J. Parasitol., 95(5), 2009, pp. 1209–1212

Parasites of the Deepwater Sculpin (*Myoxocephalus thompsonii*) Across Its Canadian Range

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ABSTRACT: Deepwater sculpin (*Myoxocephalus thompsonii*) were collected from 19 lakes across the species' distribution in Canada and examined for parasites. Six helminth species (*Crepidostomum farionis*, *Bothriocephalus cuspidatus*, *Proteocephalus* sp., *Cyathocephalus truncatus*, *Raphidascaris acus*, and *Echinorhynchus salmonis*), 1 crustacean species (*Ergasilus nerkae*), and 1 molluscan species (glochidia) parasitized these hosts. *Crepidostomum farionis*, *Proteocephalus* sp., *R. acus*, *E. nerkae*, and the glochidia represent new parasite records for this host species. Overall parasite prevalence was 78.0% while mean intensity was 6.1 ± 7.1 SD. *Bothriocephalus cuspidatus* was the most prevalent parasite and was recorded from 62.2% of the deepwater sculpin and found in 17 of the 19 lakes. The low-productivity habitat of this host limits the parasites available for transmission, and the infra- and component communities were generally species poor. With the exception of the *Proteocephalus* sp., all of the helminth parasites recovered have been reported as adults in lake trout (*Salvelinus namaycush*) or burbot (*Lota lota*), suggesting that, in the lakes where they occur, deepwater sculpin may play an important role in energetic transfer and parasitic transmission to higher trophic levels.

The deepwater sculpin (*Myoxocephalus thompsonii*) is a benthic fish species that is widely, but sporadically, distributed in landlocked, deep, freshwater lakes throughout northern North America (Scott and Crossman, 1973; Sheldon et al., 2008). The species is thought to be derived from an arctic marine ancestor that was driven south into freshwater habitats by early Pleistocene glacial advances (McAllister, 1961; Dadswell, 1972; Kontula and Vainola, 2003; Sheldon et al., 2008). Within the Great Lakes–St. Lawrence lowlands region, the deepwater sculpin is considered a species of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006). Although the biology and food habits of deepwater sculpin have been studied in the southern periphery of its distribution (the Great Lakes region), there are few ecological data for the remainder of the species range. This is due to the extreme difficulty of sampling the deep benthic habitat of the species. There are just 3 reports, recording a total of 7 parasite species, and all from the southern edge of the deepwater sculpin's range (Bangham, 1955; Black and Lankester, 1981; Muzzall et al., 1997). We initiated this study to better understand the parasite community of the deepwater sculpin.

During 2004, 127 deepwater sculpin specimens were collected from 19 lakes, including the extremes of Thirty-One Mile Lake in Quebec to the east, Upper Waterton Lake in Alberta to the southwest, and Alexie Lake in the Northwest Territories to the northwest (Fig. 1). Capture methods were specifically designed to target the species (see Sheldon et al., 2008). Host sample sizes ranged from 1 (George and Alexie lakes) to 18 (Second Cranberry Lake). Fish were measured to the nearest 0.1 mm (fork length), weighed to the nearest 0.1 g, and aged using otoliths. Fish ranged in length from 47.2–110.5 mm, in weight from 0.5–13.4 g, and in age from 3–24 yr. Seventy-three of the fish were female and 54 were male. Host specimens were fixed in 10% buffered formalin and transferred to 70% ethanol for storage.

Fish were completely necropsied, i.e., skin, fins, flesh, left set of gills, eyes, and all visceral organs were examined for parasites. A trichinoscope was used to examine the liver and spleen for larval parasites. The flesh was examined by skinning the fish, examining the surface, and then cutting transverse slices to examine the exposed musculature. Collected parasites were fixed in AFA (Hanson et al., 1982), stored in 70% EtOH, stained in acetocarmine, dehydrated in a graded alcohol series, cleared in xylene, and mounted on glass slides in Canada balsam. Parasites were initially identified using Schell (1985), Kabata (1988), Arai (1989), Gibson (1996), and Hoffman (1999) and confirmed by reference to the primary literature.

Definitions of prevalence and mean intensity followed Margolis et al. (1982). Values for mean intensity are reported as mean ± standard deviation (SD). Richness is the number of parasite species. Sample is defined as all the hosts collected from a single lake. The component community (Holmes and Price, 1986; Bush et al., 1997) refers to all parasites present in all hosts collected from a single lake; it includes all of the parasites found in a sample. Spearman's rank correlation coefficients were used to test if host size or age were correlated with infection intensity, abundance, or richness. The Mann–Whitney *U*-statistic was used to test if host sex was related to parasite intensity, abundance, or richness. Tests were run on samples that had 10 or more host individuals and on all hosts combined. Statistics were calculated using Statistix®8 (Analytical Software, 2003).

A total of 608 individuals, representing 8 parasite species, were recovered from the 127 deepwater sculpin specimens (Table I). Parasite voucher specimens have been deposited in the University of Nebraska State Museum Systematics Research Collections under accession numbers HWML 49090–49129 and 63511. For the first time, we recorded *Crepidostomum farionis*, *Proteocephalus* sp., *Raphidascaris acus*, *Ergasilus nerkae*, and anodontine glochidia from deepwater sculpin. With the exception of Burchell Lake, all of our samples represent new host–parasite locality records. Overall prevalence of parasites in deepwater sculpin was 78.0%. Parasitized deepwater sculpin had a mean intensity of 6.1 ± 7.1 SD. *Bothriocephalus cuspidatus* was the most prevalent parasite recovered, recorded from 62.2% of the deepwater sculpin captured and from 17 of the 19 lakes sampled (Table I). *Proteocephalus* sp. and *Echinorhynchus salmonis* were both found in 7 lakes, as well as in 16.5% and 14.2% of the individuals sampled, respectively. Of the parasites that infected more than a single host, the *Proteocephalus* sp. had the highest overall mean intensity (5.3 ± 7.9 SD), followed by *E. nerkae* (5.0 ± 6.9 SD) and *B. cuspidatus* (4.4 ± 5.3 SD) (Table I). Sixteen glochidia larvae of a freshwater mussel were recovered from a single deepwater sculpin from Burchell Lake. The shape of these glochidia was consistent with that of mussels in the Anodontinae. Species of *Pyganodon* or *Lasmigona* have glochidia with this shape and are known to have a distribution that encompasses Burchell Lake (Clarke, 1973). Three *C. farionis* were encysted in the cecum of a single fish from Fairbank Lake. A single *R. acus* larva was encysted in the liver of a fish from Teggau Lake.

Deepwater sculpin populations from Wollaston Lake and Clearwater Lake had the richest component communities, with 4 parasite species recorded from each lake. No parasites were recorded from the single host from Alexie Lake. Five lakes (Reindeer, George, Saganaga, Roddick, Thirty-One Mile) had single-species parasite component communities comprised of *B. cuspidatus* (Table I). Generally, prevalence of *B. cuspidatus* throughout the entire range of the deepwater sculpin was higher than previously reported from Burchell Lake (Black and Lankester, 1981). The parasite communities of the deepwater sculpin are largely depauperate, with just 5 individuals hosting 3 parasite species and 35 individuals with 2 parasite species. This likely reflects the fact that the deepwater sculpin lives at the bottom of deep, oligotrophic lakes with depauperate parasite communities. Spearman's rank correlation coefficients indicated that neither host size nor age were correlated with infection intensity, abundance, or richness, and the Mann–Whitney *U*-statistic indicated that host sex was not correlated with parasite intensity, abundance, or richness.

With the exception of a single gravid *C. farionis*, none of the helminths we observed was mature. It is possible that these parasites mature in the deepwater sculpin and that we simply did not observe adults. Alternatively, these helminths may not mature in the deepwater sculpin, but use this host to enhance transmission to a larger piscivore, where they will complete their reproductive cycle. All the helminth species we recorded have been reported as adults from lake trout (*Salvelinus namaycush*) or burbot (*Lota lota*) (Margolis and Arthur, 1979; Hoffman, 1999), and the

DOI: 10.1645/GE-2011.1

TABLE I. Infection parameters for parasites from *Myoxocephalus thompsonii* collected from 19 lakes in Canada. Lakes correspond to Figure 1, with the number of deepwater sculpin (hosts) examined from each lake in parentheses. Values are presented as prevalence (%) followed by mean intensity ± SD, with range indicated in parentheses.

Lake	*Crepidostomum farionis*	*Bothriocephalus cuspidatus*	*Proteocephalus* sp.	*Cyathocephalus truncatus*	*Raphidascaris acus*	*Echinorhynchus salmonis*	*Ergasilus nerkae*	Glochidia
Alexie (n = 1)	0	0	0	0	0	0	0	0
Upper Waterton (n = 10)	0	90 10.1 ± 8.3 (2–28)	40 2.5 ± 1.7 (1–5)	0	0	0	0	0
Great Slave (n = 9)	0	77.8 2.8 ± 2.0 (1–7)	77.8 5.2 ± 4.9 (1–15)	0	0	0	0	0
Wollaston (n = 4)	0	0	25 1 (1)	25 1 (1)	0	100 3.0 ± 2.7 (1–7)	50 1 (1)	0
Reindeer (n = 4)	0	50 1 (1)	0	0	0	0	0	0
Athapapuskow (n = 9)	0	77.8 2.2 ± 1.6 (1–5)	0	11.1 1 (1)	0	0	0	0
Second Cranberry (n = 18)	0	38.9 1.2 ± 0.5 (1–2)	5.5 1 (1)	0	0	27.8 2.8 ± 1.9 (1–6)	50 5.7 ± 8.5 (1–25)	0
Clearwater (n = 5)	0	80 10.7 ± 11.4 (1–23)	0	20 1 (1)	0	20 1 (1)	80 5.2 ± 4.5 (3–12)	0
George (n = 1)	0	100 2 (2)	0	0	0	0	0	0
Westhawk (n = 5)	0	60 2.3 ± 1.5 (1–4)	0	0	0	20 1 (1)	0	0
Lake 259 ELA (n = 6)	0	16.6 1 (1)	50 7.0 ± 6.6 (1–14)	16.6 2 (2)	0	0	0	0
Teggau (n = 2)	0	50 1 (1)	100 18.0 ± 24.0 (1–35)	0	50 1 (1)	0	0	0
Eagle (n = 11)	0	54.5 2.5 ± 2.7 (1–8)	0	0	0	18.1 2.5 ± 0.7 (2–3)	0	0
Saganaga (n = 3)	0	100 8.0 ± 10.4 (2–20)	0	0	0	0	0	0
Burchell (n = 17)	0	64.7 2.1 ± 1.2 (1–4)	0	0	0	0	0	5.8 16 (16)
Nipigon (n = 2)	0	50 2 (2)	0	0	0	100 3.5 ± 2.1 (2–5)	0	0
Fairbank (n = 6)	16.7 3 (3)	100 5.8 ± 4.1 (1–13)	50 2.3 ± 2.3 (1–5)	0	0	50 2.3 ± 1.2 (1–3)	0	0
Roddick (n = 9)	0	77.8 6.4 ± 3.9 (2–13)	0	0	0	0	0	0
Thirty One Mile (n = 5)	0	60 4.0 ± 2.6 (1–6)	0	0	0	0	0	0
Total (n = 127)	0.7 3 (0–3)	62.2 4.4 ± 5.3 (0–28)	16.5 5.3 ± 7.9 (0–35)	3.1 1.2 ± 0.5 (0–2)	0.7 1 (0–1)	14.2 2.6 ± 1.7 (0–7)	11.8 5.0 ± 6.9 (0–25)	0.7 16 (0–16)

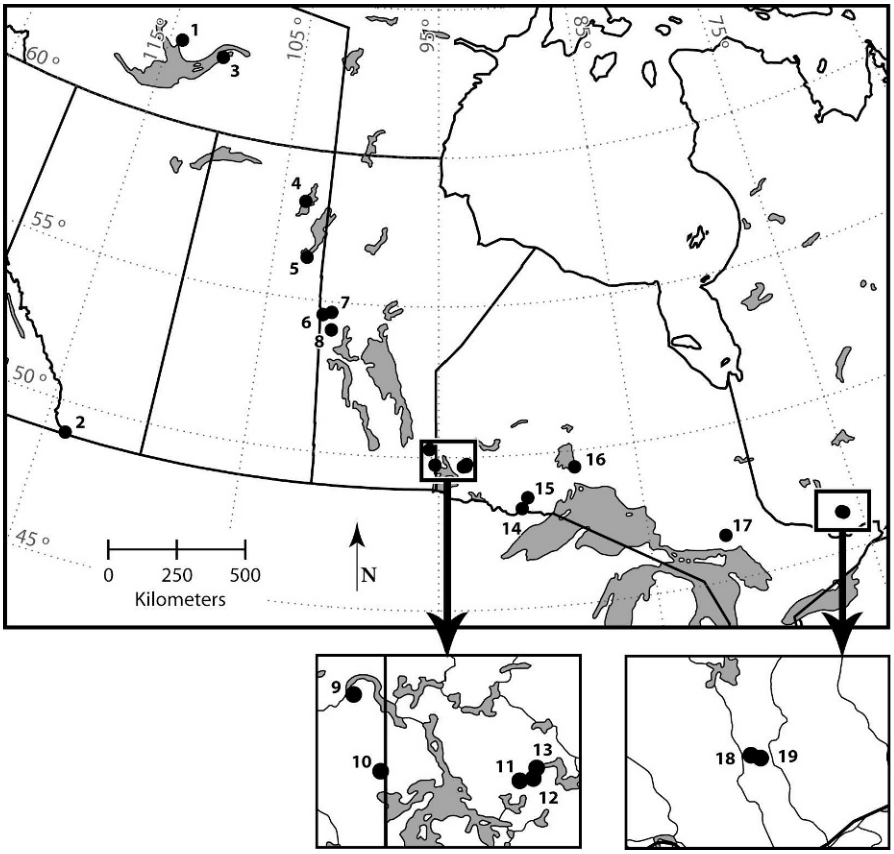

FIGURE 1. Deepwater sculpin (*Myoxocephalus thompsonii*) sample locations. 1—Alexie Lake; 2—Upper Waterton Lake; 3—Great Slave Lake; 4—Wollaston Lake; 5—Reindeer Lake; 6—Lake Athapapuskow, 7—Second Cranberry Lake; 8—Clearwater Lake; 9—George Lake; 10—Westhawk Lake; 11—Lake 259 (Experimental Lakes Area); 12—Teggau Lake; 13—Eagle Lake; 14—Saganaga Lake; 15—Burchell Lake; 16—Lake Nipigon; 17—Fairbank Lake; 18—Roddick Lake; 19—Thirty One Mile Lake.

deepwater sculpin is an important dietary item for these piscivorous fishes (Scott and Crossman, 1973).

The diet of the deepwater sculpin affects its recruitment of parasites. Immature *C. truncatus* larvae have been reported from the crustaceans *Diporeia affinis* and *Mysis relicta* (Amin, 1978), both of which are commonly recorded in the stomach contents of deepwater sculpins (Kraft and Kitchell, 1986). The presence of *Proteocephalus* sp. and *E. salmonis* can also be explained by transmission through copepods and amphipods, respectively (Muzzall et al., 1997). Three immature *C. farionis* were encysted in the cecum of a single fish from Fairbank Lake. This species has been reported from a variety of piscine hosts, including salmonids and burbot, and is transmitted by ingestion of infected mayfly larvae (Crawford, 1943). As it is known to be a salmonid parasite, *C. farionis* will most likely be rare in deepwater sculpin and, if present, comprise mostly immature worms. The crustacean *E. nerkae* has a direct life cycle and is commonly reported from salmonids, including lake trout. The presence of this parasite on deepwater sculpin indicates a sympatric association with other fish species, such as lake trout, that are known to host this parasite.

Parasites provide a useful source of information regarding foodweb dynamics (Marcogliese and Cone, 1997). Our results suggest that the deepwater sculpin may play an important role in the transmission of parasites to the trophic level of piscivorous species such as lake trout and burbot. Small lake trout and burbot, as well as deepwater sculpins, feed on *M. relicta* and *D. affinis* (Scott and Crossman, 1973). These food sources would expose these fish to infective stages of the same parasites. However, as lake trout become larger and stop feeding on zooplankton, deepwater sculpin become an important dietary item capable of transmitting parasites such as *E. salmonis* and *B. cuspidatus*, assuming the parasites could survive the gastric secretions of piscivorous fishes. The presence of typically salmonid parasite species in the deepwater sculpin may also represent spill-over from the lake trout, which is generally a dominant fish species within oligotrophic lakes (Leong and Holmes, 1981). Pending further study, we suggest that the presence of *B. cuspidatus*, *Proteocephalus* sp., *C. truncatus*, *R. acus*, and *E. salmonis* in the deepwater sculpin points to a role for this species in the transmission of parasites to deepwater piscivorous fish in oligotrophic lakes.

We thank Nicholas Mandrak, Chris Wilson, and William Franzin for guidance with field work. Funding was provided by a Natural Sciences and Engineering Research Council of Canada Discovery Grant (N.L.), the Species at Risk – Especes en Peril program of Fisheries and Oceans Canada, the Fisheries Research Program of the Great Lakes Fishery Commission, and the Northern Scientific Training Program.

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