctica. Pol. Polar Res. 28:37-42.

Lee P.E. 1992. Scanning Electron Microscopy and X-ray Microanalysis. Prentice Hall, Englewood Cliffs, New Jersey, 458 p.

Lutnicka H., Zdzitowiecki, K. 1984. On some problems related to the occurrence of *Pseudobenedinia nototheniae* Johnston, 1931. (Monogenea, Capsilidae, Trochopodinae) off the South Shetlands. Acta Ichthyol. Piscat. 14:141-147.

Palm H.W. 1999. Ecology of *Pseudoterranova decipiens* (Krabbe, 1878) (Nematoda: Anisakidae) from Antarctic waters. Parasitol. Res. 85:638-646.

Palm H., Andersen K., Klöser H., Plötz J. 1994. Occurrence of *Pseudoterranove decipiens* (Nematoda) in fish from the Southeastern Weddel Sea (Antarctic). Polar Biol. 14:539-544.

Palm H.W., Reimann N., Splinder M., Plötz J. 1998. The Role of the Rock Cod *Notothenia coriiceps* Richardson, 1844 in the Life-cycle of Antarctic Parasites. Polar Biol. 19:399-406.

Parukhin A.M., Lyadov V.N. 1981. Parasitofauna of Notothenioidei from waters of the Atlantic and Indian Oceans. Vestnik Zoologii 3:90-94 [In Russian].

Rhode K., Ho J., Smales L., Williams R. 1998. Parasites of Antarctic fishes: Monogenea, Copepoda, and Acanthocephala. Marine Freshwater Research 49:28-35.

Rocka A. 2003. Cestodes of the Antarctic fishes. Pol. Polar Res. 24:261-276.

Rocka A. 2004. Nematodes of the Antarctic fishes. Pol. Polar Res. 25:135-152.

Rocka A. 2006. Helminths of Antarctic fishes: life cycle biology, specificity and geographical distribution. Acta Parasitol. 51:26-35.

Rocka A., Zdzitowiecki K. 1998. Cestodes in fishes of the Weddell Sea. Acta Parasitol. 43:64-70.

Siegel V. 1980. Quantitative investigations on parasites of Antarctic channichthyid and nototheniid fishes. Meeresforschung 28:146-256.

Sosiński J., Janusz J. 1986. The occurrence of the parasite *Eubrachiella gaini* Quidor, 1913 in Antarctic fishes of the family Chaenichthyidae. Acta Ichthyol. Piscat. 16:87-105.

Szidat L. 1965. Estudios sobre la fauna de Parasitos de peces Antarticos I. Los parasitos de *Notothenia neglectica* Nybelin. Servicio de Hidrografia Naval, Secretaria de Mayina, Republica Argentina 910:1-57.

Walter T., Palm H.W., Piepiorka S., Rückert S. 2002. Parasites of the Antarctic rattail *Macrourus whitsoni* (Regan, 1913) (Macrouridae, Gadiformes). Polar Biol. 25:633-640.

Wojciechowska A. 1991. Some tetraphyllidean and diphyllidean cestodes from Antarctic batoid fishes. Acta Parasitol. Polonica 36:69-74.

Wojciechowska A., Zdzitowiecki K., Pisano E., Vacchi M. 1994. The tetraphyllidean cercoids from bony fishes occurring in the Ross Sea (Antarctic). Acta Parasitol. 39:13-15.

Zdzitowiecki K. 1990. Occurrence of acanthocephalans in fishes of the open sea off the South Shetlands and South Georgia (Antarctic). Acta Parasitol. Polonica 35:131-142.

Zdzitowiecki K. 1996. Acanthocephala in fish in the Weddell Sea (Antarctic) Acta Parasitol. 41:199-203.

Zdzitowiecki K. 1999. Digeneans of the families Opecoelidae and Lepocreadiidae, parasites of *Lepidonotothen macrophthalma* from the North Scotia Ridge, and remarks on the discrimination of *Neolepidapedon magnatestis* and *N. trematomi.* Acta Parasitol. 44:233-240.

Zdzitowiecki K. 2001a. Acanthocephala occurring in intermediate hosts, amphipods, in Admirality Bay (South Shetland Islands, Antarctica). Acta Parasitol. 46:202-207.

Zdzitowiecki K. 2001b. Occurrence of endoparasitic worms in fish, *Parachaenichthys charcoti* (Bathydraconidae), off the South Shetland Islands (Antarctica). Acta Parasitol. 46:18-23.

Zdzitowiecki K., Laskowski Z. 2004. Helminths of an Antarctic fish, *Notothenia coriiceps,* from the Vernadsky Station (Western Antarctica) in comparison with Admirality Bay (South Shetland Islands). Helminthologia 41:201-207.

Zdzitowiecki K., Pisano E. 1996. New records of Digenea infecting elasmobranch and teleost fish off Heard Island (Kerguelen sub-region, sub-Antarctic). Arch. Fish. Mar. Res. 43:265-272.

Zdzitowiecki K., Pisano E., Vacchi M. 1993. New data on the morphology and occurrence of a parasite of Antarctic fishes, *Derogenes johnstoni* Prudhoe et Bray, 1973 (Digenea, Hemiuroidea). Acta Parasitol. 38:69-71.

Zdzitowiecki K., Rocka A., Pisano E., Ozouf-Costaz C. 1998. A list of fish parasitic worms collected off Adelie Land (Antarctica). Acta Parasitol. 43:71-74.

Zdzitowiecki K., White M.G., Rocka A. 1997. Digenean, Monogenean and cestode infection of inshore fish at the South Orkney Islands. Acta Parasitol. 42:18-22.