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Research Note

Update on the Distribution of the Invasive Asian Fish Tapeworm, *Bothriocephalus acheilognathi*, in the U.S. and Canada

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ABSTRACT: The documented range of the invasive and potentially pathogenic Asian fish tapeworm, *Bothriocephalus acheilognathi* Yamaguti, 1934 in the United States and Canada is updated based on examination of museum depositions and original field collections. Gravid specimens of *B. acheilognathi* were collected from the fathead minnow *Pimephales promelas* Rafinesque in Peter Lake, at the University of Notre Dame Environmental Research Center (UNDERC) Land o' Lakes, Wisconsin. A single immature specimen of the parasite was collected from a white bass, *Morone chrysops* (Rafinesque) in Lake Winnipeg, Manitoba, Canada. This is the first record of *B. acheilognathi* in Canada and extends its northern range in the interior of the continent by more than 600 miles over the last documented record. The previous record of *B. acheilognathi* in Canada, from the northern pikeminnow, *Ptychocheilus oregonensis* in British Columbia, is a misidentification of *Eubothrium tulipai*. Examination of selected records of intestinal cestodes from native cyprinids, in the Harold W. Manter Laboratory of Parasitology (HWML, n = 9) collection and in the United States National Parasite Collection (USNPC, n = 8), provided evidence of the parasite in Nebraska and possibly in the upper Colorado River basin. Introductions into Wisconsin-Michigan were due to the stocking of golden shiners, whereas the source of the introduction in Manitoba remains unknown.

KEY WORDS: Asian fish tapeworm, *Bothriocephalus acheilognathi*, Canada, U.S.A, Wisconsin, Manitoba, fish, parasites, Cestoda, invasive species.

The Asian fish tapeworm, *Bothriocephalus acheilognathi* Yamaguti 1934, a species native to far east Asia, was first reported in North America, from the U.S., in 1975 (Hoffman, 1999). The parasite was most likely introduced into this continent by the translocation of grass carp, *Ctenopharyngodon idella* (Valenciennes), one of the original hosts of the tapeworm in its native range in eastern Asia. Since its introduction, the tapeworm has spread, and Hoffman's (1999) compendium lists the parasite in British Columbia, California, North Carolina, Nevada, Arizona, Utah, New Hampshire, Hawaii, New Mexico and Florida. The parasite seems to be particularly well established in native and non-native fishes in Arizona and California, especially in the native *Gila* chubs (Brouder and Hoffnagle, 1997; Kuperman et al., 2001; Warburton et al., 2002; Choudhury et al., 2004; Bonar and coworkers, unpublished data). The parasite is also widely established on the Hawaiian islands (Font and Tate, 1994; Font, 1997; Vincent and Font, 2003) and in Puerto Rico (Bunkley-Williams and Williams, 1994), and broadly distributed in Mexico (Salgado-Maldonado and Pineda-Lopez, 2003). In this report, we update the records of *B. acheilognathi* in the U.S. and Canada based on examination of museum depositions and original field collections, the results of which significantly extend the range of this invasive species.

Museum collections, particularly those that have a long history, such as the U.S. National Parasite Collection (USNPC), the Harold W. Manter Laboratory of Parasitology (HWML) and the Canadian Museum of Nature Parasite Collection (CMNPA) often provide critical data on past and present distributions of parasites. In view of the confused taxonomy and misidentifications of *Bothriocephalus* spp. in the past (see Scholz, 1997), and the predilection of *B. acheilognathi* for cyprinids, the databases of the USNPC and the HWML were searched for records of "*Bothriocephalus*" and other unidentified cestodes in cyprinids, by host genus names. Such searches yielded several records of '*Bothriocephalus* sp.' and of undetermined cestodes. Specimens corresponding to these records were examined.

Our continuing studies on fish parasites over the past few years have also provided additional specimens of *Bothriocephalus* sp. from field collections.

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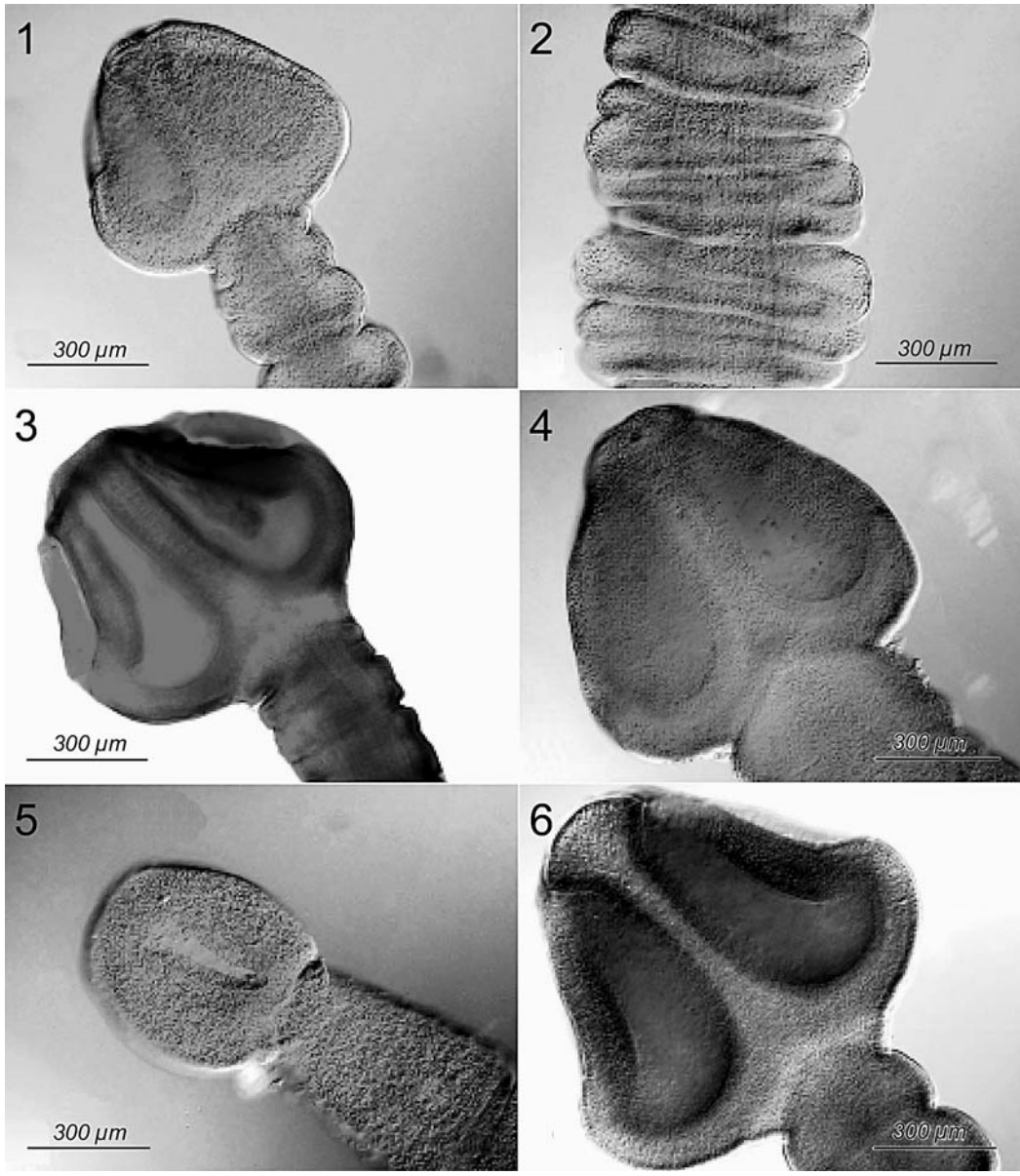
On July 7, 2001, 2 mature specimens of *Bothriocephalus* were collected from a fathead minnow, *Pimephales promelas* Rafinesque, during a limnological study in Peter Lake at the University of Notre Dame Environmental Research Center (UNDERC), Land o' Lakes, Wisconsin, near the Wisconsin–Michigan border (approx. 46°13′N, 89°31.5′W). Due to different objectives at the time, these specimens were preserved in 95% ethanol. On July 2, 2003, during routine fish collections and necropsies, a single strobilate but immature specimen of *Bothriocephalus* sp. was collected from a white bass, *Morone chrysops* (Rafinesque), from the Hillside Beach location in the southern basin of Lake Winnipeg, Manitoba, Canada (approx. 50°41′N, 96°33′W). The live specimen was cut, the posterior half fixed in 100% ethanol for molecular work and the anterior half fixed in steaming hot 10% neutral buffered formalin for morphological studies. Specimens from both sources (Wisconsin and Manitoba) were stained with acetocarmine or hematoxylin, and processed for permanent whole mounts on slides using standard techniques. Images of these and museum specimens were captured with a Digital Optronics (Optronics®, Goleta, California) camera mounted on an Olympus BX 51 microscope with DIC capabilities, using Optronics Microfire Imaging software. Tapeworms were identified as *B. acheilognathi* based on both scolex and strobilar morphology. The arrowhead or heart shaped, fleshy scolex of *B. acheilognathi*, with anterolaterally directed narrow slit like openings is unique among *Bothriocephalus* spp. (see also Scholz, 1997). Furthermore, the species lacks a distinct neck and its mature strobila is not craspedote, the proglottids having rounded edges (see Figs. 1–6). Specimens were deposited in the USNPC with the following accession numbers: *B. acheilognathi* from fathead minnow (USNPC 97790) and *B. acheilognathi* from white bass (USNPC 97792).

The examination of museum and field collections has extended the documented range of this invasive parasite (Fig. 7), which now includes Wisconsin/Michigan, possibly Colorado, and most notably, Manitoba, Canada. The record in Manitoba extends the northern range of this parasite by at least 600 miles. Until this study, the northernmost range of the parasite in wild fish was Nebraska in the U.S. and British Columbia in Canada (Scholz, 1997; Hoffman, 1999; Arai and Mudry, 1983).

The previous report of *B. acheilognathi* (as *B. opsariichthydis*) in Canada, from the northern pikeminnow, *Ptychocheilus oregonensis* (Richardson) in British Columbia (Arai and Mudry, 1983 CMNPA 1984-6125, 6278, 6280, 6289, 6296, 6346, 6348, 6407) is a misidentification of *Eubothrium tulipai* Ching and Andersen, 1983 (Ching and Andersen, 1983). The scolex of *E. tulipai* resembles that of *B. acheilognathi* in overall shape when viewed laterally, but the bothridial grooves are wide and the walls conspicuously thinner in the former. The craspedote strobila of *E. tulipai* with laterally directed cirri and vaginae opening to marginal genital pores clearly distinguishes this species from *B. acheilognathi*. The record of the Asian fish tapeworm from Lake Winnipeg (this study) appears to be the first published record of the parasite in Canada. The fact that the single specimen was immature is not surprising since the white bass does not seem to be an appropriate host of this parasite (see Hoffman, 1999; AC & PN, unpublished data on white bass parasites). The white bass is an invasive species as well, having colonized the Red River to establish successfully in the southern basin of Lake Winnipeg where it is now abundant (Scott and Crossman, 1979; Franzin et al., 2003; Stewart and Watkinson, 2004). It is unlikely to have been the primary source of the tapeworm and may have become infected due to its pelagic epilimnetic habits (Stewart and Watkinson, 2004), either directly by ingesting copepods or indirectly by feeding on infected pelagic cyprinids (see Hansen, Choudhury and Cole, in press). Hanke (1996) found the emerald shiner, *Notropis atherinoides* (Cyprinidae) to be the most common prey item for white bass past the young-of-the-year stage. However, this finding also suggests that while the presence of *B. acheilognathi* in white bass may be accidental (or incidental), the tapeworm is well established in Lake Winnipeg in some cyprinid host. Lake Winnipeg is home to several cyprinids (Stewart and Watkinson, 2004), at least one of which, *Cyprinus carpio* L., is nonnative, but their parasites remain largely unknown. The common carp established itself in Lake Winnipeg long before the tapeworm or its original host, the grass carp, was reported in any waters that could be considered a source (Scott and Crossman, 1979), ruling the common carp out as the primary source of the parasite as well. The source is most likely some other (likely a cyprinid) species.

The Asian fish tapeworm was introduced into UNDERC (Land o' Lakes, Wisconsin) waters by golden shiners, *N. crysoleucas*, which were stocked as part of on going food-web manipulation studies (Carpenter et al., 2001). The parasite apparently established in fathead minnows, which sustained the life cycle in the system and perhaps still does. Golden shiners have been nearly extirpated from the system,



Figures 1–6. Representative specimens of *Bothriocephalus acheilognathi* examined and reported in this study. **1.** Scolex, ex. white bass, Lake Winnipeg (USNPC 97792). **2.** Strobila, ex. white bass, Lake Winnipeg (USNPC 97792). **3.** Scolex, ex. fathead minnow, University of Notre Dame Environmental Research Center (USNPC 97790). **4.** Scolex (HWML 19882). **5.** Scolex (HWML 21487). **6.** Scolex (HWML 15322).

and a recent survey of 109 cyprinids (belonging to 6 species), including 41 golden shiners and 22 fathead minnows, at UNDERC (Eddie Heath and Joseph Beuchel, unpublished data, pers. comm.) did not yield any *B. acheilognathi*. Its current status in those lakes is being evaluated.

The presence of this parasite in Nebraska is corroborated by several records from native species such as the fat head minnow, *Pimephales promelas* (HWML 15322, 19755, 34182) and the red shiner, *Cyprinella lutrensis* (Baird and Girard) (HWML 19852, 19882), mainly from the South Platte River. The specimen from Indiana (HWML 21487) from *Pimephales notatus* (Rafinesque) was deposited by

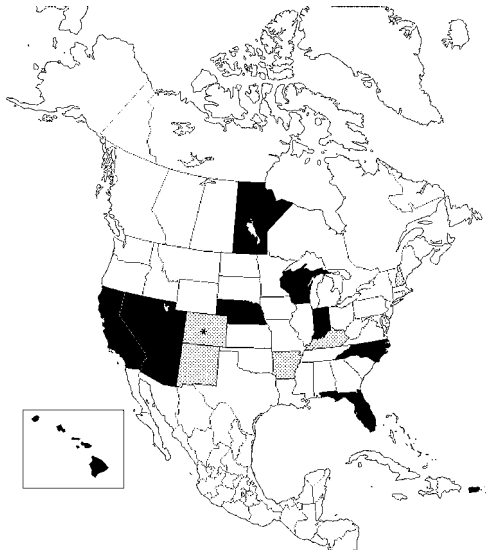


Figure 7. Map of North America showing the distribution of Bothriocephalus. acheilognathi in the U.S. and Canada. States and provinces with records of the tapeworm in wild fish are shaded black. States with reports of the parasite only from fish hatcheries are stippled. Asterisk indicates controversial record.

R.L. Buckner (as part of Buckner et al., 1985), as "*Bothriocephalus formosus*," but the morphology of the scolex and strobila indicates that this is *B. acheilognathi*, as suggested by Scholz (1997). Comparisons with specimens of *Bothriocephalus formosus* collected from its type and typical host, the troutperch, *Percopsis omiscomaycus* (Walbaum) from Lake Winnipeg by two of us (AC and PN) and with the literature (Mueller and VanCleave, 1932) confirm this identification. Buckner et al. (1985) also reported "*B. formosus*" from 2 other cyprinids, *Notropis umbratilus* (Girard) (=*Lythrurus umbratilis*) and *Phenacobius mirabilis* (Girard). It is likely that these records are also of *B. acheilognathi* but specimens from these hosts were not available.

Several other museum records also merit comment, particularly the recently accessioned 'Glen Hoffman' collection at the USNPC. The collection includes specimens of *B. acheilognathi* from the Colorado pikeminnow *Ptychocheilus lucius* Girard, from the Dexter Federal Hatchery in New Mexico (USNPC 52469, from adult fish), from the Colorado River Fishery Project in Grand Junction, Colorado, and the Fish Health Lab in Fort Morgan, Colorado (USNPC 52466, 52467, and 52468, from cultured juvenile pikeminnows). Adult pikeminnows, collected from the Colorado River, were sent for spawning to the Dexter National Fish Hatchery, New Mexico, in the late 1970s (Chuck McAda and Theophilus Inslee, pers. comm.). Cultured juvenile pikeminnows were sent back to Grand Junction and most were stocked into the upper Colorado River. Subsequently, *B. acheilognathi* was detected in some of the remaining juveniles (Chuck McAda, pers. comm.). No exotic species (grass carp, golden shiners, etc.) were ever held at the Grand Junction facility (Chuck McAda, pers. comm.), making it highly improbable that the juvenile pikeminnows became parasitized there. It is therefore likely that both juvenile and adult fish became parasitized at Dexter. It is unknown if the inadvertent stocking of potentially infected fish has resulted in the parasite being established in the upper Colorado River system. There is also a record of a *B. acheilognathi* from grass carp (HWML 35060, gravid specimen) in Colorado deposited by G.W. Schmidt in 1984, and apparently originating from the Denver Federal "Center?"(label partly illegible) but it is unknown where the fish host was collected. The parasite is already established in native and nonnative fishes in the lower Colorado River basin (Brouder and Hoffnagle, 1997; Clarkson et al., 1997; Choudhury et al., 2004).

Finally, Hoffman's collection at the USNPC also includes 2 records (USNPC 96794, 96795) of *B. acheilognathi* in a golden shiner and fathead minnow from Kentucky, dated 1978. The source (wild or hatchery) remains unknown and Hoffman (1999) does not list Kentucky as a location for this parasite but we include it in this update (Fig. 7).

Our findings suggest that the translocation of fish hosts has spread the Asian fish tapeworm substantially more widely than previously reported. The presence of reproducing populations in locations such as Wisconsin and central Canada also suggests that the colder temperature of the northern regions may not be as prohibitive a barrier as one might think and raises concerns about its potential impact on native fisheries. Finally, any record of *Bothriocephalus* in minnows and other cyprinids should be suspected to be *B. acheilognathi* since cyprinids are not suitable hosts for any of the other North American *Bothriocephalus* spp.

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