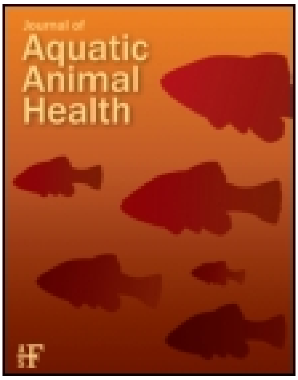

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[Communication]

Asian Fish Tapeworm *Bothriocephalus acheilognathi* in the Desert Southwestern United States

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Abstract.—The Asian fish tapeworm *Bothriocephalus acheilognathi* (Cestoda: Bothriocephalidea) is an introduced fish parasite in the southwestern United States and is often considered a serious threat to native desert fishes. Determining the geographic distribution of nonnative fish parasites is important for recovery efforts of native fishes. We examined 1,140 individuals belonging to nine fish species from southwestern U.S. streams and springs between January 2005 and April 2007. The Asian fish tapeworm was present in the Gila River, Salt River, Verde River, San Pedro River, Aravaipa Creek, and Fossil Creek, Arizona, and in Lake Tuendae at Zzyzx Springs and Afton Canyon of the Mojave River, California. Overall prevalence of the Asian fish tapeworm in Arizona fish populations was 19% (range = 0–100%) and varied by location, time, and fish species. In California, the prevalence, abundance, and intensity of the Asian fish tapeworm in Mohave tui chub *Gila bicolor mohavensis* were higher during warmer months than during cooler months. Three new definitive host species—Yaqui chub *G. purpurea*, headwater chub *G. nigra*, and longfin dace *Agosia chrysogaster*—were identified. Widespread occurrence of the Asian fish tapeworm in southwestern U.S. waters suggests that the lack of detection in other systems where nonnative fishes occur is due to a lack of effort as opposed to true absence of the parasite. To limit further spread of diseases to small, isolated systems, we recommend treatment for both endo- and exoparasites when management actions include translocation of fishes.

Originating in Asia, the Asian fish tapeworm *Bothriocephalus acheilognathi* (Cestoda: Bothriocephalidea) is a fish parasite that has been introduced worldwide, primarily through shipments of grass carp *Ctenopharyngodon idella* (Andrews et al. 1981; Font and Tate 1994; Dove and Fletcher 2000; Salgado-Malgonado and Pineda-López 2003; Marcogliese 2008). This tapeworm species was recently separated from the Pseudophyllidea (Kuchta et al. 2008). The Asian fish tapeworm was first detected in the Colorado River in 1979 (Heckmann et al. 1986) and is now well established in other systems within the basin, including the Virgin and Little Colorado rivers (Heckmann et al. 1987, 1993; Brouder and Hoffnagle 1997; Clarkson et al. 1997; Choudhury et al. 2004, 2006). The Asian fish tapeworm is known to have infected several native fish species in southern California, including the endangered Mohave tui chub *Gila bicolor mohavensis* (Warburton et al. 2002), and has also infected fish from the Salt River in southeastern Arizona (Ward 2007). The Asian fish tapeworm was recently detected in the Rio Grande and Pecos River systems in Texas and New Mexico (Bean et al. 2007; Bean 2008) and in Durango, Mexico (Martínez-Aquino and Aguilar-Aguilar 2008).

Liao and Shih (1956) described the life cycle of the Asian fish tapeworm. Eggs are passed in the feces of the definitive fish host, and coracidia hatch in 1–5 d depending on water temperature. Free-swimming coracidia are ingested by cyclopoid copepods, the intermediate host. Hexacanths develop into infective procercoids in 11–12 d at a water temperature of 29–31°C. The Asian fish tapeworm life cycle is completed when a fish eats an infected copepod and the procercoids develop into adult tapeworms.

The Asian fish tapeworm can cause complete intestinal blockage in heavily infected fish (Hoole and Nisan 1994). Infected bonytails *Gila elegans* that were fed low rations had reduced growth and increased mortality compared with uninfected fish on a low-ration diet (Hansen et al. 2006). Other species of fish infected with the Asian fish tapeworm that have shown reduced growth or survival include wild-caught western mosquitofish *Gambusia affinis*, hatchery-reared roundtail chub *Gila robusta*, and red shiners *Cyprinella lutrensis* (Granath and Esch 1983a; Brouder 1999; Bean 2008). Due to its low specificity for intermediate hosts among cyclopoid copepods and its low specificity for definitive hosts among minnows (family Cyprinidae), the Asian fish tapeworm can be a threat to native fishes, especially in the U.S. desert

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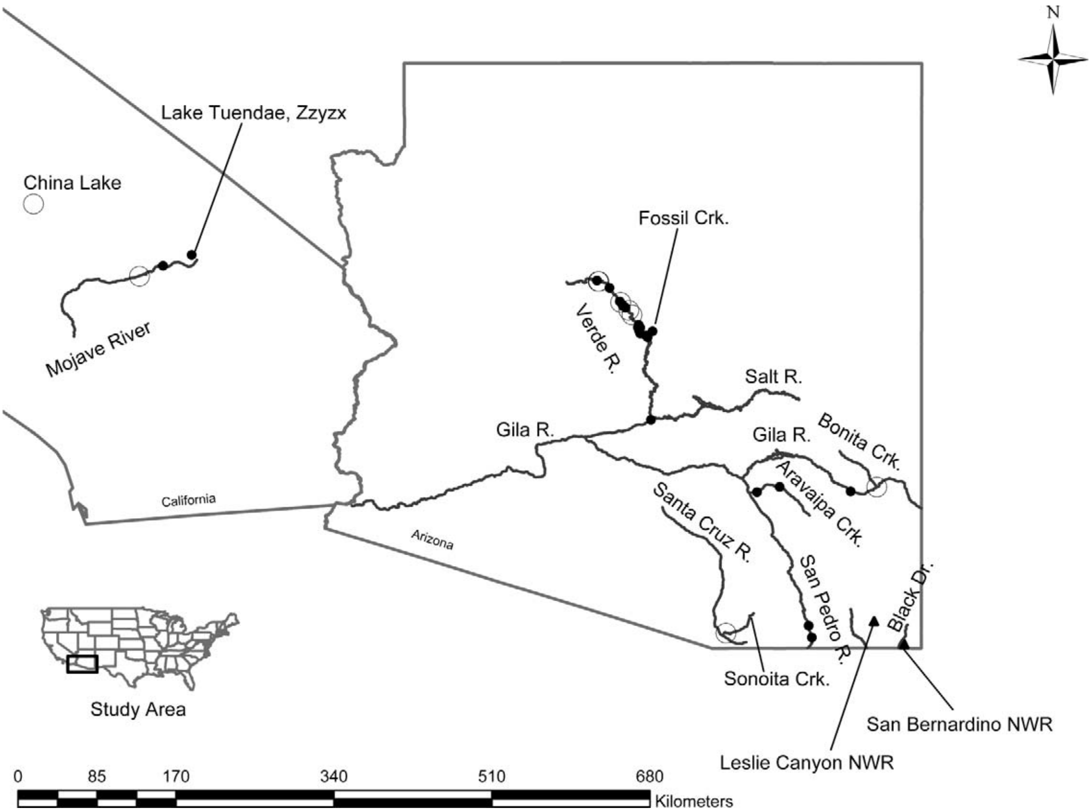

FIGURE 1.—Sampling locations and detected incidence of the Asian fish tapeworm in fishes sampled from streams in southeastern Arizona and southern California, January 2005–June 2006. Open circles represent sites where the parasite was not detected; shaded circles and triangles represent sites where the parasite was detected (NWR = National Wildlife Refuge).

Southwest, where stream temperatures are warm and where many imperiled fishes are cyprinids (Marcogliese and Esch 1989; Clarkson et al. 1997).

Upon initial entry into a new, uninfected fish population, the prevalence and intensity of the Asian fish tapeworm are high but eventually decrease over time (Heckmann et al. 1987; Hoffman 1999). Accidental transportation to new areas, especially small, isolated systems containing rare fishes, should be prevented. Determining the current geographic distribution of the Asian fish tapeworm should be a priority for management, especially when fish repatriations and translocations are common management actions. We present detections of the Asian fish tapeworm in southwestern desert areas of the United States, and we provide a list of new definitive host species.

Methods

We collected fish from southwestern desert areas between January 2005 and April 2007 (Figure 1). Fish were collected in the Verde River between 30 May and 25 June 2005. Mohave tui chub in Lake Tuendae at Zzyzx Springs, California, were sampled seven times between 19 October 2005 and 1 April 2007. We used a 3-m seine (3-mm mesh) for stream fish collections and mesh minnow traps for collection in springs. We concentrated our effort on collecting cyprinids, which typically have the highest probability of infection compared with other fish families. To determine presence–absence of the Asian fish tapeworm in nonnative fishes, we dissected fish and examined gut contents; in extremely small fish, we used the squash-plate method (Mitchell 1989). For native fishes, we filled a collapsible vinyl pool with approximately 2,000 L of water, added praziquantel at a concentration of 6.0 mg/L of water, placed individual fish in 3-L plastic containers covered with screen, and then placed each container in the pool for 24 h consistent with the methods of Ward (2007). Duration of treatment (>24 h) and concentration of praziquantel ensured that tapeworms would be removed and that the treatment would be nonlethal to fish (Mitchell 1995, 2004; Ward

TABLE 1.—Prevalence and intensity of Asian fish tapeworm infections in fishes sampled from streams in southern Arizona and California. Confidence intervals (CIs) for prevalence were calculated by Sterne's exact method (NR = not recorded; NA = not applicable; SL = standard length). Units for abundance and intensity are tapeworms/fish.

Location	Species	*N*	Host SL range (mm)	Prevalence (%) (95% CI)	Mean intensity	Median intensity	Mean abundance
Verde River	Red shiner	256	30–55	20.0 (15.5–25.3)	1.68	1	0.34
	Common carp *Cyprinus carpio*	82	75–280	20.7 (13.2–31.0)	1.59	1	0.33
San Pedro River	Longfin dace *Agosia chrysogaster*[a]	32	42–57	6.3 (1.1–20.0)	1.00	1	0.06
	Fathead minnow *Pimephales promelas*	15	39–59	40.0 (19.1–66.8)	1.83	1	0.73
	Western mosquitofish	15	25–41	7 (0.4–30.2)	1.00	1	0.07
Aravaipa Creek	Red shiner	169	34–62	20.7 (15.0–27.5)	5.89	3	1.22
	Roundtail chub[a]	10	178–247	100 (70.9–100)	NR	NR	NR
Fossil Creek	Headwater chub *Gila nigra*[a]	10	189–301	100 (70.9–100)	NR	NR	NR
Salt River	Red shiner	50	41–58	14.0 (6.7–26.8)	2.43	1	0.34
Gila River	Red shiner	30	37–54	10.0 (3.7–23.4)	1.00	1	0.10
	Fathead minnow	11	45–57	0.0 (0.0–26.4)	NA	NA	NA
	Western mosquitofish	8	33–39	0.0 (0.0–36.5)	NA	NA	NA
Sonoita Creek	Western mosquitofish	30	27–35	0.0 (0.0–11.1)	NA	NA	NA
	Red shiner	7	51–56	0.0 (0.0–37.7)	NA	NA	NA
Bonita Creek	Red shiner	15	42–54	0.0 (0.0–22.2)	NA	NA	NA
Afton Canyon[b] (Mojave River)	Arroyo chub *Gila orcuttii*	62	24–59	88.7 (78.4–94.6)	16.93	8	15.02
Lark Seep[b] (China Lake)	Mohave tui chub	30	77–175	0.0 (0.0–11.1)	NA	NA	NA
MC Spring[b] (Zzyzx Springs)	Mohave tui chub[a]	30	57–82	0.0 (0.0–11.1)	NA	NA	NA
Camp Cady[b] (Mojave River)	Mohave tui chub	30	73–191	0.0 (0.0–11.1)	NA	NA	NA

[a] Species native to the collection location.
[b] Locations in California; all other locations are in Arizona.

2007). We added several air pumps and air stones to the pool to increase oxygen exchange. After 24 h, tapeworms were expelled from fish and we were able to collect expelled tapeworms in each individual box. We measured standard length (mm) of all fish. After fish dissection or treatment with praziquantel, we counted the number of tapeworms under a compound microscope. Native fishes were returned to the place of capture. We identified Asian fish tapeworms by the segmented body and heart-shaped scolex (Hoffman 1999; A. Choudhury, St. Norbert's College, De Pere, Wisconsin, personal communication). Mean and median intensity (the average number of tapeworms per infected host), mean abundance (the average number of tapeworms per host), and prevalence (the percent of hosts infected), with bootstrapped 95% confidence intervals determined by Sterne's exact method, were calculated in QP software version 3.0 (Rózsa et al. 2000; Reiczigel 2003).

Results

We surveyed 29 sites in nine streams and four springs; 1,140 fish representing nine species were examined. In Arizona, the Asian fish tapeworm was detected at 21 of the 28 sites and in six of eight streams. The only Arizona streams where the Asian fish tapeworm was not detected were Bonita and Sonoita creeks. Infection prevalence ranged from 0% to 100% and averaged 19% among all samples combined. Mean and median intensity and mean abundance of Asian fish tapeworms in fish hosts were all low. Asian fish tapeworm prevalence, mean abundance, mean intensity, and median intensity varied by fish species, time, and location (Table 1). In all collections combined, at least one individual of each species examined was infected with the Asian fish tapeworm.

In California, the Asian fish tapeworm was present in arroyo chub sampled from the Mojave River at Afton Canyon and in Mohave tui chub sampled from Lake Tuendae at Zzyzx Springs. The Asian fish tapeworm was not found in Mohave tui chub collected in MC Spring (Zzyzx Springs), Lark Seep (China Lake Naval Air Weapons Station), or Camp Cady ponds (Mojave River; Table 1). For Mohave tui chub in Lake Tuendae, prevalence ranged from 0.0% to 62.2% and mean intensity ranged from 0.00 to 39.12 tapeworms/fish (Table 2). Asian fish tapeworm prevalence and mean intensity in Lake Tuendae Mohave tui chub were higher during the warmer months compared with cooler months (Table 2).

The Asian fish tapeworm is also known to occur in Yaqui chub *Gila purpurea* and other fishes in refugium ponds at Black Draw in the San Bernardino National Wildlife Refuge; in Leslie Creek in the Leslie Canyon National Wildlife Refuge; and at the Rancho San Bernardino wetlands in Mexico (W. Radke, U.S. Fish and Wildlife Service, personal communication). We found the Asian fish tapeworm to be widespread in the Gila River basin. Tapeworms also infected fish in the San Bernardino and Leslie Canyon National Wildlife refuges outside the Gila River basin and at two locations in the Mojave River basin, California.

TABLE 2.—Seasonal variation in Asian fish tapeworm infections in Mohave tui chub sampled from Lake Tuendae, Zzyzx Springs, California (SL = standard length). Confidence intervals (CIs) for prevalence were calculated by Sterne's exact method. Asian fish tapeworms were quantified by the methods of Ward (2007). Units for abundance and intensity are tapeworms/fish.

Date	*N*	Host SL range (mm)	Prevalence (%) (95% CI)	Mean intensity	Median intensity	Mean abundance
19 Oct 2005	30	83–185	33.3 (17.7–51.7)	9.10	2.5	3.03
25 Feb 2006	49	74–267	0.0 (0.0–1.6)			
11 May 2006	12	61–226	25 (7.1–54.3)	2.00	2.0	0.50
16 Aug 2006	45	70–206	62.2 (46.6–75.8)	39.14	2.5	24.36
14 Nov 2006	40	46–201	0.0 (0.0–8.4)			
13 Jan 2007	30	76–205	0.0 (0.0–11.1)			
1 Apr 2007	42	65–189	0.0 (0.0–8.9)			

Observations of the Asian fish tapeworm in the headwater chub, Yaqui chub, and longfin dace represent new definitive host records for this parasite.

Discussion

Many of the southwestern U.S. endemic fish species are cyprinids and are probably highly susceptible to Asian fish tapeworm infection (Clarkson et al. 1997). We found the Asian fish tapeworm in every major Gila River drainage subbasin we examined except for the Santa Cruz River basin. Some of the more troubling new locations where the Asian fish tapeworm was present included both the east and west ends of Aravaipa Canyon on Aravaipa Creek; Fossil Creek, where endangered headwater chub were infected; and Leslie Canyon, where endangered Yaqui chub were infected (Figure 1).

Aravaipa Creek hosts seven native species of fish, five of which are cyprinids and potential hosts for the Asian fish tapeworm. A barrier to fish movement into Aravaipa Creek from the San Pedro River during high waters was completed in 2001; this suggests that the Asian fish tapeworm was present in Aravaipa Creek before 2001. The Asian fish tapeworm was also present in headwater chub sampled at Fossil Creek, a tributary to the Verde River (Figure 1). A recent renovation in Fossil Creek included the collection of native fishes for holding while a piscicide treatment was applied to remove nonnative fishes. A barrier was installed to prevent fish in the Verde River from entering Fossil Creek, and native fishes were then returned to the stream. Headwater chub infected with the Asian fish tapeworm were collected after the renovation was completed. Presence of the Asian fish tapeworm in Leslie Canyon can probably be explained by the transport of eggs by birds, on clothing, or on sampling gear (W. Radke, personal communication).

In California, Mohave tui chub and arroyo chub have been reported as known hosts for the Asian fish tapeworm (Warburton et al. 2002). We confirmed both Mohave tui chub and arroyo chub as hosts for this parasite. Of all fish species examined, arroyo chub at Afton Canyon (an isolated pool in the Mojave River) exhibited the highest mean intensity, median intensity, and mean abundance of the Asian fish tapeworm. The Asian fish tapeworm was absent from Mohave tui chub inhabiting Lark Seep at the China Lake Naval Air Weapons Station, ponds at Camp Cady, and MC Spring at Zzyzx Springs. The Asian fish tapeworm was identified in Mohave tui chub only in Lake Tuendae at Zzyzx Springs. The first record of Asian fish tapeworm parasitism in Mohave tui chub was in 2001, when 100% ($n = 10$) of fish sampled were found to be infected. The introduction of the parasite is assumed to have been through inadvertent introduction of western mosquitofish (Warburton et al. 2002; S. Parmenter, California Department of Fish and Game, personal communication). The highest prevalence and intensity of the Asian fish tapeworm in Mohave tui chub occurred in summer and fall, whereas prevalence and intensity were highest in spring and summer for western mosquitofish in North Carolina (Granath and Esch 1983b). However, the parasite was not found in Mohave tui chub in Lake Tuendae after August 2006. The pattern of high prevalence followed by low prevalence (or absence) is consistent with observations of the Asian fish tapeworm in other fish populations (Heckmann et al. 1987).

The Asian fish tapeworm probably occurs at low prevalence in most systems containing nonnative cyprinid fishes, and the recent detections in the Laurentian Great Lakes and Canada (Choudhury et al. 2006; Marcogliese 2008) suggest that the parasite's tolerance of low temperatures is greater than previously assumed. Lack of detection of the Asian fish tapeworm in systems where nonnative warmwater cyprinids occur is probably due to a lack of sampling effort rather than to true absence of the parasite.

The Asian fish tapeworm is known to negatively affect growth, mortality, and fertility of individual fish (Scott and Grizzle 1979; Granath and Esch 1983a; Hoole and Nisan 1994; Hansen et al. 2006; Bean

2008), but effects on fish populations in the U.S. desert Southwest are unknown. We found that the Asian fish tapeworm was present in all of the major basins and several of the isolated systems we surveyed and was absent from only a few small, isolated waters. Eradication or control of the Asian fish tapeworm is probably impossible, especially in large streams. However, treating fish for endo- and exoparasites before translocations take place will prevent the further spread of nonnative fish parasites to small, isolated systems that contain rare native fishes.

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References

Andrews, C., J. Chubb, T. Coles, and A. Dearsley. 1981. The occurrence of *Bothriocephalus acheilognathi* Yamaguti, 1934 (*B. gowkongensis*) (Cestoda: Pseudophyllidea) in the British Isles. Journal of Fish Diseases 4:89–93.

Bean, M. G. 2008. Occurrence and impact of the Asian fish tapeworm *Bothriocephalus acheilognathi* in the Rio Grande (Rio Bravo del Norte). Master's thesis. Texas State University, San Marcos.

Bean, M. G., A. Škeříková, T. H. Bonner, T. Scholz, and D. G. Huffman. 2007. First record of *Bothriocephalus acheilognathi* in the Rio Grande with comparative analysis of ITS2 and V4-18S rRNA gene sequences. Journal of Aquatic Animal Health 19:71–76.

Brouder, M. J. 1999. Relationship between length of roundtail chub and infection intensity of Asian fish tapeworm *Bothriocephalus acheilognathi*. Journal of Aquatic Animal Health 11:302–304.

Brouder, M. J., and T. L. Hoffnagle. 1997. Distribution and prevalence of the Asian fish tapeworm, *Bothriocephalus acheilognathi*, in the Colorado River and tributaries, Grand Canyon, Arizona, including two new host records. Journal of the Helminthological Society of Washington 64:219–226.

Choudhury, A., E. Charipar, P. Nelson, J. R. Hodgson, S. Bonar, and R. A. Cole. 2006. Update on the distribution of the invasive Asian fish tapeworm, *Bothriocephalus acheilognathi*, in the U.S. and Canada. Comparative Parasitology 73:269–273.

Choudhury, A., T. L. Hoffnagle, and R. A. Cole. 2004. Parasites of native and nonnative fishes of the Little Colorado River, Grand Canyon, Arizona. Journal of Parasitology 90:1042–1053.

Clarkson, R. W., A. T. Robinson, and T. L. Hoffnagle. 1997. Asian tapeworm *Bothriocephalus acheilognathi* in native fishes from the Little Colorado River. Great Basin Naturalist 57:66–69.

Dove, A. D. M., and A. S. Fletcher. 2000. The distribution of the introduced tapeworm *Bothriocephalus acheilognathi* in Australian freshwater fishes. Journal of Helminthology 74:121–127.

Font, W. F., and D. C. Tate. 1994. Helminth parasites of native Hawaiian freshwater fishes: an example of extreme ecological isolation. Journal of Parasitology 80:682–688.

Granath, W. O. Jr., and G. W. Esch. 1983a. Survivorship and parasite-induced host mortality among mosquitofish in a predator-free, North Carolina cooling reservoir. American Midland Naturalist 110:314–323.

Granath, W. O. Jr., and G. W. Esch. 1983b. Temperature and other factors that the composition and infrapopulation densities of *Bothriocephalus acheilognathi* (Cestoda) in *Gambusia affinis* (Pisces). Journal of Parasitology 69:1116–1124.

Hansen, S. P., A. Choudhury, D. M. Heisey, J. A. Ahumada, T. L. Hoffnagle, and R. A. Cole. 2006. Experimental infection of the endangered bonytail chub (*Gila elegans*) with the Asian fish tapeworm (*Bothriocephalus acheilognathi*): impacts on survival, growth, and condition. Canadian Journal of Zoology 84:1383–1394.

Heckmann, R. A., J. E. Deacon, and P. D. Greger. 1986. Parasites of woundfin minnow, *Plagopterus argentissimus*, and other endemic fishes from the Virgin River, Utah. Great Basin Naturalist 46:662–676.

Heckmann, R. A., P. D. Greger, and J. E. Deacon. 1987. New host records for the Asian fish tapeworm, *Bothriocephalus acheilognathi*, in endangered fish species from the Virgin River, Utah, Nevada, and Arizona. Journal of Parasitology 73:226–227.

Heckmann, R. A., P. D. Greger, and R. C. Furtek. 1993. The Asian fish tapeworm, *Bothriocephalus acheilognathi*, in fishes from Nevada. Journal of the Helminthological Society of Washington 60:127–128.

Hoffman, G. L. 1999. Parasites of North American freshwater fishes, 2nd edition. University of Cornell Press, Ithaca, New York.

Hoole, D., and H. Nisan. 1994. Ultrastructural studies on intestinal response of carp, *Cyprinus carpio* L., to the pseudophyllidean tapeworm, *Bothriocephalus acheilognathi* Yamaguti, 1934. Journal of Fish Diseases 17:623–629.

Kuchta, R., T. Scholz, J. Brabec, and R. A. Bray. 2008. Suppression of the tapeworm order Pseudophyllidea (Platyhelminthes: Eucestoda) and the proposal of two new orders, Bothriocephalidea and Diphyllobothriidea. International Journal for Parasitology 38:49–55.

Liao, H., and L. Shih. 1956. Contribution to the biology and control of *Bothriocephalus gowkongensis* Yeh, a tapeworm parasitic in young grass carp (*Ctenopharyngodon* *idellus* C. and V.). Acta Hydrobiologica Sinica 2:129–185. (In Chinese.)

Marcogliese, D. J. 2008. First report of Asian fish tapeworm in the Great Lakes. Journal of Great Lakes Research 34:566–569.

Marcogliese, D. J., and G. W. Esch. 1989. Experimental and natural infection of planktonic and benthic copepods by Asian tapeworm, *Bothriocephalus acheilognathi*. Proceedings of the Helminthological Society of Washington 56:151–155.

Martínez-Aquino, A., and R. Aguilar-Aguilar. 2008. Helminth parasites of the pupfish *Cyprinodon meeki* (Pisces: Cyprinodontiformes), an endemic freshwater fish from north-central Mexico. Helminthologia 45:48–51.

Mitchell, A. J. 1989. Squash-plate technique for detecting Asian tapeworms in fish. Journal of Aquatic Animal Health 1:243–244.

Mitchell, A. J. 1995. Importance of treatment duration for praziquantel used against larval digenetic trematodes in sunshine bass. Journal of Aquatic Animal Health 7:327–330.

Mitchell, A. J. 2004. Effectiveness of praziquantel bath treatments against *Bothriocephalus acheilognathi* in grass carp. Journal of Aquatic Animal Health 16:130–6.

Reiczigel, J. 2003. Confidence intervals for the binomial parameter: some new considerations. Statistics in Medicine 22:611–621.

Rózsa, L., J. Reiczigel, and G. Majoros. 2000. Quantifying parasites in samples of hosts. Journal of Parasitology 86:228–232.

Salgado-Malgonado, G., and R. F. Pineda-López. 2003. The Asian fish tapeworm *Bothriocephalus acheilognathi*: a potential threat to native freshwater fish species in Mexico. Biological Invasions 5:261–268.

Scott, A. L., and J. M. Grizzle. 1979. Pathology of cyprinid fishes caused by *Bothriocephalus gowkongensis* Yeh, 1955 (Cestoda: Pseudophyllidea). Journal of Fish Diseases 2:69–73.

Warburton, M., B. Kuperman, V. Matey, and R. Fisher. 2002. Parasite analysis of native and non-native fish in the Angeles National Forest. 2001 Final Report to the U.S. Forest Service, Angeles National Forest and the U. S. Geological Survey, Western Ecological Research Center, San Diego, California.

Ward, D. L. 2007. Removal and quantification of Asian tapeworm from bonytail chub using praziquantel. North American Journal of Aquaculture 69:207–210.