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SHORT COMMUNICATION

Occurrence of *Camallanus cotti* in greatly diverse fish species from Danjiangkou Reservoir in central China

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Abstract Two thousand four hundred fifty-eight fish comprised of 53 species were captured in the Danjiangkou Reservoir, in the northwestern part of Hubei Province, central China during 2004, to examine *Camallanus cotti* infections. We found that 19 cypriniform, 3 siluriforme, and 4 perciforme fishes were infected by the nematode. Our study revealed the species, *Hemiculter bleekeri bleekeri*, *Culter oxycephaloide*, *Pseudolaubuca sinensis*, *Acanthobrama simony*, *Mylopharyngodon piceus*, *Ctenopharyngodon idella*, *Gnathopogon imberbis*, *G. argentatus*, *Saurogobio dabryi*, *S. dumerili*, *Gobiobotia ichangensis*, *Liobagrus marginatoides*, and *Ctenogobius shennongensis* as new hosts of the worm. The number and range of fish host species found in this survey were much greater than any of the previous investigations. The mean prevalence, prevalence, mean abundance, and intensity of infection varied in different fish species, indicating a possible host preference. Moreover, we suggest that this nematode is a native parasite of cypriniform fishes in China, perhaps initially in the reaches of the Yangtze River.

The parasitic nematode *Camallanus cotti* Fujita, 1927, originally reported from the freshwater fishes of Japan, has been considered a native parasite of Asia (Levsen and Berland 2002). However, along with the extensive trade of ornamental fishes and the introduction of various poeciliids for mosquito control, the worm has since been spread to aquarium fishes in North America (Hoffman and Schubert 1984), Europe (McMinn 1990), and Australia (Evans and Lester 2001), as well as to both aquarium-cultured and wild fishes in Hawai'i (Font and Tate 1994; Vincent and Font 2003). In the wild, the definitive host fish acquires this nematode by ingesting cyclopoid copepods carrying the infectious third-stage larvae (Levsen and Berland 2002). While under aquarium culture conditions, this nematode can also carry out a direct life cycle without the intermediate host (Stumpp 1975; Levsen and Jakobsen 2002). Nematode parasites are important pathogens that can result in evident pathological symptoms to their fish hosts, e.g., *Philometroides fulvidraconi* in the bullhead catfish, *Pseudobagrus fulvidraco* (Richardson) (Wang 2002). *C. cotti* attaches itself to the wall of the gastrointestinal tract of fish hosts by its buccal capsule, feeding on host blood or tissue fluid. This infection can cause rectal inflammation, subsequent anemia, emaciation, and occasionally even death of the fish, especially in small fish (Stumpp 1975). It may influence the sexual behaviors of the hosts as well (McMinn 1990). Considering its cosmopolitan dispersal and pathogenicity to autochthonal fishes, this nematode has garnered much attention. However, our understanding, especially of its distribution and influence on cypriniform fish species (its typical hosts), is insufficient. Cypriniform fishes are predominant freshwater species in China, making up 76% of fish species in this country (Li 1981). During recent investigations on the fauna of freshwater fish parasites in the Danjiangkou

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Reservoir, infections with *C. cotti* have been observed in 26 out of 53 fish species examined; the majority being cypriniform fishes. The studies presented here are a survey of the occurrence of *C. cotti* infection in the Danjiangkou Reservoir conducted in 2004.

The Danjiangkou Reservoir (32°25′–33°15′N; 110°7′–111°6′E), the largest reservoir in Asia, is located in the northwest of Hubei Province, central China. The reservoir, which is joined to the Yangtze River by its biggest tributary, the Hanjiang River, is built on the convergent flow of the Hanjiang and Danjiang rivers. The reservoir covers about 8 million km², with a volume of 17.4 billion m³.

Fish were netted from the reservoir or the connected river during the period of February to December 2004. In

total, 2458 fish of 53 species were obtained in five samples. The fish were transported on ice to the laboratory, where they were stored at 4°C till examination within 48 h of capture. Intestines of the fish were harvested and observed under a dissecting microscope by pressing the intestinal matter between two glass slides. Worms were identified according to the descriptions of Moravec et al. (2003). Numbers of *C. cotti* examined in each individual fish were recorded.

In total, 26 fish species, belonging to 22 genera, 8 families, and 3 orders (19 Cypriniformes, 3 Siluriformes, and 4 Perciformes), were found to be infected by *C. cotti* (Table 1). *Hypseleotris swinhonis* (Günther) was found as the host in an additional sample taken in 2005, thus, it is not included in the list in Table 1. Among these fish,

Table 1 Prevalence (P, %), intensity (I), mean prevalence, and mean abundance of *Camallanus cotti* in different fish host species in the Danjiangkou Reservoir, China

Host species	Order	February		May		August		October		December		Mean prevalence (%)	Mean abundance
		P (%)	I	P (%)	I	P (%)	I	P (%)	I	P (%)	I		
<i>Acanthorhodeus taenianalis</i>	Cypriniformes	10(20)	1	–	–	–	–	0(10)	0	–	–	6.7(30)	0.067
<i>Gobiobotia ichangensis</i>	Cypriniformes	–	–	–	–	–	–	45(20)	1–4	–	–	45(20)	0.85
<i>Saurogobio dabryi</i>	Cypriniformes	–	–	12.5(8)	1	0(5)	0	0(10)	0	–	–	4.3(23)	0.043
<i>S. dumerili</i>	Cypriniformes	–	–	15.4(13)	2	–	–	–	–	–	–	15.4(13)	0.31
<i>Gnathopogon imberbis</i>	Cypriniformes	5(20)	1	0(20)	0	0(14)	0	0(22)	0	6.7(30)	1	2.8(106)	0.028
<i>G. argentatus</i>	Cypriniformes	0(5)	0	66.7(3)	1–2	4.8(21)	1	0(23)	0	17.4(23)	1–4	9.3(75)	0.13
<i>Zacco platypus</i>	Cypriniformes	9.1(22)	1–2	9.5(21)	1–2	8.6(35)	1–3	7.4(27)	1	12.5(32)	1–2	9.5(137)	0.13
<i>Opsariichthys bidens</i>	Cypriniformes	50(22)	1–6	18.2(22)	1	32.1(53)	1–6	26.8(56)	1–6	26(50)	1–10	29.6(203)	0.65
<i>Ctenopharyngodon idellus</i>	Cypriniformes	0(3)	0	100(1)	2	0(2)	0	0(2)	0	0(4)	0	8.3(12)	0.17
<i>Mylopharyngodon piceus</i>	Cypriniformes	16.7(6)	2	0(1)	0	0(4)	0	0(2)	0	–	–	7.7(13)	0.15
<i>Squaliobarbus curriculus</i>	Cypriniformes	7.1(14)	1	0(2)	0	30(10)	2–5	30(20)	1–2	50(20)	1–5	30.3(66)	0.63
<i>Elopichthys bambusa</i>	Cypriniformes	22.2(9)	1	0(1)	0	–	–	19(21)	1–2	20(20)	1–2	19.6(51)	0.24
<i>Acanthobrama simoni</i>	Cypriniformes	–	–	0(20)	0	7.7(39)	1–2	0(20)	0	–	–	3.8(79)	0.051
<i>Pseudolaubuca sinensis</i>	Cypriniformes	0(20)	0	0(22)	0	16.1(56)	1–33	10(20)	1	15(20)	1	10.1(138)	0.35
<i>Hemiculter bleekeri bleekeri</i>	Cypriniformes	0(20)	0	4.2(24)	1	0(21)	0	0(20)	0	0(30)	0	0.87(115)	0.0087
<i>Culter erythropterus</i>	Cypriniformes	12.5(8)	1	0(2)	0	–	–	4.8(21)	1	–	–	6.5(31)	0.065
<i>Erythroculter oxycephaloides</i>	Cypriniformes	33.3(3)	6	–	–	–	–	–	–	–	–	33.3(3)	2
<i>Erythroculter ilishaeformis</i>	Cypriniformes	6.7(15)	1	10(20)	1	25(20)	1–3	10(20)	1–2	19(21)	1–13	14.6(96)	0.385
<i>Erythroculter mongolicus</i>	Cypriniformes	0(27)	0	8.3(24)	1–5	28.6(63)	1–6	35(20)	1	0(20)	0	17.5(154)	0.32
<i>Silurus asotus</i>	Siluriformes	33.3(15)	1–2	14.3(21)	1–2	10.5(19)	1	0(13)	0	15(20)	1–2	14.8(88)	0.2
<i>Liobagrus marginatoides</i>	Siluriformes	0(12)	0	0(20)	0	0(25)	0	0(3)	0	25(4)	2	1.6(64)	0.031
<i>Pelteobagrus fulvidraco</i>	Siluriformes	0(21)	0	10(20)	1	0(23)	0	0(20)	0	0(31)	0	1.7(115)	0.017
<i>Siniperca chuatsi</i>	Perciformes	0(7)	0	0(2)	0	0(20)	0	9.5(21)	1	–	–	4(50)	0.04
<i>Ophiocephalus argus</i>	Perciformes	0(5)	0	16.7(12)	1–4	0(13)	0	20(5)	1	18.2(11)	1	10.9(46)	0.17
<i>Ctenogobius shennongensis</i>	Perciformes	–	–	–	–	15(20)	1–6	20(5)	1	–	–	16(25)	0.44

Numbers in parentheses represent sample size.

(–) no data obtained

Hemiculter bleekeri bleekeri Warpachowsky, *Erythroculter oxycephaloides* (Kreyenberg et Pappenheim), *Pseudolabruca sinensis* Bleeker, *Acanthobrama simoni* Bleeker, *Mylopharyngodon piceus* (Richardson), *Ctenopharyngodon idellus* (Cuvier et Valenciennes), *Gnathopogon imberbis* (Sauvage et Dabry), *G. argentatus* (Sauvage et Dabry), *Saurogobio dabryi* Bleeker, *S. dumerili* Bleeker, *Gobiobotia ichangensis* Fang, *Liobagrus marginatoides* (Wu), and *Ctenogobius shennongensis* Yang et Xie represented new host records of the nematode.

Interestingly, the mean prevalence of *C. cotti* infection in each fish species varied greatly, from 0.87% in *H. bleekeri bleekeri* to 45% in *G. ichangensis*. Generally, the mean prevalence was about 10%, although it ranged from 29.6% in *Opsariichthys bidens* Günther and 30.3% in *Squaliobarbus curriculus* (Richardson) in relatively frequently, and 1.6% in *L. marginatoides* and 1.7% in *P. fulvidraco* in relatively infrequently. To reveal the effect of season on nematode prevalence, we graphed the observed prevalence over time for those fish that were sampled during all five sampling events, with the 95% confidence intervals including continuity correction (Fig. 1). It showed that the prevalence was relatively low in February and May. The prevalence reached its peak in August. Thereafter, it declined, but remained high in October and December.

The mean abundance in different species of fish was less than 1, from the lowest 0.0087 in *H. bleekeri bleekeri* to the highest 0.85 in *G. ichangensis*, with only one exception *E. oxycephaloides* (three fish examined) where it was 2. The highest intensities reached were 10, 13, and 33 in *O. bidens* and *Erythroculter ilishaeformis* (Bleeker) in December, and in *P. sinensis* in August, respectively. However, most intensities were not more than 6.

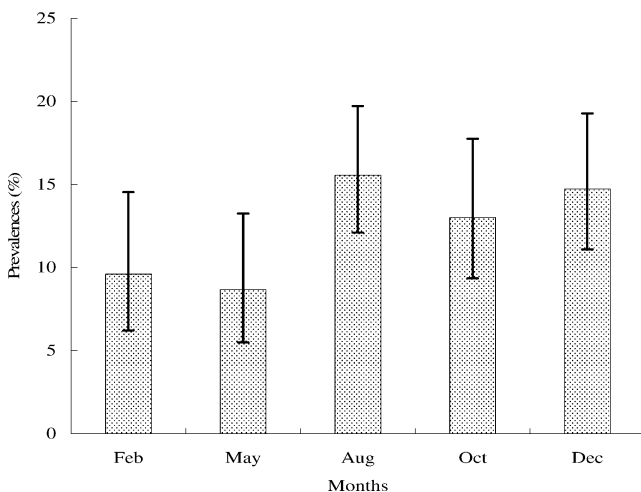


Fig. 1 Temporal variation in prevalence of *C. cotti* in those fish that were sampled during all five sampling events in Danjiangkou Reservoir in the year 2004. Bars represent the 95% confidence intervals including continuity correction

Distribution of *C. cotti* in greatly diverse fish species might reflect high adaptation of the parasite to different hosts. However, its mean prevalence, prevalence, mean abundance, and intensity of infection varied in different fish species, indicating a possible host preference.

C. cotti has previously been reported in many fish species in different field investigations by several authors (e.g., Dogiel and Akhmerov 1959; Wang et al. 1983, 1987, 1997; Wang 1985; Wu et al. 1991). However, each of these investigations within a certain region found only a few fish species that served as the hosts of the nematode. For example, nine fish host species from three families were found in the Amur River on the boundary of China and Russia (Dogiel and Akhmerov 1959), four fish hosts from one family in Hongze Lake in Jiangsu Province (Wang et al. 1983), three fish hosts from three families in Poyang Lake in Jiangxi Province (Wang 1985), five fish hosts from three families in Three Gorges of the Yangtze River (Wang et al. 1987), and seven fish hosts from four families in Bao'an Lake in Hubei Province (Wu et al. 1991). In the present survey, 26 fish species from eight families were found to be hosts of the parasite. The number and range of fish host species here numbered far more than any of the previous investigations. This phenomenon is probably not entirely due to the extent of investigation. It may also reflect the active evolution and adaptation of the parasite to its current geographic locality and water environment. However, this intriguing phenomenon needs to be clarified by further investigation and phylogenetic studies.

C. cotti exhibits a complex life cycle. Under natural conditions, an intermediate host (cyclopoid copepod) is considered essential for completion of its life cycle (Levsen and Berland 2002). Previous studies have revealed that parasites with complex life cycles involving intermediate hosts are more vulnerable in new environments than those with direct life cycles (Pérez-Ponce de León et al. 2000). Although *C. cotti* was found in many other areas outside Asia, the only report of this nematode in autochthonous freshwater fishes in natural conditions came from the island of O'ahu in Hawai'i, and the infection level there was low (Font and Tate 1994). Such facts agree with Levsen and Berland (2002) and Moravec et al. (2003) who suggested that *C. cotti* is an exotic species outside Asia. However, many studies have demonstrated that *C. cotti* can infect and develop directly in the definitive fish host when the intermediate hosts are absent, such as under aquarium conditions (Stumpff 1975; McMinn 1990; Levsen 2001; Levsen and Jakobsen 2002). This is perhaps the reason why this parasite has thrived in many ornamental fishes in aquaria worldwide. On the other hand, this nematode has also been frequently reported in different fish species in various regions throughout Asia, particularly from the

cypriniform fishes in the reaches of the Yangtze River in China (e.g., Dogiel and Akhmerov 1959; Wang et al. 1983, 1987, 1997; Wang 1985; Wu et al. 1991; Moravec et al. 2003). Our present study and previous researches have observed the occurrence of *C. cotti* within a wide variety of host species (especially cypriniform fishes) at relatively high infection levels; thus suggesting that this nematode was likely a native parasite of cypriniform fishes in China, and perhaps initially within the reaches of the Yangtze River.

The seasonality of *C. cotti* was previously reported in the largefin longbarbel catfish, *Mystus macropterus* (Bleeker), in the upper reaches of the Yangtze River, and in exotic poeciliids in the Waianu stream, O'ahu, Hawai'i, based on some limited field data (Zhang 1993; Vincent and Font 2003). These significant seasonal changes in the prevalence and mean abundance showed a high trend in the late summer and/or autumn to a low point in the spring and/or winter. However, we failed to identify any previous reports on seasonality in cypriniform fishes (the typical hosts). To understand the seasonality of *C. cotti* in cypriniform fishes in its native region, we designed our study to take observations by monthly survey in the Danjiangkou Reservoir.

It was demonstrated by Poulin (1997) that hosts that are close phylogenetically should have similar parasite fauna and share some species with each other. However, in our present study, *Zacco platypus* (Temminck et Schlegel) and *O. bidens*, species that are very close not only morphologically but also behaviorally and both belonging to the subfamily Danioninae, displayed remarkable differences in infection with *C. cotti*. *O. bidens* suffered much higher prevalence and intensity than *Z. platypus*. Regarding this phenomenon, our hypothesis is that relative specialist parasites with close kindred always share closely phylogenetic hosts, e.g., specialist louse species with consanguinity parasitize closely related pocket gophers (Page 1994); while parasites that are relative generalists may infect a broader host range, e.g., the generalist cestode *Bothriocephalus acheilognathi* infects a large spectrum of different teleost fishes without significant phylogenetic relationship. In this scenario, the infection levels of generalist parasites in different fish species are probably determined mainly by the distribution of the intermediate hosts, fish behavior and dietary habits, host immune response, and other water environmental factors, rather than the phylogenetic relationship of the hosts.

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