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ASIAN TAPEWORM (*BOTHRIOCEPHALUS ACHEILOGNATHI*) IN NATIVE FISHES FROM THE LITTLE COLORADO RIVER, GRAND CANYON, ARIZONA

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ABSTRACT.—Examination of gastrointestinal tracts of native cyprinids from the Little Colorado River (LCR) in Grand Canyon, Arizona, 1990–1994, revealed varying rates of prevalence and infrapopulation levels of Asian tapeworm (*Bothriocephalus acheilognathi*). Mean prevalence was 28% (range 0–78%) in humpback chub (*Gila cypha*) and 8% (range 0–46%) in speckled dace (*Rhinichthys osculus*), with infrapopulations as high as 46 and 28, respectively. We also note Asian tapeworm infection of the nonnatives common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), and plains killifish (*Fundulus zebrinus*) from the LCR. Reported pathogenic and chronic effects of this cestode to its definitive hosts add concern for the status of the Grand Canyon population of the federally endangered humpback chub. The rapidity with which Asian tapeworm has spread to different drainages of the Colorado River Basin likely portends an eventual cosmopolitan basin distribution in lower elevations suitable to the parasite's thermophilic life history. Such biotic changes must be considered among the most serious threats to conservation and recovery of native fish populations.

Key words: Bothriocephalus acheilognathi, *parasitism*, Gila cypha, Rhinichthys osculus, *Little Colorado River*, *conservation*.

During this century, extinctions, extirpations, and declines of native fishes in the American Southwest have been attributed to introductions of nonindigenous fishes and physical habitat alterations (Miller 1961, Minckley and Deacon 1968, Minckley and Douglas 1991). Fish translocations also may introduce pathogens and parasites (Hoffman and Shubert 1984). Introduction and spread of Asian tapeworm (*Bothriocephalus acheilognathi*) to the Colorado River Basin provides an example of the potential effects of such parasite translocations on native fishes. This cestode was first detected from the basin in minnows from the Virgin River, Arizona, Nevada, and Utah, in 1979 (Heckmann et al. 1986). Heckmann et al. (1987, 1993) later reported it from 2 Virgin River tributaries, Beaver Dam Wash, Arizona, and Muddy River and other Nevada localities. Recently, Asian tapeworm has been reported from the Colorado River (CR) and tributaries in Grand Canyon, Arizona (Brouder and Hoffnagle in press), in the San Juan River in Utah and New Mexico (J. J. Landye, U.S. Fish and Wildlife Service, personal communication), and in the Green River in Utah (T. E. Chart, Utah Division of Wildlife Resources, personal communication).

We report Asian tapeworm temporal and numeric infection patterns in 2 native cyprinids from the Little Colorado River (LCR) in Grand Canyon, Arizona. The LCR is the major spawning and early life rearing habitat of the largest remaining population of the federally endangered humpback chub (*Gila cypha*) in the Colorado River Basin (Kaeding and Zimmerman 1983). Speckled dace (*Rhinichthys osculus*) is a geographically widespread native species that codominates the LCR fish assemblage with humpback chub. We also present tapeworm prevalence data for the nonnative cyprinids fathead minnow (*Pimephales promelas*) and common carp (*Cyprinus carpio*), and the cyprinodontid plains killifish (*Fundulus zebrinus*). We examine implications of Asian tapeworm translocation on conservation and recovery of native fishes in the Colorado River Basin.

METHODS

The LCR was sampled in 1991–1994 from the confluence with CR upstream approximately 15 km, where we collected primarily early life stage fishes for stomach content analyses. We also accessed unpublished 1989–1990 LCR data from the Arizona Game and Fish

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Department. Sampling in 1991–1994 was primarily by seine and dip net, while earlier collections also included trammel, gill, and hoop net captures of larger fish. Fish were measured to total length (mm) and preserved in 10% formalin immediately following capture. Larvae and early postlarvae were identified to species using keys of Snyder (1981) and Snyder and Muth (1990). Gastrointestinal (GI) tracts were excised in the lab, where contents were identified and enumerated when possible. Relative volumes of GI tract content categories were visually estimated. J. J. Landye of the U.S. Fish and Wildlife Service (personal communication 1991) made the initial identification of this distinctive tapeworm, and it was later confirmed using Mitchell's (1994) key.

RESULTS

The first observation of Asian tapeworm in the LCR was from 2 subadult humpback chub collected in May 1990 (Minckley 1990). None of the 24 age-1+ humpback chub (>100 mm total length), 3 age-0 juveniles (51–100 mm), 12 postlarvae (26–50 mm), and 6 larvae (<26 mm) examined from 1989 were infected. During 1990, 92.5% of age-0 (including larvae) and 44.4% of age-1+ specimens harbored tapeworms (Table 1). We did not detect Asian tapeworm in the 1991 humpback chub cohort until it approached 50 mm in total length beginning in September. Prevalence in 1992 was 48% overall, but the tapeworm was not found in larval humpback chub. We recorded the parasite in 1 of 62 early life stage humpback chub examined in 1993, and the parasite was absent from 107 larvae examined in 1994 (Table 1).

Asian tapeworm occurrence in speckled dace also was greatest in 1990 at 46%; prevalence in 1991–1993 ranged from 5% to 14% (Table 1). The cestode was absent from early life stages of speckled dace examined in 1994.

Fathead minnow harbored Asian tapeworm in 6 of 75 specimens (8%) collected between 1991 and 1994 (Table 1). Single specimens of plains killifish ($n = 21$) and common carp ($n = 4$) were found infected during this period. The parasite was not found in 480 bluehead sucker (*Pantosteus discobolus*), 71 flannelmouth sucker (*Catostomus latipinnis*), 21 channel catfish (*Ictalurus punctatus*), or 2 rainbow trout (*Oncorhynchus mykiss*) examined from 1990 to 1994.

Tapeworm infrapopulations (mean number per infected fish) in humpback chub GI tracts were 3.7 for larvae ($n = 23$), 3.5 for postlarvae ($n = 15$), 6.9 for age-0 juveniles ($n = 67$), and 10.4 for age-1+ specimens ($n = 12$). Maximum numbers observed in humpback chub were 12 in larvae, 9 in postlarvae, 44 in age-0 juveniles, and 46 in age-1+ specimens. Tapeworms accounted for a mean relative volume of GI tract contents of 51% (maximum 100%) in infected humpback chub.

Infrapopulations in speckled dace were 0.5 ($n = 2$) in larvae (<19 mm total length), 5.3 ($n = 10$) in juveniles (19–50 mm), and 3.5 ($n = 32$) in adults (>50 mm), while maximum densities were 1, 18, and 28, respectively. Relative volume of tapeworms in infected speckled dace averaged 38%. Tapeworm infrapopulations were 2 ($n = 6$; 6 maximum) in fathead minnow (17% relative volume), 3 ($n = 1$) in common carp (<1% relative volume), and 7 ($n = 1$) in plains killifish (100% relative volume).

DISCUSSION

Seasonal (or ontogenctic) and annual differences in prevalence of Asian tapeworm in humpback chub and speckled dace presumably reflect complex interactions among environmental conditions and intermediate (cyclopoid copepod) and definitive host populations (Granath and Esch 1983a, 1983b, Riggs and Esch 1987, Marcogliese and Esch 1989). Infrapopulation dynamics of the parasite may be related to temperature, temperature-dependent rejection responses, immune responses, host distributions, density-dependent factors, or other poorly studied phenomena (Granath and Esch 1983a).

Pathological effects of Asian tapeworm on fish hosts may include intestinal abrasion and disintegration, loss or separation of gut microvilli and enterocytes (Hoole and Nisan 1994), or blockage and perforation of the GI tract (Hoffman 1980, Mitchell 1994). Chronic effects are not well studied but may include the following: emaciation and anemia (Scott and Grizzle 1979); decreases in intestinal, liver, and pancreatic enzymes (Hoole 1994); reduced growth and reproductive capacity, depressed swimming ability via elevated muscle fatigue, and other debilitating influences (Heckmann et al. 1986, Hoole 1994). Weakened fish may develop secondary bacterial infections (Mitchell

TABLE 1. Percent frequency of occurrence (sample size in parentheses) of Asian tapeworm (*Bothriocephalus acheilognathi*) in gastrointestinal tracts of fishes from the lower Little Colorado River, Arizona, 1990–1994. With the exception of larvae, age/stage designations are approximate. Dashes indicate no fish specimens were collected.

	Year				
Species and length	1990	1991	1992	1993	1994
HUMPBACK CHUB					
larvae (≤25 mm)	91.7 (24)	0 (50)	0 (28)	1.8 (56)	0 (107)
postlarvae (26–50 mm)	100 (13)	3.0 (33)	100 (1)	0 (6)	—
older age-0 (51–100 mm)	66.7 (3)	81.2 (32)	67.2 (58)	—	—
age-1+ (>100 mm)	44.4 (18)	37.5 (8)	66.7 (12)	100 (1)	—
SPECKLED DACE					
larvae (≤18 mm)	0 (1)	0 (128)	3.0 (33)	2.8 (36)	0 (95)
juveniles (19–50 mm)	60.0 (10)	4.0 (50)	26.7 (30)	0 (15)	0 (1)
adults (>50 mm)	0 (2)	17.7 (79)	14.4 (111)	50.0 (4)	—
FATHEAD MINNOW					
larvae (≤18 mm)	—	—	0 (4)	—	—
juveniles (19–50 mm)	—	0 (3)	6.9 (29)	0 (4)	0 (3)
adults (>50 mm)	—	0 (2)	8.7 (23)	—	33.3 (6)
COMMON CARP					
juveniles (51–100 mm)	—	—	25.0 (4)	—	—
PLAINS KILLIFISH					
larvae (≤18 mm)	0 (2)	—	—	—	—
juveniles (19–50 mm)	0 (5)	50.0 (2)	0 (8)	—	—
adults (>50 mm)	—	0 (1)	0 (3)	—	—

1994). Granath and Esch (1983c) showed that Asian tapeworm significantly reduced laboratory survivorship of mosquitofish (*Gambusia affinis*) compared to controls, but cautioned that these effects would not necessarily be exhibited in the wild.

More research is needed to determine exact effects of this parasite on native fish populations in Grand Canyon and elsewhere, but clearly Asian tapeworm has the potential to regulate fish populations. The observed patterns of Asian tapeworm prevalence and infrapopulations in humpback chub and speckled dace in the LCR may arise from (1) mortality of hosts with high infrapopulations, (2) density-dependent mortality of parasites, and (3) acquired host resistance to reinfection (Anderson 1982). The fact that our study area is the humpback chub's only major spawning and early life rearing site in Grand Canyon adds concern for the status of this population.

Since its initial detection in the Virgin River in 1979, the rapidity with which Asian tapeworm has spread to different drainages of the Colorado River Basin likely portends an eventual cosmopolitan basin distribution in lower elevations suitable to the parasite's thermophilic life history. Roughly half of the native ichthyofauna in this geographic range comprises cyprinids (Asian tapeworm's most common hosts), with most of those already endangered, threatened, or of special concern. The endangered poeciliid Gila topminnow (*Poeciliopsis o. occidentalis*) of the Gila River subbasin may be vulnerable to this parasite. Because biotic changes to the Colorado River Basin resulting from fish and pathogen translocations are virtually ubiquitous and seemingly irreversible, they must be considered among the most serious threats to conservation and recovery of native fish populations.

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