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Salvelinema salmonicola (Nematoda, Cystidicolidae): Heavy Infection in Lacustrine Sockeye Salmon *Oncorhynchus nerka* from Northern Japan, with Implication of the Host's Feeding Habits

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Abstract. Six hundred fifteen specimens of the cystidicolid nematode *Salvelinema salmonicola* (Ishii, 1916) were found in the swimbladder of a sockeye salmon *Oncorhynchus nerka* from Lake Toya, central Hokkaido, northern Japan. The stomach of this fish contained many, benthic gammaridean amphipods *Jesogammarus jesoensis*, which are most likely to serve as an intermediate host for *S. salmonicola* in the lake. While sockeye salmon are known to exclusively prey on small fish when the zooplankton biomass remains low in this locality, the present findings of *S. salmonicola* and *J. jesoensis* indicate that these salmon feed on benthic amphipods as well and get infected with the nematode.

Key words: *Salvelinema salmonicola*, fish parasite, *Oncorhynchus nerka*, sockeye salmon, *Jesogammarus jesoensis*, amphipod

Introduction

Salvelinema salmonicola (Ishii, 1916) Margolis, 1966 is a nematode parasite which lives in the swimbladder of freshwater salmonids (Margolis, 1967, 1968; Moravec & Nagasawa, 1999; Nagasawa & Furusawa, 2006). Since its original description in Japan (Ishii, 1916), this parasite has been recorded from various localities of the North Pacific rim countries, including Japan, Far Eastern Russia, Alaska (U.S.A.), and northern British Columbia (Canada). In Japan, it is known to occur in Hokkaido, Honshu, and the southern Kurile Islands (Nagasawa *et al*., 1987; Nagasawa & Furusawa, 2006). Life cycle studies, primarily by Margolis & Moravec (1982) and Moravec & Nagasawa (1986), indicate that amphipods are the intermediate hosts. Currently, a heavy infection with *S. salmonicola* was found in a lacustrine (lake-resident) sockeye salmon *Oncorhynchus nerka* (Walbaum) from Lake Toya, Hokkaido: this case is very unusual, because most reports of *S. salmonicola* were based on the samples from rivers and hatcheries. We herein report on this nematode infection of lacustrine sockeye salmon.

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Materials and Methods

A sockeye salmon *Oncorhynchus nerka* was caught by an angler on March 8, 2009 with rod and line in Lake Toya (42°36′N, 140°51′E), central Hokkaido, northern Japan. When opened, this fish was found to harbor many nematodes and then sent to the laboratory of Hiroshima University, where it was measured (total length [TL]) and examined. Nematodes were taken from the swimbladder, fixed in 70% ethanol, and identified based on Moravec & Nagasawa (1986, 1999). They were examined for their sex and body length

(BL). The maturity of postlarval females was classified as immature (=without eggs), mature (with non-larvated eggs), or gravid (with larvated eggs). Stomach contents of the fish were fixed in 5% formalin. A fish and amphipods from the stomach were identified and measured for TL and BL (from the tip of the rostrum to the base of the telson), respectively. Voucher specimens of nematodes are deposited in the Aschelminthes (As) collection at the National Museum of Nature and Science, Tokyo (NSMT-As 3643). The scientific names of fishes follow Froese & Pauly (2010).

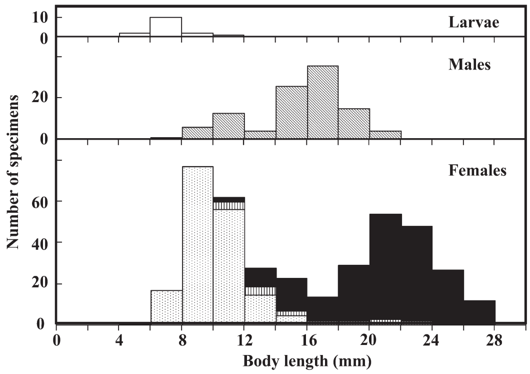

Fig. 1. Size-frequency distributions of larvae (top), males (middle), and females (bottom) of *Salvelinema salmonicola* from *Oncorhynchus nerka* from Lake Toya. The maturity of females was separated into immature (stippled), mature (striped), or gravid (black). Data of damaged specimens (*N*=95 for females and *N*=8 for males) are excluded.

Results

A total of 615 nematodes were found in the swimbladder of *Oncorhynchus nerka* (404 mm TL) and identified as *Salvelinema salmonicola*. The majority of these nematodes were females (*N*=487, 79.2%), followed by males (113, 18.4%) and larval worms (15, 2.4%). Of these, the larval worms were smallest (ranging from 5.2–10.5 mm BL) (Fig. 1) and regarded as third-stage larvae, because the worms had no spicules or vulva but exhibited some morphological features, such as the mouth with two small, lateral pseudolabia, a funnel-shaped prostom, and a conical tail with a small caudal process at its tip. Both the male and female nematodes showed a bimodal size-frequency distribution (Fig. 1). All of the males were adults with a pair of spicules. The females smaller than 12 mm BL were mostly immature, while the females larger than 16 mm BL were almost all gravid.

The stomach of *O. nerka* contained one fish and 33 crustaceans, which were identified as a Japanese smelt *Hypomesus nipponensis* McAllister (Osmeriformes, Osmeridae) and *Jesogammarus jesoensis* (Schellenberg) (Amphipoda, Gammaridea, Anisogammaridae), respectively. The Japanese smelt was 87 mm TL, and the undigested amphipods (*N*=20) ranged from 9.0–15.0 (mean 12.2) mm BL.

Discussion

Among the fish nematodes, *Salvelinema salmonicola* is a comparatively well studied species (see Nagasawa *et al*., 1987; Nagasawa & Furusawa, 2006 for the literature). Most previous reports, however, dealt with the morphology of the species from salmonids collected in rivers and hatcheries, and little information is available on the number of nematodes in these fishes. According to Margolis (1967), 1–91 and 6–86 nematodes were recorded from downstream migrant sockeye salmon *Oncorhynchus nerka* in Alaska and from young coho salmon *O. kisutch* (Walbaum) in British Columbia, respectively. Nagasawa & Furusawa (2006) found up to 79 nematodes in river-resident amago salmon *O. masou ishikawae* Jordan & McGregor in Japan. On the other hand, it is said that *S. salmonicola* is sometimes so abundant (as “countless” [Ishii, 1916] and “up to thousands” [Okada, 1935]) in hatchery-reared salmonids, but no exact data are available. Thus, when compared with the past, available records, the number of *S. salmonicola* (*N*=615) found in this study is regarded as being extremely high. One of the possible reasons to explain it is that, as discussed below, the fish we examined had preyed on many individuals of the anisogammarid amphipod *Jesogammarus jesoensis*, a possible intermediate host for *S. salmonicola*.

Relating to the life cycle of *S. salmonicola*, it is interesting to note that more than 30 individuals of *J.*

jesoensis were found in the stomach of *O. nerka*, because gammaridean amphipods have been reported to serve as obligate intermediate hosts for the nematode species (Margolis & Moravec, 1982). In Japan, natural infections with larval *S. salmonicola* have been found in an unidentified amphipod (as "*Gammarus* sp.") and *Sternomoera japonica* (Tattersall) (as "*Paramoera japonica*") (Koshida, 1905, 1910; Moravec & Nagasawa, 1986). Our larval specimens of *S. salmonicola* found in the swimbladder of *O. nerka* are morphologically identical with those from the hemocoel of *S. japonica*, which have been regarded as being at the infective third-stage (Moravec & Nagasawa, 1986). The larval specimens in the present study ranged from 5.2–10.5 mm BL, which was almost the same as the size of larvae (7.89–9.03 mm BL) from *S. japonica* (Moravec & Nagasawa, 1986). Thus, it is highly probable that our specimen of *O. nerka* acquired infections with larval *S. salmonicola* by feeding on infected *J. jesoensis* immediately before capture. In other words, it appears that *J. jesoensis* plays a role as an intermediate host in Lake Toya to transmit *S. salmonicola* to *O. nerka*.

Our male and female specimens of *S. salmonicola* consisted of two, small- and large-sized, cohorts (Fig. 1). In particular, these cohorts of the females corresponded to immature and gravid worms. As both cohorts were differentiated from each other by size and maturity, it is likely that the two cohorts of *S. salmonicola* infected sockeye salmon in different periods and also that infection by the small-sized cohort occurred slightly before the date of capture (March 8, 2009). Further, in Lake Toya, sockeye salmon feed abundantly on amphipods in December (Sakano *et al*., 2001, fig. 4), which may be a period of infection by the large-sized cohort.

Sockeye salmon are generally known to be zooplanktivorous in Japanese lakes (*e.g*. Osanai & Tanaka, 1971; Mayama, 1978), but this is not the case in Lake Toya when the zooplankton biomass remains low there. Sakano *et al*. (2001) reported that, in this lake, sockeye salmon preyed exclusively on Japanese smelt *Hypomesus nipponensis* during such a period. In our study, in addition to this fish, many individuals of *J. jesoensis* were found in the fish stomach, which shows that, as indicated above, sockeye salmon feed on benthic gammaridean amphipods as well and get nematode infections.

In this study, we examined only one *O. nerka* that was heavily infected with *S. salmonicola* from Lake Toya, where three other salmonids (masu salmon *O. masou masou* (Brevoort), rainbow trout *O. mykiss* (Walbaum), and whitespotted char *Salvelinus leucomaenis leucomaenis* (Pallas)) are also found (Motoda, 1950; Kurohagi, 1989). More information is needed on nematode infection in the four salmonid species to understand the host utilization by *S. salmonicola* in this lake. In addition, *J. jesoensis* is found in streams and lakes of northern Japan, including Hokkaido and Honshu (Kusano, 2000, 2001; Kusano & Ito, 2003, 2004; Tomikawa, 2007). Sampling and examination of specimens of this amphipod from Lake Toya and other localities in this region is necessary to clarify the life cycle of *S. salmonicola*, which is a relatively frequent parasite of freshwater salmonids there (Nagasawa *et al*., 1987; Nagasawa & Furusawa, 2006).

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