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▣ ORIGINAL ARTICLE

Infection Status with *Metagonimus* spp. Metacercariae in Fishes from Seomjin-gang and Tamjin-gang in Republic of Korea

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Abstract: To grasp the infection status of *Metagonimus* spp. metacercariae (MsMc), the freshwater fishes were surveyed from Seomjin-gang (river) and Tamjin-gang in the Republic of Korea. Total 1,604 fishes from 7 local sites of Seomjin-gang and 1,649 fishes from 2 sites of Tamjin-gang were examined for 6 years (2012-2017) by the artificial digestion method. MsMc were detected in fishes from 7 sites, i.e., Osucheon in Imsil-gun (36.3% fish in 6 spp.), Seomjin-gang in Sunchang-gun (49.8% in 18 spp.), Songdaecheon in Namwon-si (64.5% in 8 spp.), Seomjin-gang in Gokseong-gun (72.4% in 14 spp.) and in Gurye-gun (78.8% in 17 spp.), Hoengcheon (75.9% in 11 spp.) and Namsancheon (58.9% in 7 spp.) in Hadong-gun. Their average densities were 4.2, 86.8, 39.9, 43.1, 246.5, 173.6 and 67.5 per fish infected respectively. Prevalence with MsMc in rasborinid fish from Seomjin-gang was 89.2% and their intensity was 73.6 per fish infected. Endemicities of MsMc in rasborinid fish from Seomjin-gang were significantly higher in fishes from the lower reaches (prevalence: 98.7%; density: 137) rather than in fishes from the middle (93.5%; 38) and upper (72.4%; 13) reaches. MsMc were also detected in 56.1% and 66.4% fishes from 2 surveyed areas, i.e., the middle reaches in Jangheung-gun and the lower reaches in Gangjin-gun, of Tamjin-gang, and their densities were 147 and 121 per fish infected. In susceptible fishes from Tamjin-gang, the prevalence was 84.1% and density was 227 per fish infected. By the present study, it was confirmed that MsMc is highly prevalent in the fishes from Seomjin-gang and Tamjin-gang in Korea.

Key words: *Metagonimus* spp., metacercaria, Seomjin-gang, Tamjin-gang

INTRODUCTION

Members in the genus *Metagonimus* Katsurada, 1912 (Digenea: Heterophyidae) are comprised more than 7 nominal species, i.e., *M. yokogawai* Katsurada, 1912, *M. takahashii* Suzuki, 1930, *M. minutus* Katsuta, 1932, *M. katsuradai* Izumi, 1935, *M. otsurui* Saito and Shimizu, 1968, *M. miyatai* Saito et al., 1997 and *M. hakubensis* Shimazu, 1999. Among 7 *Metagonimus* species, 3 ones, i.e., *M. yokogawai*, *M. takahashii*, and *M. miyatai*, are known to distribute in the Republic of Korea (Korea) [1,2]. Human infection by these species of fluke, metagonimiasis, is an important endemic disease together with clonorchiasis in Korea [1-3]. Infections by *M. yokogawai* are chiefly prevalent in the riverside areas of eastern and southern coast of Korean peninsula [3-7]. Human cases by *M. takahashii* were first reported in inhabitants of Eumseong-gun (gun = county), Chungcheongnam-do (do = Province), along the upper reaches of the Namhan-gang [6]. Endemic areas of *M. miyatai* were confirmed among peoples residing around lakes and along the rivers and/or streams in inland of Korea [9-11]. These *Metagonimus* species give rise to severe gastrointestinal troubles and chronic diarrhea in heavily infected cases [1,2,12].

As the infection sources of metagonimiasis, lots of fish species have been reported in Korea [13]. The sweet smelt (*Plecoglossus altivelis*), the sea rundace (*Tribolodon hakonensis*) and the Japanese seabass (*Lateolabrax japonicus*), are known to be the second intermediate hosts of *M. yokogawai* [13-16]. The crusian carp (*Carassius auratus*), common carp (*Cyprinus carpio*), sea rundace, and Japanese seabass are reported as the second intermediate hosts of *M. takahashii* [13,16,17]. As the second

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intermediate hosts of *M. miyatai*, many species of fish, including the sea rundace, pale chub, (*Zacco platypus*) and dark chub (*Z. temminckii*), are listed in Korea [13,16,18].

On the other hand, many Korean workers have been investigated the infection status with zoonotic trematodes (ZT), i.e., *C. sinensis*, *Metagonimus* spp. including *M. yokogawai*, *Centrocestus armatus* and *Echinostoma* spp., metacercariae in fishes from various endemic areas to estimate the endemicities of these trematode infections [1,13]. In case of *Metagonimus* spp., most of studies were performed on the infection status of *M. yokogawai* in sweet smelts from the specific regions [19-25]. Recently, Cho et al. [26] surveyed on the infection status of ZT metacercariae including *Metagonimus* spp. in freshwater fish from Gangwon-do, Korea. Sohn et al. [27] investigated the infection status of digenetic trematode metacercariae in freshwater fish from the water systems of Hantan-gang and Imjin-gang located in relatively northern regions of Korea. Sohn et al. [28] and Yoon et al. [29] reported the infection status with *C. sinensis* metacercariae in fishes from Seomjin-gang and Tamjin-gang. However, the infection status with MsMc in fish from Seomjin-gang and Tamjin-gang has not been widely and systematically examined yet, although these 2 riverside areas has been known as the endemic areas of heterophyid flukes including *M. yokogawai* [3,4,30-32]. Therefore, we performed the present study to know the infection status with MsMc in fishes from 2 rivers, Seomjin-gang and Tamjin-gang, located in the southern parts of Korea.

MATERIALS AND METHODS

Collection sites of fish

We collected total 1,604 freshwater fishes in 7 local sites of Seomjin-gang, i.e., Osucheon ("cheon" means stream) (Latitude: 35.528473; Longitude: 127.328177) in Imsil-gun, Seomjin-gang (35.409674; 127.219528) in Sunchang-gun, Songdaecheon (35.352539; 127.189819) in Namwon-si, Jeollabuk-do, Seomjin-gang (35.212588; 127.371886) in Gokseong-gun, Seomjin-gang (35.200735; 127.491839) in Gurye-gun, Jeollanam-do, Hoengcheon (35.107203; 127.807894) and Namsancheon (35.095020; 127.798093) in Hadong-gun, Gyeongsangnam-do, for 5 years (2012-2016) (Fig. in [28]). We also collected total 1,132 fishes (22 species) in the middle reaches of Tamjin-gang in Jangheung-gun (Latitude: 34.425719; Longitude: 126. 543227) for 4 years (2014-2017) and total 517 fishes (17 species) in the lower reaches of Tamjin-gang in Gangjin-gun (Latitude: 34. 380531; Longitude: 126. 485115), Jeollanam-do, Korea in 2104 and 2017.

Fishes examined in the upper reaches of Seomjin-gang

Total 236 freshwater fish (11 species) from Osucheon in Imsil-gun, Jeollabuk-do were examined in 2012 and 2013. Fish species (No. of fish) examined were *Squalidus japonicus coreanus* (20), *Microphysogobio jeoni* (6), *Pseudogobio esocinus* (5), *Carassius auratus* (3), and *Hemibarbus longirostris* (1) including 6 ones with MsMc in Table 1. Total 310 freshwater fish (29 species) from Seomjin-gang in Sunchang-gun, Jeollabuk-do were examined in 2014 and 2015. Fish species (No. of fish) examined were *Coreoperca herzi* (19), *Acheilognathus koreensis* (12), *Odontobutis platycephala* (9), *Coreoleuciscus splendidus* (4), *Acheilognathus yamatsutae* (3), *Abbottina springeri* (3), *Cobitis tetralin-*

Table 1. Infection status of *Metagonimus* spp. metacercariae in freshwater fish from the upper reaches of Seomjin-gang (River)

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Osucheon in Imsil-gun				
Zacco platypus	80	48 (60.0)	1-32	4.2
Hemibarbus labeo	56	1 (1.8)	-	1.0
Squalidus chankaensis	35	8 (22.9)	1-10	3.3
Opsariichthys uncirostris	21	13 (61.9)	1-25	5.1
Acanthorhodeus gracilis	6	1 (16.7)	-	3.0
Rhodeus ocellatus	3	2 (66.7)	2-4	3.0
Subtotal	201	73 (36.3)	1- 32	4.2
Seomjin-gang in Sunchang-gun				
Pungtungia herzi	56	13 (23.2)	1-9	1.9
Zacco platypus	51	45 (88.2)	1-200	25.8
Pseudogobio esocinus	32	13 (40.6)	1-60	6.9
Zacco koreanus	15	11 (73.3)	1-36	7.9
Opsariichthys uncirostris	14	14 (100)	1-45	9.9
Carassius auratus	14	1 (7.1)	-	5.0
Sarcocheilichthys variegatus	12	4 (33.3)	1-6	2.8
Squalidus japonicus coreanus	11	3 (27.3)	-	1.0
Acheilognathus rhombeus	10	3 (30.0)	1-4	2.3
Siniperca scherzeri	10	1 (10.0)	-	2.0
Squalidus gracilis majimae	6	1 (16.7)	-	1.0
Acanthorhodeus gracilis	6	5 (83.3)	7-40	16.2
Gnathopogon strigatus	5	4 (80.0)	5-14	7.5
Hemibarbus longirostris	5	4 (80.0)	2-14	8.0
Hemibarbus labeo	4	1 (25.0)	-	2.0
Plecoglossus altivelis	3	3 (100)	282-6,750	3,146
Cyprinus carpio	2	1 (50.0)	-	1.0
Hemiculter leucisculus	1	1 (100)	-	1.0
Subtotal	257	128 (49.8)	1-6,750	86.8
Total	458	201 (43.9)	1-6,750	56.8

eata (2), *Acheilognathus lanceolatus* (1), *Acanthorhodeus macropterus* (1), *Cobitis lutheri* (1), and *Misgurnus anguillicaudatus* (1) including 18 ones with MsMc in Table 1.

Fishes examined in the middle reaches of Seomjingang

Total 196 freshwater fish (14 species) from Songdaecheon in Namwon-si, Jeollabuk-do were examined in 2012 and 2013. Fish species (No. of fish) examined were *C. herzi* (6), *Pseudorasbora parva* (2), *A. springeri* (2), *P. esocinus* (1), *Iksookimia longicorpus* (1), and *Lepomis macrochirus* (1) including 8 ones with MsMc in Table 2. Total 289 freshwater fish (15 species) from Seomjin-gang in Gokseong-gun, Jeollanam-do were examined in 2015 and 2016. Fish species (No. of fish) examined were *Ladislabia taczanowskii* (1) including 14 ones with MsMc in Table 2.

Table 2. Infection status of *Metagonimus* spp. metacercariae in freshwater fish from the middle reaches of Seomjin-gang (River)

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Songdaecheon in Namwon-si				
Zacco koreanus	57	56 (98.3)	2-334	60.5
Pungtungia herzi	47	10 (21.3)	1-4	2.0
Zacco platypus	46	45 (97.8)	1-175	28.4
Rhynchocypris oxycephalus	21	1 (4.8)	-	1.0
Microphysogobio koeensis	5	1 (20.0)	-	4.0
Carassius auratus	3	1 (33.3)	-	1.0
Gnathopogon strigatus	2	2 (100)	1-8	4.5
Squalidus gracilis majimae	2	2 (100)	-	1.0
Subtotal	183	118 (64.5)	1-334	39.9
Seomjin-gang in Gokseong-gun				
Zacco koreanus	52	41 (78.9)	1-124	18.0
Zacco platypus	43	43 (100)	1-130	23.4
Coreoleuciscus splendidus	37	15 (40.5)	1-6	1.9
Sarcocheilichthys variegatus	31	21 (67.7)	1-15	3.8
Squalidus japonicus coreanus	27	22 (81.5)	1-10	2.7
Pungtungia herzi	22	13 (59.1)	1-5	2.3
Hemibarbus longirostris	20	19 (95.5)	1-33	12.0
Microphysogobio koeensis	16	8 (50.0)	1-4	2.4
Pseudogobio esocinus	16	13 (81.3)	1-65	12.9
Coreoperca herzi	11	2 (18.2)	2-5	3.5
Acheilognathus majusculus	5	4 (80.0)	3-9	5.0
Plecoglossus altivelis	2	2 (100)	1,370-4,380	2,875
Hemibarbus labeo	2	2 (100)	2-9	5.5
Opsariichthys amurensis	2	2 (100)	11-762	386.5
Subtotal	286	207 (72.4)	1-4,380	43.1
Total	469	325 (69.3)	1-4,380	41.9

Fishes examined in the lower reaches of Seomjin-gang

Total 183 freshwater fish (21 species) from Seomjin-gang in Gurye-gun, Jeollanam-do were examined in 2014. Fish species (No. of fish) examined were *C. auratus* (5), *O. platycephala* (4), *A. lanceolatus* (3), and *S. scherzeri* (1) including 17 ones with MsMc in Table 3. Total 156 freshwater fish (13 species) from Hoengcheon in Hadong-gun, Gyeongsangnam-do were examined in 2014 and 2016. Fish species (No. of fish) examined were *C. auratus* (1) and *O. platycephala* (1) including 11 ones with MsMc in Table 3. Total 234 freshwater fish (12 species) from Namsancheon in Hadong-gun, Gyeongsangnam-do were examined in 2015 and 2016. Fish species (No. of fish) examined were *C. auratus* (16), *A. koreensis* (7), *A. gracilis* (2), *C. splendidus* (1), and *O. platycephala* (1) including 7 ones with MsMc in Table 3.

Fishes examined in Tamjin-gang

In the middle reaches in Jangheung-gun, total 1,132 fishes in 22 species were examined for 4 years (2014-2017). Fish species (No. of fish) examined were *Micropterus salmoides* (8), *A. koreensis* (7), and *Cyprinus carpio* (2) including 19 ones with MsMc in Table 5. In the lower reaches in Gangjin-gun, a total of 517 fishes in 17 species were examined in 2014 and 2017. Fish species (No. of fish) examined were *A. lanceolatus* (22), *C. herzi* (3), and *Mugil cephalus* (1) including 14 ones with MsMc in Table 5.

Examination methods

All collected fishes with ice were transferred to the laboratory of the Department of Parasitology and Tropical Medicine, Gyeongsang National University College of Medicine, Jinju, Korea. After the identification of fish species, they were individually ground with a mortar or grinder. Each ground fish meat was mixed with artificial gastric juice and the mixture was incubated at 36˚C for 2 hr. The digested material was filtered with 1×1 mm of mesh, and washed with 0.85% saline untill the supernatant is clear. The sediment was carefully examined under a stereomicroscope. The metacercariae of *Metagonimus* spp. (MsMc) were separately collected by the general feature [13], and they were counted to get hold of infection rates (%) and densities (No. of MsMc per fish infected) by fish species.

Table 3. Infection status of *Metagonimus* spp. metacercariae in freshwater fish from the lower reaches of Seomjin-gang (River)

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Seomjin-gang in Gurye-gun				
Zacco platypus	24	24 (100)	6-520	126.3
Pungtungia herzi	21	14 (66.7)	1-8	2.6
Squalidus japonicus coreanus	15	12 (80.0)	1-10	3.7
Zacco koreanus	14	11 (78.6)	3-290	64.0
Sarcocheilichthys nigripinnis	14	13 (92.9)	1-52	13.6
Opsariichthys uncirostris	13	13 (100)	52-495	143.8
Acheilognathus rhombeus	11	10 (90.9)	17-150	54.0
Coreoperca herzi	10	4 (40.0)	1-3	1.8
Hemibarbus labeo	10	3 (30.0)	-	1.0
Squalidus gracilis majimae	8	5 (62.5)	1-2	1.4
Pseudogobio esocinus	7	7 (100)	6-62	28.1
Microphysogobio koeensis	6	6 (100)	2-22	6.2
Acanthorhodeus gracilis	5	4 (80.0)	10-58	37.5
Abbottina rivularis	5	1 (20.0)	-	2.0
Plecoglossus altivelis	3	3 (100)	6,280-10,750	8,727
Pseudorasbora parva	3	3 (100)	4-31	15.7
Hemibarbus longirostris	1	1 (100)	-	3.0
Subtotal	170	134 (78.8)	1-10,750	246.5
Hoengcheon in Hadong-gun				
Zacco koreanus	35	35 (100)	1-5,860	369.2
Zacco platypus	27	27 (100)	2-1,510	115.3
Acheilognathus koreensis	20	1 (5.0)	-	1.0
Pungtungia herzi	16	7 (43.8)	1-3	2.1
Coreoperca herzi	11	5 (45.5)	1-2	1.4
Zacco temminckii	10	10 (100)	6-480	156.5
Hemibarbus longirostris	8	8 (100)	2-145	63.0
Pseudogobio esocinus	7	6 (85.7)	4-16	8.5
Abbottina springeri	7	4 (57.1)	3-358	97.8
Coreoleuciscus splendidus	4	3 (75.0)	-	1.0
Squalidus gracilis majimae	1	1 (100)	-	1.0
Subtotal	146	107 (73.3)	1-5,860	173.6
Namsancheon in Hadong-gun				
Zacco koreanus	57	57 (100)	1-2,860	104.3
Pseudogobio esocinus	46	4 (8.7)	1-2	1.3
Zacco platypus	41	41 (100)	3-101	27.4
Pungtungia herzi	35	7 (20.0)	1-7	2.3
Hemibarbus longirostris	14	1 (7.1)	-	1.0
Zacco temminckii	11	11 (100)	2-580	104.5
Squalidus gracilis majimae	3	1 (33.3)	-	1.0
Subtotal	207	122 (58.9)	1-2,860	67.5
Total	523	363 (69.4)	1-10,750	165

RESULTS

Infection status with MsMc in the upper reaches of Seomjin-gang

The metacercariae of *Metagonimus* spp. (MsMc) were detected in 201 (43.9%) out of 458 fishes in 20 species from the upper reaches of Seomjin-gang, i.e., Osucheon in Imsil-gun and Seomjin-gang in Sunchang-gun, Jeollabuk-do, and their average density was 56.8 per fish infected. The infection status by the fish species and surveyed areas was detailedly shown in Table 1.

Infection status with MsMc in the middle reaches of Seomjin-gang

MsMc were detected in 325 (69.3%) out of 469 fishes in 18 species from the middle reaches of Seomjin-gang, i.e., Songdaecheon in Namwon-si, Jeollabuk-do and Seomjin-gang in Gokseong-gun, Jeollanam-do, and their average density was 41.9 per fish infected. The infection status by the fish species and surveyed areas was detailedly revealed in Table 2.

Infection status with MsMc in the lower reaches of Seomjin-gang

MsMc were detected in 363 (69.4%) out of 523 fishes in 21 species from the lower reaches of Seomjin-gang, i.e., Seomjin-gang in Gurye-gun, Jeollanam-do, Hoengcheon and Namsancheon in Hadong-gun, Gyeongsangnam-do, and their average

Table 4. Infection status of *Metagonimus* spp. metacercariae in rasborinid fish from Seomjin-gang (River)

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Upper reaches				
Zacco platypus	131	93 (71.0)	1-200	14.6
Zacco koreanus	15	11 (73.3)	1-36	7.9
Opsariichthys uncirostris	35	27 (77.1)	1-45	7.6
Subtotal	181	131 (72.4)	1-200	12.6
Middle reaches				
Zacco platypus	89	88 (98.9)	1-175	26.0
Zacco koreanus	109	97 (89.0)	1-334	42.5
Opsariichthys amurensis	2	2 (100)	11-762	386.5
Subtotal	200	187 (93.5)	1-762	38.4
Lower reaches				
Zacco platypus	92	92 (100)	2-1,510	79.0
Zacco koreanus	106	103 (97.2)	1-5,860	190.0
Zacco temminckii	21	21 (100)	2-580	129.2
Opsariichthys amurensis	13	13 (100)	52-495	143.8
Subtotal	232	229 (98.7)	1-5,860	137.2
Total	613	547 (89.2)	1-5,860	73.6

density was 165 per fish infected. The infection status by the fish species and surveyed areas was detailedly shown in Table 3.

Infection status with MsMc in rasborinid fish from Seomjin-gang

MsMc were detected in 547 (89.2%) out of total 613 rasborinid fishes from Seomjin-gang, and their average density was 73.6 per fish infected. The infection status by the rasborinid fish species and surveyed reaches of river was detailedly revealed in Table 4.

Table 5. Infection status of *Metagonimus* spp. metacercariae in fishes from Tamjin-gang (River) in Jeollanam-do, Korea

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Middle reaches in Jangheung-gun				
Zacco temminckii	152	143 (94.1)	1-2,460	65.2
Pungtungia herzi	152	51 (33.6)	1-20	2.4
Zacco platypus	138	110 (79.7)	1-140	16.3
Carassius auratus	116	63 (54.3)	1-924	126.6
Pseudogobio esocinus	86	70 (81.4)	1-86	12.0
Coreoperca kawamebari	84	31 (36.9)	1-61	13.9
Hemibarbus longirostris	77	49 (63.6)	1-45	7.3
Sarcocheilichthys variegatus	54	17 (31.5)	1-7	2.0
Plecoglossus altivelis	52	51 (98.1)	1-5,320	1,339
Acheilognathus lanceolatus	52	1 (1.9)	-	2.0
Odontobutis platycephala	48	7 (14.6)	1-8	3.1
Sarcocheilichthys nigripinnis	29	6 (13.3)	1-32	8.3
Acheilognathus yamatsutae	23	2 (8.7)	4-5	4.5
Coreoperca herzi	16	3 (18.8)	-	1.0
Acanthorhodeus gracilis	11	10 (90.9)	1-55	31.9
Acheilognathus rhombeus	10	6 (60.0)	1-1,400	417.7
Siniperca scherzeri	6	1 (16.7)	-	1.0
Hemiculter eigenmanni	6	2 (33.3)	-	4.0
Squalidus gracilis majimae	3	3 (100)	1-5	2.7
Subtotal	1,115	626 (56.1)	1-5,320	147
Lower reaches in Gangjin-gun				
Zacco platypus	75	70 (93.3)	1-58	8.1
Pungtungia herzi	70	23 (32.9)	1-8	2.4
Carassius auratus	62	54 (87.1)	1-780	38.1
Pseudogobio esocinus	51	41 (80.4)	1-20	5.4
Plecoglossus altivelis	40	40 (100)	26-4,280	841
Sarcocheilichthys nigripinis	33	14 (42.4)	1-17	3.2
Acanthorhodeus macropterus	28	12 (42.9)	1-10	3.2
Zacco temminckii	26	25 (96.2)	1-875	110.3
Odontobutis platycephala	26	5 (19.2)	1-6	2.8
Coreoperca kawamebari	25	9 (36.0)	1-5	1.9
Hemibarbus longirostris	24	19 (79.2)	1-15	4.9
Sarcocheilichthys variegatus	20	3 (15.0)	2-4	3.0
Acheilognathus rhombeus	9	9 (100)	2-67	25.8
Lateolabrax japonicus	2	2 (100)	1-4	2.5
Subtotal	491	326 (66.4)	1-4,280	121
Total	1,606	952 (59.3)	1-5,320	138

Infection status with MsMc in fishes from Tamjin-gang

MsMc were detected in 626 (56.1%) out of 1,115 fishes in positive fish species from the middle reaches in Jangheung-gun and their average density was 147 per fish infected. MsMc were found in 326 (66.4%) out of 491 fishes in positive fish species from the lower reaches in Gangjin-gun and their average density was 121 per fish infected. The infection status by the fish species and surveyed areas was detailedly revealed in Table 5.

Infection status with MsMc in the susceptible fish species from Tamjin-gang

MsMc were detected in 556 (84.1%) out of total 661 susceptible fishes from Tamjin-gang, and their average density was 227 per fish infected. The infection status by the fish species and surveyed areas was detailedly revealed in Table 6.

DISCUSSION

By the present study, it was confirmed that MsMc are more or less prevalent in fishes from Seomjin-gang and Tamjin-gang. The positive rates with MsMc were very similar, 55.4% and 59.3%, in fishes from 2 rivers, but average metacercarial densities were 96 and 138 per fish infected, higher in fishes from Tamjin-gang. We couldn't compare the endemicity of

Table 6. Infection status of *Metagonimus* spp. metacercariae in susceptible fishes from Tamjin-gang (River) in Jeollanam-do, Korea

Locality and fish sp.	No. of fish examined	No. (%) of fish infected	No. of MsMc detected	
			Range	Average
Tamjin-gang in Jangheung-gun				
Zacco platypus	138	110 (79.7)	1-140	16.3
Zacco temminckii	152	143 (94.1)	1-2,460	65.2
Carassius auratus	116	63 (54.3)	1-924	126.6
Plecoglossus altivelis	52	51 (98.1)	1-5,320	1,339
Subtotal	458	367 (80.1)	1-5,320	238
Tamjin-gang in Gangjin-gun				
Zacco platypus	75	70 (93.3)	1-58	8.1
Zacco temminckii	26	25 (96.2)	1-875	110.3
Carassius auratus	62	54 (87.1)	1-780	38.1
Plecoglossus altivelis	40	40 (100)	26-4,280	841
Subtotal	203	189 (93.1)	1-4,280	205
Total	661	556 (84.1)	1-5,320	227

Table 7. Comparison of the infection status[a] with *Metagonimus* spp. metacercariae in fishes from Seomjin-gang and Tamjin-gang

Items	Infection status of MsMc in fishes from		
	Seomjin-gang	Tamjin-gang	Total
No. (%) of fish examined	1,604 (49.3)	1,649 (50.7)	3,253 (100)
Overall positive rate (%)	889/1,604 (55.4)	952/1,649 (57.7)	1,841/3,253 (56.6)
Total metacercarial density	95.5	138.1	117.5
No. (%)[b] of rasborinids examined	613 (38.2)	391 (23.7)	1,004 (30.9)
No. (%) of rasborinids infected	547 (89.2)	348 (89.0)	895 (89.1)
MsMc density in rasborinids	73.6	41.5	61.1

[a]Positive rate: No. of fish infected/No. of fish examined×100; metacercarial density: mean No. of MsMc per fish infected.
[b]No. of rasborinid fish/Total No. of fish examined×100.

MsMc in the most susceptible fish species, sweet smelt (*P. altivelis*), so the number of fish examined (8 from Seomjin-gang and 92 from Tamjin-gang) was too much different in 2 rivers. However, their prevalences were 100% and 98.9% and densities were 5,171 and 1,120 per fish infected in sweet smelts from Seomjin-gang and Tamjin-gang each. In another MsMc susceptible fish group, rasborinid fish such as *Zacco* spp. and *O. uncirostris amurensis*, the prevalences were very similar, 89.2% and 89.0%, in 2 rivers, but average metacercarial densities were 74 and 42 per fish infected, more or less higher in Seomjin-gang (Table 7). On the other hand, in the rasborinid fish from Seomjin-gang, the prevalences were 72.4% (the upper reaches), 93.5% (the middle reaches), and 98.7% (the lower reaches), and metacercarial densities were 12.6, 38.4, and 137.2 per fish infected respectively. These findings suggested that the endemicity with MsMc is more higher in fish from the lower reaches than in fish from the upper and middle reaches of Seomjin-gang. In the susceptible fish species, i.e., *Zacco* spp., *C. auratus* and *P. altivelis*, from Tamjin-gang, the prevalence was 84.1% (80.1% in the middle reaches and 93.1% in the lower reaches) and MsMc density was 227 (238 in the middle reaches and 205 in the lower reaches) per fish infected. Therefore, the endemicity with MsMc is similar in fish from 2 surveyed sites of Tamjin-gang.

With regard to the infection status of MsMc in sweet smelts, *P. altivelis*, from Seomjin-gang and Tamjin-gang, at least 4 studies were available [4,21,22,25]. In 1977, Chai et al. [4] reported 100% prevalence and 15,688 MsMc per fish in 20 sweet smelts from a water reservoir nearby Tamjin-gang in Jangheung-gun. Seo et al. [22] detected av. 14,887 MsMc in all 16 sweet smelts from Tamjin-gang in Gangjin-gun. In 1985, Song et al. [21] reported 92.3% prevalence and 636 MsMc per fish in 12 sweet smelts from Tamjin-gang in Gangjin-gun. Cho et al. [25] detected av. 1,037 and 1,511 MsMc per fish in 16 sweet smelts from Tamjin-gang in Gangjin-gun and in 20 ones from Seomjin-gang in Gurye-gun, Jeollanam-do. Song et al. [21] also reported 2,724 and 2,412 MsMc per fish in each 5 sweet smelts from Seomjin-gang in Gokseong-gun and Gurye-gun, Jeollanam-do. In this study, all 8 sweet smelts from Seomjin-gang were infected with av. 5,171 MsMc, and 91 (98.9%) sweet smelts from Tamgin-gang were infected with 1,120 MsMc per fish infected. From the above findings of present and previous studies, we can suppose that the sweet smelts naturally produced in 2 rivers are highly infected with MsMc and the riverside areas are to be the highly endemic regions of metagonimiasis.

The rasborinid fish, i.e., *Z. platypus*, *Z. koreanus*, *Z. temminckii* and *O. uncirostris amurensis*, are known as the susceptible fish hosts of MsMc in both regions without and/or with sweet smelts in Korea. These fish species are also known as the second intermediate hosts of *M. miyatai* [9,18]. One of them, *Z. platypus*, is the most dominant species in the water systems of Korea. And then the rasborinid fish, especially *Zacco* spp., are highly recommended as the index fish of MsMc to evaluate the endemicity of metagonimiasis. In the present study, total 1004 (30.9%) rasborinid fish (613 from Seomjin-gang: 38.2% and 391 from Tamjin-gang: 23.7%) were examined, and 895 (89.1%) ones (547 in Seomjin-gang: 89.2% and 348 in Tamjin-gang: 89.0%) were to be infected with MsMc. Their density was 61.1 per fish infected (73.6 in Seomjin-gang and 41.5 in Tamjin-gang) (Table 7). In the water systems of Gangwon-do, the prevalences with MsMc were 23.5-100% (85.2% in average) in rasborinid fish and their densities were 3.4-108 (29.7 in average) in 10 surveyed areas [26]. Sohn et al. [27] reported 73.9% and 72.1% MsMc prevalences in the rasborinid fish from the water systems of Hantan-gang and Imjin-gang. They also reported av. 43.1 and 18.6 MsMc densities in the rasborinid fish from 2 surveyed areas [27]. From the aforementioned findings, we can suppose that the endemicities with MsMc in

fishes from Seomjin-gang and Tamjin-gang are more higher than those from the water systems of Gangwon-do, Hantan-gang and Imjin-gang.

Among fishes from Seomjin-gang, some rasborinid fishes, i.e., *Z. koreanus* and *Z. temminckii* from Hoengcheon and Namsancheon in Hadong-gun, *O. uncirostris amurensis* from Seomjin-gang in Gurye-gun and *Z. platypus* from Seomjin-gang in Gurye-gun and Hoengcheon in Hadong-gun, were revealed 100% prevalences and more than 100 MsMc densities. In fishes from Tamjin-gang, crusian carp, *C. auratus*, from Jangheung-gun and dark chub, *Z. temminckii*, from Gangjin-gun were highly and heavily infected with MsMc. Among fishes from the water systems of Gangwon-do, 90.0% sea rundace, *T. hakonensis*, from Namdaecheon in Yangyang-gun and 97.4% dark chub, *Z. temminckii*, from Joyang-gang in Jeongseon-gun were infected with 449 and 130 MsMc per fish infected [26]. Sohn et al. [27] reported 92.3% and 100% prevalences and 132 and 102 MsMc densities in 26 *P. esocinus* and 22 *Z. platypus* from Hantan-gang in Cheorwon-gun, Gangwon-do. These findings on the high infection status with MsMc will be helpful to perform a study on the experimental metagonimiasis to be needed massive MsMc.

More than 7 valid species have been reported in the genus *Metagonimus* flukes in the literatures. All of them mainly distributed in Asian countries such as Japan, Korea, China and Taiwan [2]. At least 3 human infecting species, i.e., *M. yokogawai*, *M. takahashii* and *M. miyatai*, are known to exist commonly in Japan and Korea [1,2]. They are morphologically differentiated in adult stage by the locations of uterus and vitellaria, and the size of eggs, but not in metacercarial stages in the fish intermediate hosts. The cercariae of *Metagonimus* spp. naturally shed from freshwater snails, *Semisulcospira coreana* and *S. libertina*, which are known as the first intermediate hosts in Korea, and they penetrate into the second intermediate hosts. As the second intermediate hosts of *Metagonimus* spp., numerous species of fish have been reported in Korea. However, some fish species are known as hosts of specific *Metagonimus* species, i.e., *P. altivelis*, *T. hakonensis* and *L. japonicus* for *M. yokogawai* [13-16]; *C. auratus*, *C. carpio*, *T. hakonensis* and *L. japonicus* for *M. takahashii* [13,16,17]; *Z. platypus* and *Z. temminckii* for *M. miyatai* [13,18]. Does each species of *Metagonimus* spp. cercariae have the host-specificity? How does each species of cercariae encyst in the favorable fish hosts only in even highly endemic environment like Seomjin-gang and Tamjin-gang? Studies on the host-specificity of each *Metagonimus* sp. in fish hosts should be clarified in the near future through the morphological analysis of adult worms recovered from experimental animals, which are infected with MsMc from some susceptible species of fish, i.e., sweet smelt, sea rundace, crusian carp, pale chub and dark chub from a same endemic area.

Conclusively, by the present study, it was confirmed that MsMc are more prevalent in fishes from Seomjin-gang and Tamjin-gang than from any other rivers in Korea. Peoples residing in riverside areas of the 2 rivers should pay attention to the raw consumption of the susceptible fish hosts like chubs, *Zacco* spp., and crusian carp, *C. auratus* as well as sweet smelt, *P. altivelis*.

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CONFLICT OF INTEREST

The authors have no conflicts of interest concerning the work reported in this paper.

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