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Occurrence of *Pseudoterranova decipiens* (Nematoda) in fish from the southeastern Weddell Sea (Antarctic)

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Abstract Eleven fish species from the Weddell Sea (Antarctic) were examined for infestation with anisakid nematodes. Two species of the genus *Contracaecum* and the sealworm *Pseudoterranova decipiens* were isolated from the liver and the body cavity of fish affected. Only two specimens of *P. decipiens* (1.4%) partly invaded the belly flaps. The following fish species were infested by *P. decipiens* at the given prevalences: *Cygnodraco mawsoni* (74.4%), *Trematomus scotti* (23.2%), *Pagetopsis maculatus* (10.0%), *Cryodraco antarcticus* (7.1%), *Trematomus lepidorhinus* (3.0%), and *Dolloidraco longedorsalis* (2.7%). All of these, except *Trematomus scotti*, are new host records. *Chaenodraco wilsoni*, *Chionodraco myersi*, *Gerlachea australis*, *Racovitzia glacialis* and *T. eulepidotus* were not infested. The reasons for low prevalence and intensity of infestation are seen in the difficulties of *P. decipiens* in completing its benthic life cycle in the Weddell Sea environment, in the absence of shallow coastal waters due to the floating shelf-ice. *Cygnodraco mawsoni* is a crucial intermediate host, without which completion of the parasite life cycle might not be possible. In order to clarify the taxonomical position of Antarctic *Pseudoterranova*, morphological comparisons with specimens of *P. decipiens* from the German and Norwegian coast were made using scanning electron microscopy. Results revealed no differences; hence, all specimens studied belong to the same species *P. decipiens*.

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Introduction

The anisakid nematode genus *Pseudoterranova* Mozgovoi, 1951 is one of the most important flesh parasites of fish in the North Atlantic (Templeman 1990). The adults and the 4th stage larvae (L4) are parasitic in seals: the first intermediate hosts are benthic harpacticoid or cyclopoid copepods, and macroinvertebrates (including crustaceans, polychaetes and molluscs) serve as second intermediate hosts. The 3rd stage larvae (L3), known as sealworm or codworm, occur mainly in benthic fish species as third intermediate hosts (Bristow and Berland 1992).

Currently *Pseudoterranova decipiens* Krabbe, 1878 is presumed to be the only valid, cosmopolitan species in the genus (Möller 1988). However, Paggi et al. (1991) using multilocus electrophoresis, split the northern *P. decipiens* into three sibling species A, B, and C, which are not morphologically distinguishable. The identity of the Antarctic form is still unclear. No comparisons of the Antarctic form with those from the northern hemisphere exist.

The first record of the genus *Pseudoterranova* from the Antarctic region is that of von Linstow (1888) who, on finding the parasite in the Antarctic fur seal *Arctocephalus gazella*, described it as *Ascaris simplex*. Other synonyms are listed in Table 1. The L3 was first found in a "common" fish, probably a *Trematomus* or a *Notothenia* species (Linstow 1907). Johnston (1938) found it in *Trematomus bernacchii* and *Notothenia coriiceps*.

Reimer (1987) presented abundance and intensity of infestation data of *P. decipiens* in the fish species *Champsocephalus gunnari*, *Chionodraco kathleenae*, *Notothenia gibberifrons* and *Pseudochaenichthys georgianus* from the South Shetlands and South Georgia. Hoogesteger and White (1981) studied *Notothenia neglecta* from the South Orkney Islands. Though a number of investigations have been carried out on Antarctic fish parasites (Siegel 1980; Kock 1982; Kock et al. 1984; Feiler 1987), no quantitative data concerning infestation with *Pseudoterranova* in fish from the high Antarctic are available.

The Weddell seal *Leptonychotes weddellii* is known to be an important final host for the Antarctic *Pseudoterranova* (Beverly-Burton 1971; Klöser 1985). The present study represents the first large-scale investigation of the occurrence of *Pseudoterranova* in fish species of the Weddell Sea that feature in the diet of *Leptonychotes weddellii* (Plötz et al. 1991). A morphological comparison of L3 from *Cygnodraco mawsoni* (Antarctic), *Osmerus eperlanus* (German Wadden Sea) and *Myxocephalus scorpius* (Vega, Norway) is made, by scanning electron microscopy, to clarify their taxonomical position.

Materials and methods

A total of 354 fish specimens belonging to 11 notothenoid species from four families were caught by midwater or bottom trawls in the Weddell Sea. The fish were collected during the Antarctic expedition ANT V of the German research vessel "Polarstern" from different sampling sites along the southeastern Weddell Sea coast between October 1986 and February 1987 (Table 2). The depth of the sampling stations ranged between 182 and 710 m. Fish were identified and preserved deep-frozen until further investigation. Parasites were removed from the flesh, body cavity and internal organs. The

Table 1 Synonyms of *Pseudoterranova decipiens* reported from the Antarctic in chronological order

Synonym	Host	Authors
Ascaris simplex	*Arctocephalus gazella*	von Linstow (1888)
Ascaris rectangula	*Leptonychotes weddellii*	von Linstow (1907)
Ascaris decipiens	*Leptonychotes weddellii* *Ommatophoca rossi* "Common fish"[a]	Railliet and Henry (1907)
Physaloptera guiarti	*Leptonychotes weddellii*	Garin (1913)
Terranova antarctica	*Mustelus antarcticus*[a]	Leiper and Atkinson (1914)
Porrocaecum antarctica (*nov. comb.*)	–	Baylis (1920)
Porrocaecum decipiens	*Arctocephalus gazella* *Leptonychotes weddellii* *Ommatophoca rossi*	Baylis (1937)
Porrocaecum sp.	*Notothenia coriiceps*[a] *Trematomus bernachii*[a]	
Phocanema sp.	*Notothenia neglecta*[a]	Hoogesteger and White (1981)
Phocanema decipiens	*Trematomus scotti*[a]	Bartsch (1985)
Terranova decipiens	*Notothenia rossi rossi*[a]	Lyadov (1981)
Phocanema antarctica	*Champsocephalus gunnari*[a] *Chionodraco kathleenae*[a] *Notothenia gibberifrons*[a] *Pseudochaenichthys georgianus*[a]	Reimer (1987)
Pseudoterranova sp.	*Notothenia* sp.[a]	Feiler (1987, 1990)

[a]Intermediate host of 3rd stage larvae

Table 2 Sampling sites of Antarctic fish species

Expedition	Station	Date	Position		Depth (m)
Ant V/3	517	19/10/86	72-52, 0'S	019-35, 6'W	600
Ant V/3	531	23/10/86	72-48, 9'S	019-21, 4'W	436
Ant V/3	536	24/10/86	72-50, 4'S	019-36, 8'W	595
Ant V/3	537	24/10/86	73-05, 6'S	020-14, 4'W	420
Ant V/3	553	31/10/86	74-02, 4'S	024-22, 7'W	350
Ant V/3	561	03/11/86	72-52, 5'S	019-30, 2'W	430
Ant V/3	580	08/11/86	72-51, 4'S	019-41, 4'W	710
Ant V/3	592	14/11/86	73-55, 0'S	022-58, 6'W	211
Ant V/3	593	14/11/86	73-56, 3'S	023-29, 3'W	343
Ant V/3	594	15/11/86	73-42, 3'S	021-59, 9'W	370
Ant V/4	692	25/01/87	71-14, 6'S	012-00, 9'W	182
Ant V/4			71-15, 1'S	012-02, 9'W	202
Ant V/4	738	09/02/87	74-40, 6'S	035-04, 2'W	496
Ant V/4			74-40, 1'S	035-04, 8'W	495
Ant V/4	796	21/02/87	72-53, 3'S	019-06, 6'W	415
Ant V/4			72-52, 5'S	019-11, 4'W	418

occurrence of *Contracaecum osculatum* and *C. radiatum* is the subject of another study (Klöser et al. 1992). Larval *Pseudoterranova* in Antarctic fish were easily distinguished from both species of the genus *Contracaecum* by their characteristic pyloric caecum, larger body size and blood-red colour.

Specimens of *Pseudoterranova decipiens* were taken from the musculature of the smelt *Osmerus eperlanus*, caught by a commercial vessel in the German Wadden Sea, and from the flesh of the bull-rout *Myxocephalus scorpius*, caught by ground net fishing at Vega, northern Norway. The specimens were fixed and stored in 70% ethanol or 4% formalin.

Morphometrical data for Antarctic *Pseudoterranova* from *Cygnodraco mawsoni* were taken using a stereo microscope. Scanning electron microscopy (SEM) was used to study the anterior and posterior extremities and the surface structures of nematode larvae from the Weddell Sea and from European waters. The specimens were dehydrated in a graded ethanol series, transferred to ether, air-dried and mounted with silver paint on SEM stubs. All stubs were coated with gold-palladium in an argon atmosphere at 1.2 kV/40 mA per 0.1 torr, and examined and photographed in a Jeol JSM-35C scanning electron microscope at 15 kV.

Results

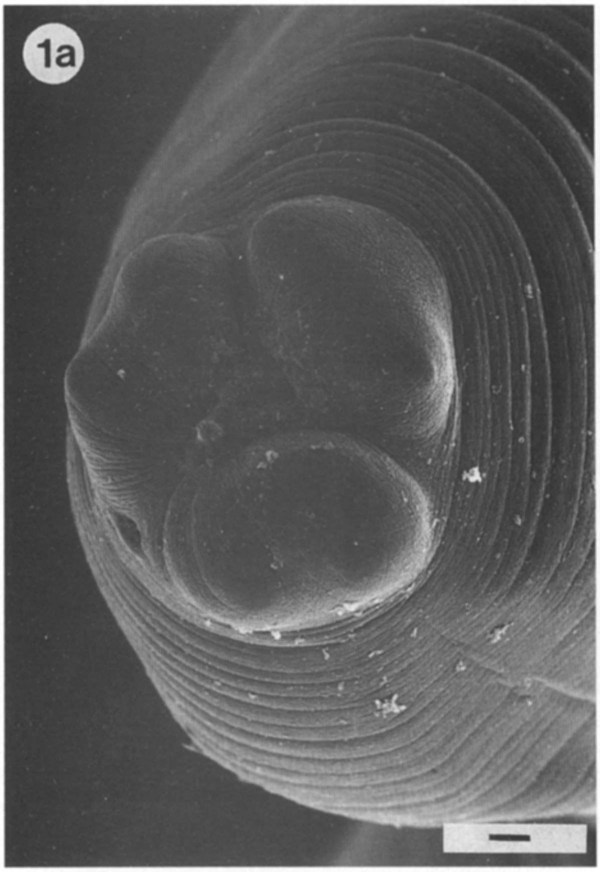
Third stage larvae of *Pseudoterranova decipiens* were found in six Antarctic fish species belonging to four families: *Dolloidraco longedorsalis* (Artedidraconidae); *Cygnodraco mawsoni* (Bathydraconidae); *Cryodraco antarcticus, Pagetopsis maculatus* (Channichthyidae); *Trematomus lepidorhinus* and *T. scotti* (Nototheniidae). All, except *T. scotti*, are new host records. The prevalence and mean intensity of infestation are given in Table 3. The other fish species investigated were not infested with *Pseudoterranova decipiens.*

Most of the parasites were found either free in the body cavity and in the liver, or on the liver surface. None of the nematodes were encapsulated. Only one larva in each of two specimens of *Cygnodraco mawsoni* had partly invaded the belly flaps with free ends in the body cavity. No other helminths were found in the musculature of any fish.

The mean total length of Antarctic *Pseudoterranova* L3 was 34.2 mm ($n = 16$). The mean caecum length was 0.83 mm, and the mean distance of genital primordium from the posterior end was 0.4 mm. Figures 1–3 show SEM micrographs of the L3 of *Pseudoterranova decipiens* from the three different geographical regions. The heads of all the specimens show the typical boring tooth, an excretory pore, and one dorsal and two ventro-lateral lip primordia. On the dorsal lip two papillae are visible, and on each ventral lip one papilla can be seen (Figs. 1a, 2, 3). Surface structure and size of the specimens are similar. The posterior extremity of the L3 from the Antarctic shows a small, elongated mucron typical for *P. decipiens* (Fig. 1b). Morphologically, no differences were seen between Antarctic and North Atlantic *Pseudoterranova* L3 specimens.

Table 3 Occurrence of *Pseudoterranova decipiens* in fish from the southeastern Weddell Sea

Family and species	No. examined	Length (cm)	No. infested	Prevalence (%)	Mean intensity (range)
Artedidraconidae					
Dolloidraco longedorsalis	37	6.2–11.8	1	2.7	3 (3)
Bathydraconidae					
Cygnodraco mawsoni	43	34.0–44.5	32	74.4	4.4 (1–25)
Gerlachea australis	10	17.5–25.0	0	0	–
Racovitzia glacialis	12	19.5–26.5	0	0	–
Channichthyidae					
Chaenodraco wilsoni	3	24.0–25.0	0	0	–
Chionodraco myersi	77	22.5–43.5	0	0	–
Cryodraco antarcticus	28	24.5–44.5	2	7.1	1 (1)
Pagetopsis maculatus	10	16.5–21.5	1	10.0	3 (3)
Nototheniidae					
Trematomus eulepidotus	32	12.2–26.0	0	0	–
Trematomus lepidorhinus	33	11.8–23.4	1	3.0	1 (1)
Trematomus scotti	69	4.9–14.7	16	23.2	1.5 (1–3)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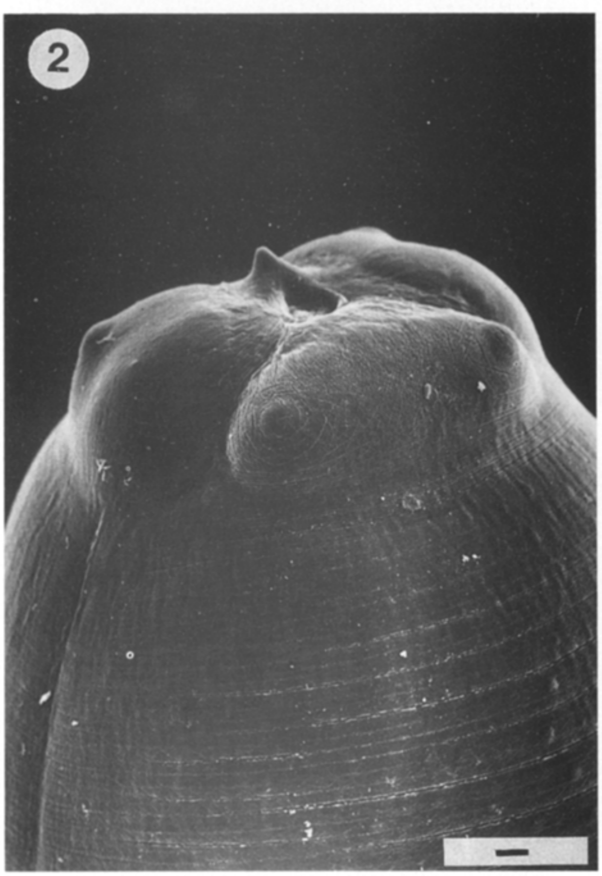
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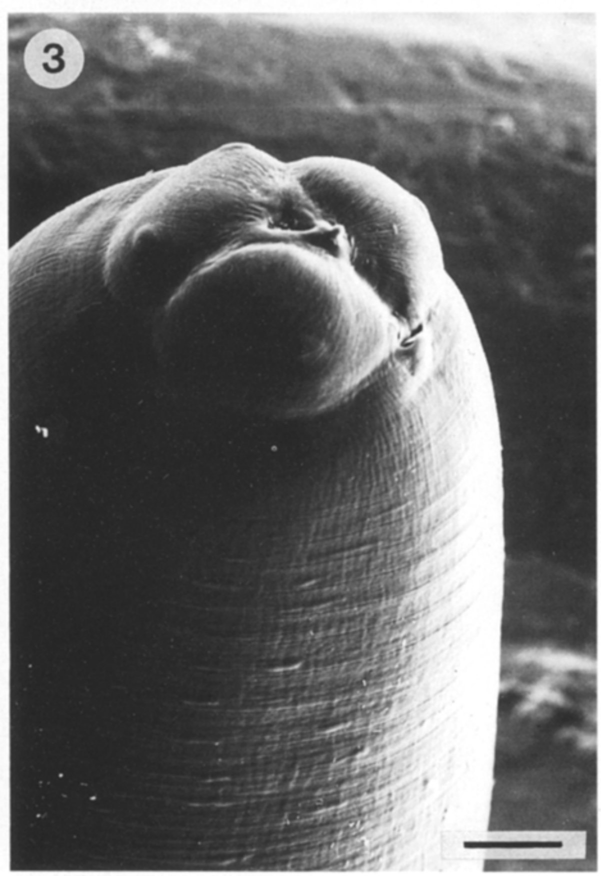
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Discussion

The southeastern Weddell Sea environment does not appear to be a favourable one for *Pseudoterranova decipiens*. Compared with *Pseudoterranova* infestations of fish from the northern hemisphere (Kerstan 1992; Möller and Klatt 1990; Templeman 1990), the prevalence and intensity of infestation reported in this study are low. These results agree with earlier findings on the parasite infestation of the main final host for *P. decipiens*, the Weddell seal *Leptonychotes weddellii*. In contrast to an extremely high infestation with two species of the related anisakid nematode genus *Contracaecum* (Beverly-Burton 1971; Klöser et al. 1992), they harbour *Pseudoterranova* only in small numbers (Railliet and Henry 1907; Garin 1913; Klöser et al. 1992) or not at all (Beverly-Burton 1971).

A first reason for such a low worm burden might be seen in cold water temperatures, which slow down the development of eggs and larvae considerably, as reported from North Atlantic waters: the mean developmental time to hatching for eggs of *P. decipiens* ranged from 16 days at 12° C to approximately 125 days at 1.7°C (Brattey 1990). The seldom infestation of cod from northeastern Newfoundland, Labrador, Greenland and the Norwegian Arctic was assumed to be attributable to retarded or arrested development of the parasite eggs and larval stages in cold waters, rather than to a scarcity of suitable definitive hosts (McClelland 1990). Though Ronald (1960) showed that water temperatures under 0°C do not seriously harm the L3 in fish, the negative effects of such temperatures on the survival rate of the 1 and 2 larval stages cannot be excluded. However, as the material for this study was collected from the cold Weddell Sea shelf-water (– 2°C– – 1.6°C: Carmack 1974), low water temperatures were not considered a decisive factor for the survival of the Antarctic parasite population.

Another significant factor leading to low infestation rates in the high Antarctic could be the presence of the floating shelf-ice, which precludes shallow waters typical for other coastal regions. In the northern hemisphere, *Pseudoterranova decipiens* has a benthic life cycle (Bristow and Berland 1992; Möller 1989). Gadids and other benthic or benthopelagic fishes are the most important third intermediate hosts. In waters such as the Wadden Sea, a quick development of eggs and larvae due to higher water temperatures, as well as a better access to intermediate and final hosts in shallow waters, may lead to shorter reproduction cycles of *P. decipiens*. Consequently the infestation rates in such regions can be assumed to be high. During this study, only benthic or benthopelagic fish species were found to harbour *Pseudoterranova decipiens* larvae, the infestation being low, while an earlier investigation on the herring-like midwater fish *Pleuragramma antarcticum* from the same area of investigation yielded no parasite larvae (Bartsch 1985). In the Weddell Sea such benthic or benthopelagic fish species are confined to deep water, due to the characteristics of the shelf-ice coast. Such bottom-dwelling fishes (as third intermediate hosts) may not lend themselves to easy predation by Weddell seals, and therefore hinder quick transmission of the parasite to the final host. A combination of low temperatures for larval development and an impeded reproduction cycle of the parasite may lead to low infestation rates of host organisms with *Pseudoterranova decipiens* in the Weddell Sea.

However, much more attention must be given to the influence of the invertebrate intermediate host as the weak point in the life cycle of *Pseudoterranova decipiens*. Klöser et al. (1992) believe that the regulation of *Contracaecum* populations in the same area must be expected to take place in the first but not in the second intermediate or final host. The use of pelagic hosts by *Contracaecum radiatum* may perhaps be considered as an adaption to conditions of perennially ice-covered seas (Klöser et al. 1992). This would explain higher total numbers of the endemic *C. radiatum* (pelagic life cycle) than of *C. osculatum* (benthic life cycle) in the Weddell seals and the fish. Consequently, for *Pseudoterranova decipiens* with its benthic life cycle, access to the first and second invertebrate intermediate hosts can be assumed to be the most important reason for reduced infestation rates of fish and Weddell seals. Reports from lower Antarctic latitudes, where the coastal zone is not ice-covered, indicate a higher abundance of *Pseudoterranova* there (Linstow 1907; Baylis 1937; Johnston 1938).

In such a critical situation, completion of the life cycle of *P. decipiens* in high Antarctic latitudes will only be guaranteed by at least one obligatorily highly infested fish species, the "required" intermediate host as defined by Holmes (1979). This role is taken by the bathydraconid *Cygnodraco mawsoni*, which exhibited by far the highest prevalence and intensity of infestation. It is interesting to note that in the case of the much more abundant *Contracaecum osculatum* in seals and fish from the same area, this crucial role is occupied by channichthyids (Klöser et al. 1992). This might explain the success of transmission of *C. osculatum* compared with *Pseudoterranova decipiens*, both having a benthic life-cycle.

No significant differences in morphology between *P. decipiens* L3 from Antarctic and North Atlantic fish were found. The extremities and surfaces appeared to be similar. The morphometrical data were similar to those given by McClelland and Ronald (1974) for

Figs. 1–3 Scanning electron micrographs of Antarctic and North Atlantic *Pseudoterranova decipiens* 3rd stage larvae: **Fig. 1a** Head of *Cygnodraco mawsoni* larva, Weddell Sea; **b** tail of the same larva. *Bar*, 10 μm **Fig. 2** Head of *Osmerus eperlanus* larva, southeastern North Sea. *Bar*, 10 μm **Fig. 3** Head of *Myxocephalus scorpius* larva, northern Norway. *Bar*, 50 μm cultivated North Atlantic *P. decipiens*. We conclude that all the specimens studied were *P. decipiens*. However, three siblings from the northern hemisphere belonged to the *Pseudoterranova decipiens* complex and could not be separated on a morphological basis only (Paggi et al. 1991). Bristow and Berland (1992) showed that the sibling C could be seen as the Arctic *Pseudoterranova* and assumed some form of isolation (geographical or ecological) as the reason for the origin of the siblings. As the geographical distance between northern and southern populations will allow only a restricted exchange of genes, the possible existence of another endemic sibling species in Antarctic waters should be considered.

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