

Prevalence of *Clonorchis sinensis* Metacercariae in Freshwater Fish from Three Latitudinal Regions of the Korean Peninsula

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Abstract: A large-scale survey was conducted to investigate the infection status of fresh water fishes with *Clonorchis sinensis* metacercariae (CsMc) in 3 wide regions, which were tentatively divided by latitudinal levels of the Korean peninsula. A total of 4,071 freshwater fishes were collected from 3 regions, i.e., northern (Gangwon-do: 1,543 fish), middle (Chungcheongbuk-do and Gyeongsangbuk-do: 1,167 fish), and southern areas (Jeollanam-do, Ulsan-si, and Gyeongsangnam-do: 1,361 fish). Each fish was examined by the artificial digestion method from 2003 to 2010. In northern areas, only 11 (0.7%) fish of 2 species, *Pungtungia herzi* and *Squalidus japonicus coreanus* from Hantan-gang, Cheolwon-gun, Gangwon-do were infected with av. 2.6 CsMc. In middle areas, 149 (12.8%) fish were infected with av. 164 CsMc. In southern areas, 538 (39.5%) fish were infected with av. 159 CsMc. In the analysis of endemicity in 3 regions with an index fish, *P. herzi*, 9 (6.2%) of 146 *P. herzi* from northern areas were infected with av. 2.8 CsMc. In middle areas, 34 (31.8%) of 107 *P. herzi* were infected with av. 215 CsMc, and in southern areas, 158 (92.9%) of 170 *P. herzi* were infected with av. 409 CsMc. From these results, it has been confirmed that the infection status of fish with CsMc is obviously different among the 3 latitudinal regions of the Korean peninsula with higher prevalence and burden in southern regions.

Key words: *Clonorchis sinensis*, metacercaria, freshwater fish, prevalence, latitudinal level

INTRODUCTION

Recent trends of helminthic infections in the Republic of Korea are characterized by a remarkable decrease of soil-transmitted nematodiasis and moderate endemicity of foodborne trematode (FBT) infections. Among FBT infections prevailing in the Republic of Korea, clonorchiasis has been known as the most important endemic disease, and its endemicity has maintained at relatively high levels in riverside areas [1-6]. Especially, in 1981, Seo et al. [1] reported prevalence rates of clonorchiasis among the residents in 7 major rivers, Nakdong-gang (River) (40.2%), Youngsan-gang (30.8%), Seomjin-gang (17.3%),

Tamjin-gang (15.9%), Han-gang (15.7%), Gum-gang (12.0%), and Mangyeong-gang (8.0%). In 2008, Cho et al. [5] reported the egg positive rates of residents living in 4 river basins, Nakdong-gang (17.1%), Seomjin-gang (11.2%), Youngsan-gang (5.5%), and Gum-gang (4.6%), located in southern parts of Korea. Although the Korea Association of Health Promotion (KAHP) and the Korea Center for Disease Control and Prevention (KCDCP) have been performing control programmes of clonorchiasis for more than 20 years, clonorchiasis is still prevalent throughout the country [3,6].

Clonorchiasis is contracted by eating raw or undercooked fish intermediate hosts containing the metacercariae of *C. sinensis*. As the second intermediate hosts of *C. sinensis*, total 40 species of freshwater fishes have been reported in Korea [2,7]. Among them, some species, such as *Pseudorasbora parva*, *Pungtungia herzi*, *Sarcocheilichthys* spp., *Squalidus* spp., and *Pseudogobio esocinus*, have been known as the more susceptible hosts to cercariae, and they have sometimes enormous amount of

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metacercariae [8-12].

On the other hand, the survey on the infection status of FBT metacercariae in intermediate hosts is one of the important epidemiological indices together with surveys on adult worm infections in the definitive and reservoir hosts. Many Korean workers have investigated the infection status of *C. sinensis* metacercariae (CsMc) in fishes from various endemic areas to estimate the endemicity of clonorchiasis [8,9,11-17]. Especially, Kim et al. [12] investigated 677 freshwater fish of 21 species to know the current infection status with CsMc in Korea. However, large-scale surveys have not been conducted to compare the prevalence and density of CsMc in freshwater fishes collected by different latitudinal levels of the Korean peninsula. Therefore, in the present study, we investigated on the infection status of CsMc in freshwater fish from 3 wide regions, which were tentatively divided by the latitudinal levels of the Korean peninsula.

MATERIALS AND METHODS

Surveyed areas

Surveyed areas were largely divided into 3 latitudinal regions of the Korean peninsula (Fig. 1). The northern area was comprised of 7 administrative regions of Gangwon-do, ① Inje-gun, ② Hongcheon-gun, ③ Cheolwon-gun, ④ Yanggu-gun, ⑤ Yangyang-gun, ⑥ Youngweol-gun, and ⑦ Samcheok-si, which are located over 37° North Latitude. The middle area contained 10 regions of Chungcheongbuk-do (⑧ Gum-gang in Okcheon-gun, ⑨ Cheong-cheon in Goisan-gun, and ⑩ Daecheong-ho), and Gyeongsangbuk-do (⑪ Ahndong-si, ⑫ Sangju-si, ⑬ Bonghwa-gun, ⑭ Yecheon-gun, ⑮ Youngyang-gun, ⑯ Youngdeok-gun, and ⑰ Gunwi-gun), which are located between 36° and 37° North Latitude. The southern area was comprised of 8 administrative regions of Jeollanam-do (⑱ Gokseong-gun, ⑲ Gurye-gun, ⑳ Naju-si, ㉑ Gangjin-gun, ㉒ Jangheung-gun, and ㉓ Boseong-gun), Ulsan Metropolitan City (㉔ Taehwa-gang) and Gyeongsangnam-do (㉕ Sancheong-gun), which are located below 36° North Latitude.

Freshwater fishes examined

In western parts of Gangwon-do, we collected 678 freshwater fishes (36 species) from 4 localities, Soyang-gang (Inje-gun in October 2003 and April 2004), Hongcheon-gang (Hongcheon-gun in October 2003, and July and October 2010), Hantan-gang (Cheolwon-gun in April 2005 and October 2010),

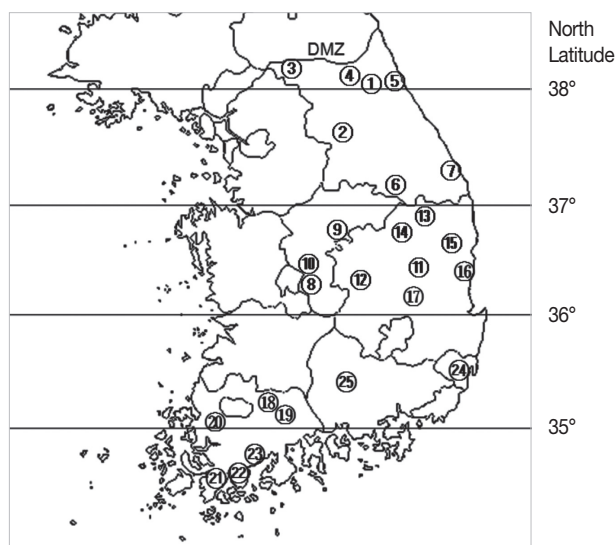


Fig. 1. The surveyed areas. The northern area located over 37° North Latitude is comprised of 7 administrative regions of Gangwon-do (① Inje-gun: Soyang-gang, ② Hongcheon-gun: Hongcheon-gang, ③ Cheolwon-gun: Hantan-gang and Hwa-gang, ④ Yanggu-gun: Sooip-cheon, ⑤ Yangyang-gun: Namdae-cheon, ⑥ Youngweol-gun: Dong-gang and ⑦ Samcheok-si: Osip-cheon and Gagok-cheon). The middle area located between 36° and 37° North Latitude is contained 3 regions of Chungcheongbuk-do (⑧ Okcheon-gun: Gum-gang, ⑨ Goisan-gun: Cheong-cheon and ⑩ Daecheong-ho), and 7 regions of Nakdong-gang (⑪ Ahndong-si, ⑫ Sangju-si, ⑬ Bonghwa-gun, ⑭ Yecheon-gun, ⑮ Youngyang-gun, ⑯ Youngdeok-gun and ⑰ Gunwi-gun) in Gyeongsangbuk-do. The southern area located below 36° North Latitude is comprised of 6 administrative regions of Jeollanam-do (⑱ Gokseong-gun: Seomjin-gang, ⑲ Gurye-gun: Seomjin-gang, ⑳ Naju-si: Youngsan-gang, ㉑ Gangjin-gun: Tamjin-gang, ㉒ Jangheung-gun: Tamjin-gang and ㉓ Boseong-gun: Boseong-gang), and ㉔ Ulsan Metropolitan City (Taehwa-gang) and ㉕ Sancheong-gun (Yangcheon-gang) in Gyeongsangnam-do.

and Hwa-gang (Cheolwon-gun in June 2010) in Gangwon-do. We also collected 865 fishes (32 species) from 5 localities of eastern parts of Gangwon-do, Sooip-cheon (Yanggu-gun), Namdae-cheon (Yangyang-gun), Dong-gang (Youngweol-gun), Osip-cheon, and Gagok-cheon (Samcheok-si) 2 times in June and October 2009. The numbers and species of fish examined are shown in Tables 1 and 2.

In middle regions, a total of 451 fishes (32 species) were collected from 3 sites, Gum-gang (Okcheon-gun in April and September 2006), Cheong-cheon (stream in Goisan-gun on June 2003) and Daecheong-ho (Lake, on June 2003), located in Chungcheongbuk-do. The numbers and species of fish examined are shown in Table 3. To investigate the infection status of CsMc in fishes from the upper reaches of Nakdong-gang, we collected total 716 freshwater fishes (35 species) from 7 locali-

Table 1. Fishes^a collected from northern regions (Gangwon-do), Korea

Species of fish	No. of fish collected from 6 localities ^b						Total
	①	②-1	②-2	③-1	③-2	③-3	
Cypriniforms							
<i>Zacco platypus</i>	40	10	20	16	30	3	119
<i>Pungtungia herzi</i>	14	20	25	8	7	13	87
<i>Zacco temminckii</i>	6	-	16	19	30	10	81
<i>Hemibarbus longirostris</i>	5	-	20	14	3	12	54
<i>Pseudogobio esocinus</i>	10	1	23	5	8	3	50
<i>Coreoleuciscus splendidus</i>	5	3	18	19	-	2	47
<i>Microphysogobio longidorsalis</i>	-	-	20	4	-	8	32
<i>Carassius auratus</i>	6	-	2	2	3	5	18
<i>Acheilognathus signifer</i>	-	10	-	-	-	4	14
<i>Hemibarbus labeo</i>	10	-	1	2	-	-	13
<i>Acheilognathus majusculus</i>	-	-	6	-	6	-	12
<i>Cyprinus capio</i>	5	-	-	-	-	-	5
<i>Acheilognathus yamatsutae</i>	-	-	-	5	-	-	5
<i>Acheilognathus rhombeus</i>	-	-	-	-	5	-	5
<i>Opsariichthys uncirostris</i>	3	-	2	-	-	-	5
<i>Pseudopungtungia tenuicorpa</i>	1	3	-	-	-	-	4
<i>Pseudobagrus fulvidraco</i>	-	-	-	4	-	-	4
<i>Hemibarbus mylodon</i>	-	-	-	1	3	-	4
<i>Acanthorhodeus gracilis</i>	-	-	-	3	-	-	3
<i>Acheilognathus lanceolatus</i>	-	-	-	-	1	2	3
<i>Hemiculter leucisculus</i>	3	-	-	-	-	-	3
<i>Koreocobitis rotundicaudata</i>	-	-	-	3	-	-	3
<i>Orthrias toni</i>	-	3	-	-	-	-	3
<i>Rhynchocypris steidachneri</i>	-	-	-	-	3	-	3
<i>Rhynchocypris oxycephalus</i>	-	-	-	2	-	-	2
<i>Squalidus japonicus coreanus</i>	-	-	-	-	2	-	2
<i>Sarcocheilichthys nigripinnis</i>	-	-	-	-	1	-	1
<i>Microphysogobio jeoi</i>	-	-	-	-	1	-	1
<i>Abbottina springeri</i>	1	-	-	-	-	-	1
<i>Abbotina revulais</i>	-	1	-	-	-	-	1
Siluriformes							
<i>Liobagrus andersoni</i>	4	10	-	-	-	-	14
<i>Leiocassis ussuriensis</i>	3	-	-	-	-	-	3
Perciformes							
<i>Coreoperca herzi</i>	-	15	20	3	5	7	50
<i>Siniperca scherzeri</i>	7	-	11	-	-	-	18
<i>Odontobutis platycephala</i>	-	6	2	-	-	-	8
Total	123	82	186	110	108	69	678

^aTotal 678 freshwater fishes of 36 species were examined. ^b① Inje-gun (Soyang-gang); ②-1 Hongcheon-gun (Hongcheon-gang, 2003); ②-2 Hongcheon-gun (Hongcheon-gang, 2010); ③-1 Cheolwon-gun (Hantan-gang, 2005); ③-2 Cheolwon-gun (Hantan-gang, 2010); ③-3 Cheolwon-gun (Hwagang, 2010).

ties, Ahndong-si, Sangju-si, Bonghwa-gun, Yecheon-gun, Youngyang-gun, Youngdeok-gun and Gunwi-gun, Gyeongsangbuk-do in October and November, 2008 (Table 4).

In western parts of southern localities, 452 freshwater fishes (35 species) were collected from 6 localities, Seomjin-gang (Gokseong-gun in September 2004 and May 2005) (Gurye-gun in September 2004), Youngsan-gang (Naju-si in October

2005), Tamjin-gang (Gangjin-gun and Jangheung-gun, in October 2005) and Boseong-gang (Boseong-gun in October 2005), in Jeollanam-do. The numbers and species of fish examined are shown in Table 5. In eastern parts, we also collected 909 freshwater fishes (24 species) from Taehwa-gang (Ulsan Metropolitan City in April and September 2006) and Yangcheon-gang (Sancheong-gun in each October of 2006 and 2007, June

Table 2. Fishes^a collected from northern regions (Gangwon-do), Korea (2009)

Species of fish	No. of fish collected from 5 localities ^b					Total
	④	⑤	⑥	⑦-1	⑦-2	
Cypriniforms						
<i>Zacco platypus</i>	26	30	30	23	19	128
<i>Zacco temminckii</i>	23	30	30	-	20	103
<i>Coreoleuciscus splendidus</i>	27	-	30	30	8	95
<i>Pungtungia herzi</i>	11	15	16	-	17	59
<i>Tribolodon hakonensis</i>	-	30	-	21	-	51
<i>Microphysogobio longidorsalis</i>	25	-	25	-	-	50
<i>Rhynchocypris oxycephalus</i>	10	3	-	1	25	39
<i>Hemibarbus longirostris</i>	14	-	16	-	-	30
<i>Pseudogobio esocinus</i>	11	-	10	-	-	21
<i>Gobiobotia brevibarba</i>	-	-	18	-	-	18
<i>Carassius auratus</i>	14	2	-	-	-	16
<i>Hemibarbus labeo</i>	-	-	13	-	-	13
<i>Koreocobitis rotundicaudata</i>	-	-	13	-	-	13
<i>Hemibarbus mylodon</i>	2	-	10	-	-	12
<i>Acanthorhodeus macropterus</i>	-	-	10	-	-	10
<i>Orthrias toni</i>	-	-	-	8	-	8
<i>Opsariichthys uncirostris</i>	5	-	-	-	-	5
<i>Misgurnus mizolepis</i>	-	-	5	-	-	5
<i>Ladislavia taczanowskii</i>	-	-	-	3	-	3
<i>Gobiobotia macrocephala</i>	-	-	3	-	-	3
<i>Iksookimia koreensis</i>	-	-	2	-	-	2
<i>Cyprinus capio</i>	1	-	-	-	-	1
<i>Pseudobagrus fulvidraco</i>	-	-	1	-	-	1
Osmeriformes						
<i>Plecoglossus altivelis</i>	-	25	-	29	-	54
Salmoniformes						
<i>Onchorhynchus masou masou</i>	-	5	-	2	3	10
Siluriformes						
<i>Liobagrus andersoni</i>	10	-	3	-	-	13
<i>Silurus asotus</i>	-	-	1	-	-	1
Perciformes						
<i>Coreoperca herzi</i>	17	10	15	-	-	42
<i>Chaenogobius urotaenia</i>	-	-	-	19	8	27
<i>Tridentiger brevispinis</i>	-	-	-	15	9	24
<i>Rhinogobius giurinus</i>	-	-	-	4	-	4
<i>Acanthogobius pflaumi</i>	-	4	-	-	-	4
Total	196	154	251	155	109	865

^aTotal 865 freshwater fishes of 32 species were examined. ^b5 localities, ④ Yanggu-gun (Sooip-cheon); ⑤ Yangyang-gun (Namdae-cheon); ⑥ Youngweol-gun (Dong-gang); ⑦-1 Samcheok-si (Osip-cheon); ⑦-2 Samcheok-si (Gagok-cheon).

and July 2010) in Gyeongsangnam-do (Table 6).

Examination methods

All collected fishes with ice were transferred to the laboratory of the Department of Parasitology, Gyeongsang National University School of Medicine, Jinju, Korea. After identification of fish species [18], they were individually ground with a mortar with a pestle or a grinder. Each ground fish meat was

mixed with artificial gastric juice and the mixture was incubated at 36°C for 2-3 hr. The digested material was filtered with 1 × 1 mm of mesh, and washed with 0.85% saline until the supernatant is clear. The sediment was carefully examined under a stereomicroscope. The metacercariae of *C. sinensis* were collected based on their general features [7], and they were counted to get hold of the infection densities by fish species.

Table 3. Fishes^a collected from middle regions (Chungcheongbuk-do), Korea

Species of fish	No. of fish collected from 3 localities ^b			Total
	⑧	⑨	⑩	
Cypriniforms				
<i>Zacco platypus</i>	43	20	2	65
<i>Acheilognathus lanceolatus</i>	49	-	2	51
<i>Acanthorhodeus gracilis</i>	41	-	-	41
<i>Hemibarbus labeo</i>	34	-	5	39
<i>Hemiculter eigenmanni</i>	28	-	4	32
<i>Pungtungia herzi</i>	25	6	-	31
<i>Carassius auratus</i>	21	-	10	31
<i>Opsariichthys uncirostris</i>	14	-	10	24
<i>Squalidus gracilis majimae</i>	20	-	-	20
<i>Culter brevicauda</i>	20	-	-	20
<i>Pseudogobio esocinus</i>	12	5	-	17
<i>Hemibarbus longirostris</i>	-	15	-	15
<i>Cyprinus carpio</i>	6	-	7	13
<i>Acheilognathus rhombeus</i>	5	-	-	5
<i>Sarcocheilichthys variegatus</i>	2	3	-	5
<i>Squalidus japonicus coreanus</i>	4	-	-	4
<i>Acanthorhodeus macropterus</i>	4	-	-	4
<i>Pseudorasbora parva</i>	3	-	-	3
<i>Coreoleuciscus splendidus</i>	-	2	-	2
<i>Sarcocheilichthys nigripinnis</i>	2	-	-	2
<i>Squaliobarbus curriculus</i>	1	-	1	2
<i>Pseudorasbora parva</i>	1	-	-	1
<i>Pseudopungtungia nigra</i>	1	-	-	1
<i>Rhynchocypris oxycephalus</i>	1	-	-	1
<i>Aphyocypris chinensis</i>	1	-	-	1
<i>Cobitis lutheri</i>	-	1	-	1
<i>Plecoglossus altivelis</i>	1	-	-	1
Siluriformes				
<i>Leiocassis ussuriensis</i>	1	-	-	1
Perciformes				
<i>Odontobutis platycephala</i>	12	-	-	12
<i>Siniperca scherzeri</i>	2	-	1	3
<i>Coreoperca herzi</i>	2	1	-	3
Total	356	53	42	451

^aTotal 451 freshwater fishes of 32 species were examined. ^b3 localities, ⑧ Okcheon-gun (Gum-gang); ⑨ Goisan-gun (Cheong-cheon); ⑩ Daecheong-ho (Lake).

RESULTS

Infection status of freshwater fish from northern areas

The metacercariae of *C. sinensis* were found in only 2 fish species, *P. herzi* and *Squalidus japonicus coreanus*, collected from Hantan-gang in Cheolwon-gun, Gangwon-do. Total 6 CsMc were detected in 3 out of 8 *P. herzi* examined in April, 2005. They were also detected in 6 (85.7%) of 7 *P. herzi* and both 2

of *S. japonicus coreanus* examined in October 2010. The metacercarial densities were 3.2 and 2.0 per infected fish. However, they were not found in fishes from 7 localities, Hongcheon-gun in Hongcheon-gun, Hwa-gang in Cheolwon-gun, Sooip-cheon in Yanggu-gun, Namdae-cheon in Yangyang-gun, Donggang in Youngweol-gun, and Osip-cheon and Gagok-cheon in Samcheok-si, Gangwon-do.

Infection status of freshwater fish from middle areas

A total of 50 CsMc were detected in 22 (10 species) of 356 freshwater fish (28 species) collected from Gum-gang, and total 27 metacercariae were found in 6 (3 species) of 53 fish from Cheong-cheon. Their infection status by fish species were as shown in Table 7. No CsMc were found in 42 fishes from Daecheong-ho.

CsMc were found in 3 (12.5%) of 24 *P. herzi* and only 1 (4.8%) *Zacco platypus* from Ahndong-si, and their average densities were 62 in *P. herzi* and only 1 in *Z. platypus* infected. They were also detected in all 6 *P. herzi* and only 1 of 2 *Acanthorhodeus gracilis* from Sangju-si, and their average densities were 11 in *P. herzi* and only 1 in *A. gracilis* infected. Total 46 CsMc were detected in 10 (35.7%) of 28 *Squalidus gracilis majimae* from Youngdeok-gun. However, CsMc were not found in other fishes from Bonghwa-gun.

A total of 68 CsMc were found in 9 (15.8%) out of 57 fish of 7 species, *Ladislabia taczanowskii*, *Culter brevicauda*, *P. herzi*, *Z. platypus*, *Pseudogobio esocinus*, *Hemibarbus longirostris*, and *Hemibarbus labeo* from Yecheon-gun. Total 31 (36.0%) fishes of 6 species, *P. herzi*, *Squalidus chankaensis tsuchigae*, *Microphysogobio koeensis*, *Coreoleuciscus splendidus*, *Acheilognathus signifer* and *Z. platypus*, out of 86 fish in 12 species from Youngyang-gun, were infected with 1-630 CsMc (av. 126 per fish). Among 136 fishes of 16 species collected from Gunwi-gun, 70 (51.5%) of 14 species were infected with 1-2,105 CsMc (av. 287). The infection status in fishes from Yecheon-gun, Youngyang-gun, and Gunwi-gun were detailed in Table 8.

Infection status of freshwater fish from southern areas

Among 191 fishes (22 species) from Seomjin-gang in Gokseong-gun, 42 (13 species) were infected with 2,496 CsMc (av. 59), and 37 fishes (9 species) from Seomjin-gang in Guryu-gun were infected with total 1,390 CsMc (av. 49). Their infection status by fish species were shown in Table 9.

A total of 1,831 CsMc (av. 80) were detected in 23 (9 species) of 65 freshwater fish (11 species) from Youngsan-gang in Naju-

Table 4. Fishes^a collected from middle regions (Gyeongsangbuk-do), Korea

Species of fish	No. of fish collected from 7 localities ^b							Total
	⑪	⑫	⑬	⑭	⑮	⑯	⑰	
Cypriniforms								
<i>Zacco platypus</i>	21	-	11	26	24	39	37	158
<i>Pungtungia herzi</i>	24	6	11	2	15	14	4	76
<i>Zacco temminckii</i>	25	-	7	-	8	2	9	51
<i>Squalidus gracilis majimae</i>	5	-	-	-	-	28	9	42
<i>Coreoleuciscus splendidus</i>	13	-	17	-	8	-	-	38
<i>Carassius auratus</i>	1	3	-	14	-	1	14	33
<i>Squalidus japonicus coreanus</i>	-	-	-	-	-	-	29	29
<i>Niwaella multifasciata</i>	3	-	10	-	15	-	-	28
<i>Pseudogobio esocinus</i>	-	3	-	12	-	-	1	16
<i>Hemibarbus longirostris</i>	-	-	-	10	-	-	4	14
<i>Acanthorhodeus gracilis</i>	-	2	-	10	-	-	2	14
<i>Acheilognathus signifer</i>	4	-	-	-	2	-	6	12
<i>Cyprinus capio</i>	-	2	-	10	-	-	-	12
<i>Misgurnus anguillicaudatus</i>	8	2	-	-	1	-	-	11
<i>Hemibarbus labeo</i>	-	6	-	3	-	-	1	10
<i>Opsariichthys uncirostris</i>	-	-	-	4	-	-	6	10
<i>Acheilognathus yamatsutae</i>	-	-	-	-	-	-	9	9
<i>Pseudobagrus fulvidraco</i>	-	-	-	9	-	-	-	9
<i>Koreocobitis naktongensis</i>	-	-	8	-	-	-	-	8
<i>Tribolodon hakonensis</i>	-	-	-	-	-	6	-	6
<i>Pseudobagrus koreanus</i>	-	3	-	2	-	-	-	5
<i>Microphysogobio koreensis</i>	-	-	1	-	2	-	-	3
<i>Iksookimia yongdokensis</i>	-	-	-	-	-	3	-	3
<i>Culter brevicauda</i>	-	-	-	2	-	-	-	2
<i>Squalidus chankaensis tsuchigae</i>	-	-	-	-	1	-	-	1
<i>Ladislabia taczanowskii</i>	-	-	-	2	-	-	-	2
<i>Pseudorasbora parva</i>	-	-	-	-	-	-	1	1
<i>Cobitis sinensis</i>	-	-	-	-	-	-	1	1
Osmeriformes								
<i>Plecoglossus altivelis</i>	-	-	-	-	-	10	-	10
Siluriformes								
<i>Liobagrus andersoni</i>	-	-	15	-	-	-	-	15
<i>Liobagrus obesus</i>	-	-	10	-	1	-	-	11
<i>Silurus microdorsalis</i>	1	-	-	8	-	-	-	9
Perciformes								
<i>Coreoperca herzi</i>	6	10	6	11	6	-	3	42
<i>Siniperca scherzer</i>	-	1	-	1	-	-	-	2
<i>Odontobutis platycephala</i>	7	7	1	5	3	-	-	23
Total	118	45	97	131	86	103	136	716

^aTotal 716 freshwater fishes in 35 species were examined. ^b⑪ Ahndong-si; ⑫ Sangju-si; ⑬ Bonghwa-gun; ⑭ Yecheon-gun; ⑮ Youngyang-gun; ⑯ Youngdeok-gun; ⑰ Gunwi-gun.

si. Among 58 fishes (11 species) from Tamjin-gang in Gangjin-gun, 39 (9 species) were infected with total 8,020 CsMc (av. 206), and a total of 162 CsMc (av. 32) were detected in 5 (4 species) of 18 freshwater fish (10 species) collected from Boseong-gang in Boseong-gun, Jeollanam-do. Infection status by fish species from 3 aforementioned regions were presented in Table 10. No CsMc were found in 52 fish from Tamjin-gang in

Janghung-gun, Jeollanam-do.

Total 175 CsMc (av. 22) were detected in 8 (32.0%) of 25 *S. chankaensis tsuchigae*, and 5 CsMc in 3 (5.0%) *Z. platypus* collected from Taehwa-gang in Ulsan Metropolitan City. Total 381 (48.2%) of 790 fish from Yangcheon-gang in Sancheong-gun, Gyeongsangnam-do were infected with 1-2,345 CsMc (av. 187). The infection status by fish species and examination year were

Table 5. Fishes^a collected from southern regions (Jeollanam-do), Korea

Species of fish	No. of fish collected from 6 localities ^b						Total
	⑬	⑭	⑮	⑯	⑰	⑱	
Cypriniforms							
<i>Zacco platypus</i>	42	1	20	10	10	1	84
<i>Carassius auratus</i>	13	7	10	-	2	2	34
<i>Squalidus chankaensis tsuchigae</i>	4	25	-	-	-	-	29
<i>Acheilognathus yamatsutae</i>	12	7	3	2	-	3	27
<i>Pungtungia herzi</i>	12	1	-	6	3	2	24
<i>Pseudogobio esocinus</i>	8	3	3	3	3	2	22
<i>Liobagrus mediadiposalis</i>	21	-	-	-	-	-	21
<i>Acheilognathus lanceolatus</i>	-	1	8	-	10	-	19
<i>Zacco temminckii</i>	8	-	-	1	10	-	19
<i>Sarcocheilichthys variegatus</i>	4	-	-	15	-	-	19
<i>Coreoleuciscus splendidus</i>	17	1	-	-	-	-	18
<i>Acanthorhodeus macropterus</i>	-	-	-	8	10	-	18
<i>Hemibarbus longirostris</i>	2	6	4	3	-	-	15
<i>Squalidus japonicus coreanus</i>	12	-	1	-	-	-	13
<i>Hemibarbus labeo</i>	3	-	8	-	-	-	11
<i>Sarcocheilichthys nigripinis</i>	-	10	-	-	-	-	10
<i>Opsariichthys uncirostris</i>	3	-	2	-	-	1	6
<i>Hemiculter eigenmanni</i>	5	-	-	-	-	-	5
<i>Acheilognathus majusculus</i>	4	-	-	-	-	-	4
<i>Abbottina springeri</i>	3	-	-	-	-	-	3
<i>Gnathopogon strigatus</i>	-	-	-	3	-	-	3
<i>Rhodeus ocellatus</i>	-	-	-	-	3	-	3
<i>Cobitis lutheri</i>	-	-	-	-	-	3	3
<i>Ladislavia taczanowskii</i>	2	-	-	-	-	-	2
<i>Microphysogobio koreensis</i>	-	2	-	-	-	-	2
<i>Pseudorasbora parva</i>	-	-	-	1	-	-	1
<i>Cyprinus capio</i>	1	-	-	-	-	-	1
<i>Misgurnus anguillicaudatus</i>	-	-	-	-	-	1	1
<i>Microphysogobio longidorsalis</i>	-	1	-	-	-	-	1
Osmeriformes							
<i>Plecoglossus altivelis</i>	-	2	-	6	-	-	8
Siluriformes							
<i>Liobagrus mediadiposalis</i>	-	-	-	-	-	1	1
Perciformes							
<i>Coreoperca herzi</i>	7	-	-	-	-	-	7
<i>Siniperca scherzeri</i>	5	1	-	-	-	-	6
<i>Micropterus salmoides</i>	-	-	5	-	-	-	5
<i>Odontobutis platycephala</i>	3	-	1	-	1	2	7
Total	191	68	65	58	52	18	452

^aTotal 452 freshwater fishes of 35 species were examined; ^b⑬ Gokseong-gun (Seomjin-gang); ⑭ Gurye-gun (Seomjin-gang); ⑮ Naju-si (Youngsan-gang); ⑯ Gangjin-gun (Tamjin-gang); ⑰ Jangheung-gun (Tamjin-gang); ⑱ Boseong-gun (Boseong-gang).

shown in Table 11.

Comparative prevalence and density of CsMc in freshwater fish from 3 regions

Among 1,543 fish from northern areas, only 11 (0.7%) of 2 species, *P. herzi* and *S. japonicus coreanus*, from Hantan-gang in Cheolwon-gun, were infected with total 29 CsMc (av. 2.6 per

infected fish). Total 149 (12.8%) of 1,167 fish from middle areas were infected with total 24,384 CsMc (av. 163.7). Of 1,361 fish from southern areas, 538 (39.5%) were infected with total 85,428 CsMc (av. 158.8).

In an analysis with an index fish, *P. herzi*, total 25 CsMc (av. 2.8) were detected in 9 (6.2%) of 146 fishes from northern areas. Among 107 *P. herzi* from middle areas, 34 (31.8%) were

Table 6. Fishes^a collected from southern regions (Ulsan Metropolitan City and Gyeongsangnam-do), Korea

Species of fish	No. of fish collected from 3 localities ^b				Total
	㉔	㉔-1	㉔-2	㉔-3	
Cypriniforms					
<i>Pungtungia herzi</i>	-	24	44	78	146
<i>Zacco platypus</i>	60	21	19	44	144
<i>Pseudogobio esocinus</i>	-	34	16	60	110
<i>Zacco temminckii</i>	4	34	20	32	90
<i>Carassius auratus</i>	5	36	13	18	72
<i>Hemibarbus longirostris</i>	-	31	15	22	68
<i>Acheilognathus majusculus</i>	-	25	13	10	48
<i>Squalidus chankaensis tsuchigae</i>	25	7	2	3	37
<i>Acanthorhodeus macropterus</i>	-	15	-	15	30
<i>Squalidus gracilis coreanus</i>	-	-	2	9	11
<i>Pseudorasbora parva</i>	5	-	-	1	6
<i>Acheilognathus signifer</i>	-	-	6	-	6
<i>Hemibarbus labeo</i>	5	-	-	-	5
<i>Acheilognathus rhombeus</i>	-	3	-	2	5
<i>Acheilognathus koreensis</i>	-	-	4	-	4
<i>Culter brevicauda</i>	-	-	4	-	4
<i>Sarcocheilichthys variegates</i>	-	-	2	2	4
<i>Hemiculter eigenmanni</i>	2	-	2	-	4
<i>Opsariichthys uncirostris</i>	3	-	-	-	3
<i>Pseudobagrus koreanus</i>	-	2	-	-	2
<i>Sarcocheilichthys nigripinnis</i>	-	-	1	-	1
Perciformes					
<i>Coreoperca herzi</i>	2	19	8	30	59
<i>Siniperca scherzeri</i>	-	2	-	-	2
<i>Odontobutis platycephala</i>	8	8	8	24	48
Total	119	261	179	350	909

^aTotal 909 freshwater fishes of 24 species were examined; ^b㉔ Ulsan Metropolitan City (Taehwa-gang); ㉔-1 Sancheong-gun (Yangcheon-gang, 2006); ㉔-2 Sancheong-gun (Yangcheon-gang, 2007); ㉔-3 Sancheong-gun (Yangcheon-gang, 2010).

infected with total 7,300 CsMc (av. 214.7). Total 158 (92.9%) of 170 *P. herzi* collected from southern areas were infected with total 64,674 CsMc (av. 409.3). On the other hand, no CsMc were found in 247 *Z. platypus* from northern areas. Of 223 *Z. platypus* from middle areas, 17 (7.6%) were infected with total 147 CsMc (av. 8.6). Total 13 (5.7%) of 228 *Z. platypus* from southern areas were infected with 139 CsMc (av. 10.7) (Table 12).

DISCUSSION

As the second intermediate hosts of *C. sinensis*, total 102 species of freshwater fishes (59 genera, 15 families) have been reported in China, including Taiwan, and total 40 species (31 ge-

nera, 6 families) have been listed in the Republic of Korea [7, 19]. In the present study, CsMc were detected in 36 fish species. Of the 36 positive fish species, 28 have been already known as the second intermediate hosts of *C. sinensis*. However, 8 species, namely, *Pseudopuntungia nigra*, *Rhynchocypris oxycephalus*, *Ladislabia taczanowskii*, *Microphysogobio longidorsalis*, *Acheilognathus majusculus*, *Acheilognathus koreensis*, *Acanthorhodeus macropterus*, and *Odontobutis platycephala*, have not been listed in the Republic of Korea [7]. Among aforementioned 8 new fish hosts, *R. oxycephalus* is the same fish species with *Phoxinus* (or *Morocco*) *oxycephalus*, which has been already recorded. Accordingly, total 47 fish species (34 genera, 7 families) are included among the second intermediate hosts of *C. sinensis* in the Republic of Korea.

The successful sampling of subjected materials is one of the important factors in epidemiological surveys. A satisfactory fish collection is not easy in surveys like the present study. Fish ecologies are variable by natural conditions, and collected fish species are different by the catching methods (netting, casting net, and trapping) and timings. Although a total of 4,071 freshwater fish were examined in the present study, the fish examined more than 200 in number were only 7 species, i.e. *Z. platypus* (698), *P. herzi* (423), *Zacco temminckii* (344), *Pseudogobio esocinus* (236), *C. auratus* (204), *Coreoperca herzi* (203), and *C. splendidus* (200). Among 7 major fish species examined, *Z. platypus* and *P. herzi* were predominant, and they were evenly collected in each of 3 regions. Total 247, 223, and 228 *Z. platypus* and 146, 107, and 170 *P. herzi* were examined in each of 3 regions, northern, middle, and southern areas of Korea. Therefore, these 2 fish species are good to use as index fish species to compare the endemicities of *C. sinensis* infection in 3 regions of the present study. Until now the susceptible fish host for CsMc, *P. parva*, has been used as an index species for distribution of *C. sinensis* at certain areas [10,12,20-22]. However, in this study, their number examined were limited.

By the present study, it is confirmed again that the southern areas are highly endemic for clonorchiasis in Korean peninsula [1-6]. The positive rates and infection densities of CsMc are higher in over all fish examined, as well as in *P. herzi*, from these southern areas, although they are exceptionally higher in fish species, i.e. *P. herzi*, *P. esocinus*, *S. gracilis majimae* and *S. japonicus coreanus*, from Gunwi-gun, Gyeongsangbuk-do. In the analysis with the index fish, *P. herzi*, the positive rates are relatively proportioned with the average metacercarial density per infected fish. Therefore, the highly susceptible fish species, *P. herzi*,

Table 7. Prevalence and density of *C. sinensis* metacercariae in fishes from Chungcheongbuk-do, a middle region of Korea

Location and fish sp.	No. of fish examined	No. (%) of fish infected	No. of metacercariae detected		
			Total	Range	Average
⑧ Gum-gang (River)					
<i>Sarcocheilichthys nigripinnis</i>	2	1 (50.0)	20	-	20.0
<i>Pungtungia herzi</i>	25	1 (4.0)	2	-	2.0
<i>Squalidus gracilis majimae</i>	20	8 (40.0)	15	1-4	1.9
<i>Acanthorhodeus gracilis</i>	41	4 (9.8)	5	1-2	1.3
<i>Acheilognathus lanceolatus</i>	49	3 (6.1)	3	-	1.0
<i>Hemibarbus labeo</i>	34	1 (2.9)	1	-	1.0
<i>Hemiculter eigenmanni</i>	28	1 (3.6)	1	-	1.0
<i>Sarcocheilichthys variegatus</i>	2	1 (50.0)	1	-	1.0
<i>Pseudopungtungia nigra</i>	1	1 (100)	1	-	1.0
<i>Rhynchocypris oxycephalus</i>	1	1 (100)	1	-	1.0
Subtotal	203	22 (10.8)	50	1-20	2.3
⑨ Cheong-cheon (Stream) in Goisan-gun					
<i>Pungtungia herzi</i>	6	4 (66.7)	23	2-12	5.8
<i>Zacco platypus</i>	20	1 (5.0)	3	-	3.0
<i>Sarcocheilichthys variegatus</i>	3	1 (33.3)	1	-	1.0
Subtotal	29	6 (20.7)	27	1-12	4.5
Total	232	28 (12.1)	77	1-20	2.8

can be the real index fish of clonorchiasis transmission in the natural condition, and the presence of metacercariae in this fish species may suggest the maintaining of *C. sinensis* life cycle in subjected areas.

On the other hand, in case of *Z. platypus*, CsMc were not detected in 247 fish from northern areas. Total 17 (7.6%) out of 223 *Z. platypus* from middle areas were infected with 147 CsMc, and 13 (5.7%) out of 228 fishes from southern areas were infected with 139 CsMc. From the above findings, we could not find any special trend in the endemicity of *C. sinensis* infection in 3 regions. Therefore, it is confirmed that a less susceptible fish species, like *Z. platypus*, is unsuitable as an index fish, although they are widely collected in 3 regions as dominant fish species.

CsMc were not found in all fishes from 9 localities in northern areas except 2 species, *P. herzi* and *S. japonicus coreanus*, from Hantan-gang in Cheolwon-gun, Gangwon-do. In the study by Kim et al. [12], all the fish from upper regions of Cheongju, Chungcheongbuk-do were negative for CsMc, even though the number of susceptible fishes examined were limited. It is interesting that CsMc were detected only in fishes from Hantan-gang in northern areas. First of all, as an important epidemiologic factor for clonorchiasis, the availability of the snail intermediate host, *Parafossarulus manchouricus*, should be investigated in the near future in Hantan-gang in Cheolwon-gun, Gangwon-do. There have been few studies on the CsMc infection status

of fishes from Gangwon-do, whereas many studies have been performed to investigate the infection status of intestinal flukes, including *Metagonimus* spp. in fishes from Gangwon-do [23-28]. It is probably due to the reason that Gangwon-do is endemic for intestinal fluke infections rather than clonorchiasis.

Among the 47 fish species listed as the second intermediate hosts of *C. sinensis* in Korea, *Hypomesus olidus* (the pond smelt) and *Z. platypus* are favorably eaten raw in Korea. Fortunately, they are relatively unsusceptible for CsMc. In our study, CsMc were not found in 247 *Z. platypus* from Gangwon-do, and in extensive examinations of pond smelts from several lakes in Korea previously by Cho et al. [29]. Moreover, in the present study, they were not detected in 1,532 fishes from Gangwon-do, and in 42 fish from Daecheong-ho. However, Park et al. [30] detected CsMc in *H. olidus* and *Z. platypus* from Soyang-ho and Daecheong-ho. Especially, it was remarkable that total 369 CsMc were detected in 100 *H. olidus* from Daecheong-ho [30]. Judging by aforementioned data and ecological and biological characteristics of *C. sinensis*, the findings of Park et al. (2004) need further verification.

The positive rates and densities of CsMc were relatively high in fishes from the upper reaches of Nakdong-gang in Youngyang-gun and Gunwi-gun, Gyeongsangbuk-do. Of the 86 fishes from Youngyang-gun, 31 (36.0%) were infected with av. 126 CsMc, and 70 (51.5%) of 136 fishes from Gunwi-gun were infected with av. 287 CsMc. Chung et al. [31] examined 794 fish-

Table 8. Prevalence and density of *C. sinensis* metacercariae in fishes from Nakdong-gang, Gyeongsangbuk-do, a middle region of Korea

Location and fish sp.	No. of fish examined	No. (%) of fish infected	No. of metacercariae detected		
			Total	Range	Average
⑭ Yecheon-gun					
<i>Ladislabia taczanowskii</i>	2	2 (100)	33	5-28	16.5
<i>Culter brevicauda</i>	2	2 (100)	19	2-17	9.5
<i>Pungtungia herzi</i>	2	1 (50.0)	8	-	8.0
<i>Zacco platypus</i>	26	1 (3.8)	4	-	4.0
<i>Pseudogobio esocinus</i>	12	1 (8.3)	1	-	1.0
<i>Hemibarbus longirostris</i>	10	1 (10.0)	2	-	2.0
<i>Hemibarbus labeo</i>	3	1 (33.3)	1	-	1.0
Subtotal	57	9 (15.8)	68	1-28	7.6
⑮ Youngyang-gun					
<i>Pungtungia herzi</i>	15	15 (100)	3,736	13-630	249.1
<i>Squalidus chankaensis tsuchigae</i>	1	1 (100)	56	-	56.0
<i>Microphysogobio koeensis</i>	2	2 (100)	54	1-53	27.0
<i>Coreoleuciscus splendidus</i>	8	7 (87.5)	45	1-16	6.4
<i>Acheilognathus signifer</i>	2	1 (50.0)	4	-	4.0
<i>Zacco platypus</i>	24	5 (20.8)	13	1-6	2.6
Subtotal	52	31 (59.6)	3,908	1-630	126.1
⑰ Gunwi-gun					
<i>Pseudogobio esocinus</i>	1	1 (100)	2,105	-	2,105
<i>Squalidus gracilis majimae</i>	9	9 (100)	7,463	385-1,875	829.2
<i>Pungtungia herzi</i>	4	4 (100)	3,279	329-1,180	819.8
<i>Squalidus japonicus coreanus</i>	29	29 (100)	6,872	9-875	237.0
<i>Acanthorhodeus gracilis</i>	2	2 (100)	136	54-82	68.0
<i>Zacco platypus</i>	37	9 (24.3)	126	1-77	14.0
<i>Pseudorasbora parva</i>	1	1 (100)	11	-	11.0
<i>Hemibarbus longirostris</i>	4	4 (100)	34	3-13	8.5
<i>Acheilognathus signifer</i>	6	6 (100)	43	2-11	7.2
<i>Zacco temminckii</i>	9	1 (11.1)	3	-	3.0
<i>Acheilognathus yamatsutae</i>	9	1 (11.1)	2	-	2.0
<i>Opsariichthys uncirostris</i>	6	1 (16.7)	1	-	1.0
<i>Coreoperca herzi</i>	3	1 (33.3)	1	-	1.0
<i>Hemibarbus labeo</i>	1	1 (100)	1	-	1.0
Subtotal	111	70 (63.1)	20,077	1-2,105	286.8
Total	220	110 (50.0)	24,053	1-2,105	218.7

es, including 140 *P. herzi* from Youngyang-gun, and they detected 2.1 CsMc per gram of muscles from only 10 (23.3%) of 43 *Gnathopogon atromaculatus* (= *Squalidus chankaensis tsuchigae*) examined. Kim et al. [32] detected 11.6 CsMc per gram of muscles in 61 (43.9%) of 139 fishes from Wicheon in Uiseong-gun, Gyeongsangbuk-do. Accordingly, we could determine that the endemicity of CsMc in fishes from Youngyang-gun and Gunwi-gun are a little higher in the present study than in previous reports.

There have been few studies that examined the infection status of CsMc in fishes from Jeollanam-do. Kim et al. [12] roughly revealed the distribution of fishes infected with CsMc based

on individual fish species. The present study showed a more detailed information on the endemicity of CsMc in fishes from 6 localities, Gokseong-gun, Gurye-gun, Naju-si, Gangjin-gun, Jangheung-gun, and Boseong-gun, in Jeollanam-do. The endemicity was relatively higher in fishes from 5 localities except Jangheung-gun. Especially, it is interesting to note that the endemicity of *C. sinensis* in fishes from Gangjin-gun is high, because Gangjin-gun has been well known as a highly endemic area of metagonimiasis [33,34].

Studies on the CsMc infection status of fishes from Taehwagang in Ulsan Metropolitan City were performed by some workers. Joo [15,35] examined 504 and 697 freshwater fishes from

Table 9. Prevalence and density of *C. sinensis* metacercariae in fishes from Seomjin-gang (River), Jeollanam-do, a southern region of Korea

Location and fish sp.	No. of fish examined	No. (%) of fish infected	No. of metacercariae detected		
			Total	Range	Average
⑬ Gokseong-gun					
<i>Ladislabia taczanowskii</i>	2	2 (100)	604	259-345	302.0
<i>Sarcocheilichthys variegatus</i>	4	2 (50.0)	379	20-359	189.5
<i>Zacco platypus</i>	42	1 (2.4)	118	-	118.0
<i>Pungtungia herzi</i>	12	10 (83.3)	1,139	1-275	113.9
<i>Squalidus japonicus coreanus</i>	12	3 (25.0)	164	20-93	54.7
<i>Abbottina springeri</i>	3	2 (66.7)	27	2-25	13.5
<i>Squalidus chankaensis</i>	4	3 (75.0)	31	4-16	10.3
<i>Hemibarbus longirostris</i>	2	2 (100)	7	2-5	3.5
<i>Cyprinus capio</i>	1	1 (100)	2	-	2.0
<i>Acheilognathus majusculus</i>	4	2 (50.0)	4	-	2.0
<i>Coreoleuciscus splendidus</i>	17	11 (64.7)	18	1-3	1.6
<i>Carassius auratus</i>	13	1 (7.7)	1	-	1.0
<i>Hemibarbus labeo</i>	3	2 (66.7)	2	-	1.0
Subtotal	119	42 (35.3)	2,496	1-359	59.4
⑭ Gurye-gun					
<i>Pungtungia herzi</i>	1	1 (100)	377	-	377.0
<i>Squalidus chankaensis tsuchigae</i>	25	19 (76.0)	771	1-351	40.6
<i>Sarcocheilichthys nigripinis</i>	10	10 (100)	217	6-62	21.7
<i>Microphysogobio koreensis</i>	2	1 (50.0)	14	-	14.0
<i>Siniperca scherzeri</i>	1	1 (100)	4	-	4.0
<i>Hemibarbus longirostris</i>	6	1 (16.7)	3	-	3.0
<i>Pseudogobio esocinus</i>	3	2 (66.7)	2	-	1.0
<i>Acheilognathus yamatsutae</i>	7	1 (14.3)	1	-	1.0
<i>Microphysogobio longidorsalis</i>	1	1 (100)	1	-	1.0
Subtotal	56	37 (66.1)	1,390	1-377	37.6
Total	175	79 (45.1)	3,886	1-377	49.2

Taehwa-gang, and reported 31 (6.2%) and 126 (18.1%) fish infected with CsMc. Rim et al. [36] also reported 29 (47.5%) CsMc positive fishes, of 2 species, *P. parva* and *S. chankaensis tsuchigae*, out of 61 fishes examined in Taehwa-gang. In the present study, we detected total 180 CsMc in 11 (9.2%) fishes of only 2 species, *S. chankaensis tsuchigae*, and *Z. platypus*, out of 119 fishes from Taehwa-gang. Therefore, we could determine that the endemicity of CsMc in the present study is much lower than those in the previous studies.

Bae et al. [37] extensively surveyed on *C. sinensis* infections in the first and second intermediate hosts, definitive hosts, and inhabitants, residing along Nam-gang, in Gyeongsangnam-do. Especially on the second intermediate hosts, they reported that 83 (34.7%) of 239 fishes, including 64 *P. parva*, were infected with CsMc. In the present study, we examined total 790 freshwater fishes from Yangcheon-gang, a stream of Nam-gang, in Sancheong-gun, Gyeongsangnam-do, and detected av. 187 CsMc from 381 (48.2%) fishes. Until now the endemicity of

CsMc in fishes from streams of Nam-gang, including Yangcheon-gang, is as high as in old days. It seems to be one of the reasons why Sancheong-gun is the most highly endemic area of clonorchiasis around the whole country [5]. Therefore, inhabitants residing in endemic areas, like Sancheong-gun, should pay attention to clonorchiasis, and consumption of raw freshwater fish naturally produced in these areas should be avoided.

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Table 10. Prevalence and density of *C. sinensis* metacercariae in fishes from rivers in Jeollanam-do, southern regions of Korea

Location and fish sp.	No. of fish examined	No. (%) of fish infected	No. of metacercariae detected		
			Total	Range	Average
㉑ Youngsan-gang in Naju-si					
<i>Squalidus japonicus coreanus</i>	1	1 (100)	815	-	815.0
<i>Acheilognathus lanceolatus</i>	5	5 (100)	730	2-460	146.0
<i>Hemibarbus longirostris</i>	4	4 (100)	215	23-107	53.8
<i>Opsariichthys uncirostris</i>	2	1 (50.0)	28	-	28.0
<i>Pseudogobio esocinus</i>	3	3 (100)	24	1-12	8.0
<i>Acheilognathus yamatsutae</i>	3	2 (66.7)	10	1-9	5.0
<i>Zacco platypus</i>	20	1 (5.0)	2	-	2.0
<i>Hemibarbus labeo</i>	8	5 (62.5)	6	1-2	1.2
<i>Carassius auratus</i>	10	1 (10.0)	1	-	1.0
Subtotal	56	23 (41.1)	1,831	1-460	79.6
㉒ Tamjin-gang in Gangjin-gun					
<i>Pungtungia herzi</i>	6	6 (100)	2,520	95-846	420.0
<i>Sarcocheilichthys variegatus</i>	15	15 (100)	5,342	65-682	356.1
<i>Gnathopogon strigatus</i>	3	3 (100)	122	30-52	40.7
<i>Pseudorasbora parva</i>	1	1 (100)	6	-	6.0
<i>Acanthorhodeus macropterus</i>	8	5 (62.5)	14	1-9	2.8
<i>Pseudogobio esocinus</i>	3	3 (100)	6	1-3	2.0
<i>Acheilognathus yamatsutae</i>	2	2 (100)	4	1-3	2.0
<i>Hemibarbus longirostris</i>	3	3 (100)	5	1-3	1.7
<i>Zacco platypus</i>	10	1 (10.0)	1	-	1.0
Subtotal	51	39 (76.5)	8,020	1-846	205.6
㉓ Boseong-gang in Boseong-gun					
<i>Pungtungia herzi</i>	2	2 (100)	157	9-148	78.5
<i>Pseudogobio esocinus</i>	2	1 (50.0)	2	-	2.0
<i>Acheilognathus yamatsutae</i>	3	1 (33.3)	2	-	2.0
<i>Zacco platypus</i>	1	1 (100)	1	-	1.0
Subtotal	8	5 (62.5)	162	1-148	32.4
Total	115	67 (58.3)	10,013	1-846	149.4

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Table 11. Prevalence and density of *C. sinensis* metacercariae in fishes from Yangcheon-gang (River), Sancheong-gun, Gyeongsangnam-do, a southern region of Korea

Year examined and fish sp.	No. of fish examined	No. (%) of fish infected	No. of metacercariae detected		
			Total	Range	Average
2006					
<i>Pungtungia herzi</i>	24	24 (100)	19,044	324-1,408	793.5
<i>Squalidus chankaensis tsuchigae</i>	7	7 (100)	1,775	100-380	253.6
<i>Pseudogobio esocinus</i>	34	34 (100)	3,643	2-313	107.2
<i>Acheilognathus rhombeus</i>	3	3 (100)	187	37-112	62.3
<i>Acanthorhodeus macropterus</i>	15	10 (66.7)	335	1-83	33.5
<i>Acheilognathus majusculus</i>	25	18 (72.0)	100	1-44	5.6
<i>Hemibarbus longirostris</i>	31	7 (22.6)	13	1-3	1.9
<i>Zacco temminckii</i>	34	4 (11.8)	6	1-3	1.5
<i>Zacco platypus</i>	21	3 (14.3)	3	-	1.0
Subtotal	194	110 (56.7)	25,106	1-1,408	228.2
2007					
<i>Pungtungia herzi</i>	44	44 (100)	28,294	106-2,345	707.4
<i>Squalidus chankaensis tsuchigae</i>	2	2 (100)	658	178-480	329.0
<i>Sarcocheilichthys variegatus</i>	2	2 (100)	551	145-406	275.5
<i>Squalidus gracilis coreanus</i>	2	2 (100)	298	89-209	149.0
<i>Pseudogobio esocinus</i>	16	13 (81.3)	817	1-197	62.9
<i>Sarcocheilichthys nigripinnis</i>	1	1 (100)	11	-	11.0
<i>Hemiculter eigenmanni</i>	2	2 (100)	14	-	7.0
<i>Acheilognathus signifer</i>	6	6 (100)	35	1-16	5.8
<i>Coreoperca herzi</i>	8	1 (12.5)	4	-	4.0
<i>Hemibarbus longirostris</i>	15	8 (53.3)	23	1-10	2.9
<i>Zacco platypus</i>	19	1 (5.3)	2	-	2.0
<i>Acheilognathus koreensis</i>	4	2 (50.0)	4	1-3	2.0
<i>Acheilognathus majusculus</i>	13	9 (69.2)	16	1-4	1.8
<i>Carassius auratus</i>	13	1 (7.7)	1	-	1.0
<i>Odontobutis platycephala</i>	8	1 (12.5)	1	-	1.0
Subtotal	155	95 (61.3)	30,729	1-2,345	323.4
2010					
<i>Sarcocheilichthys variegatus</i>	2	2 (100)	542	240-302	271.0
<i>Pungtungia herzi</i>	78	71 (91.0)	13,143	1-1,286	185.1
<i>Squalidus chankaensis tsuchigae</i>	3	3 (100)	235	48-131	78.3
<i>Pseudorasbora parva</i>	1	1 (100)	45	-	45.0
<i>Acheilognathus rhombeus</i>	2	2 (100)	51	15-36	25.5
<i>Squalidus gracilis coreanus</i>	9	8 (88.9)	191	2-59	23.9
<i>Acheilognathus macropterus</i>	15	11 (73.3)	263	4-98	23.9
<i>Pseudogobio esocinus</i>	60	55 (91.7)	994	1-136	18.1
<i>Zacco platypus</i>	44	5 (11.4)	12	1-8	2.4
<i>Hemibarbus longirostris</i>	22	17 (77.3)	37	1-6	2.2
<i>Acheilognathus majusculus</i>	10	1 (10.0)	1	-	1.0
Subtotal	246	176 (71.5)	15,514	1-1,286	88.1
Total	595	381 (64.0)	71,349	1-2,345	187.3

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Table 12. Comparative prevalence^a and density^a of *C. sinensis* metacercariae in fishes from 3 latitudinal regions

Items	Infection status (%) in fishes from			
	Northern	Middle	Southern	Total
No. (%) of fish examined	1,543 (37.9)	1,167 (28.7)	1,361 (33.4)	4,071 (100)
Total positive rate (%)	11/1,543 (0.7)	149/1,167 (12.8)	538/1,361 (39.5)	698/4,071 (17.1)
Overall metacercarial density/fish	2.6	163.7	158.8	157.4
Positive rate (%) of <i>P. herzi</i>	9/146 (6.2)	34/107 (31.8)	158/170 (92.9)	201/423 (47.5)
Metacercarial density in <i>P. herzi</i>	2.8	214.7	409.3	358.2
Positive rate (%) of <i>Z. platypus</i>	0/247 (0)	17/223 (7.6)	13/228 (5.7)	30/698 (4.3)
Metacercarial density in <i>Z. platypus</i>	0	8.6	10.7	9.5

^aPrevalence: no. of fish infected/no. of fish examined × 100; density: mean no. of metacercariae per infected fish.

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