

Infections with Digenetic Trematode Metacercariae in Freshwater Fishes from Two Visiting Sites of Migratory Birds in Gyeongsangnam-do, Republic of Korea

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Abstract: The infection status of digenetic trematode metacercariae (DTM) was investigated in fishes from 2 representative visiting sites of migratory birds in Gyeongsangnam-do, the Republic of Korea (Korea). A total of 220 freshwater fishes (7 species) were collected from Junam-jeosuji (reservoir), and 127 fishes (7 species) were also collected from Woopo-neup (swamp) in June and October 2017. As the control group, total 312 fish (22 spp.) from Yangcheon in Sancheong-gun, Gyeongsangnam-do were also collected in June and October 2017. All fishes collected in 3 sites were examined with the artificial digestion method. In the fishes from Junam-jeosuji, more than 4 species, i.e., *Clonorchis sinensis*, *Echinostoma* spp., *Diplostomum* spp. and *Cyathocotyle orientalis*, of DTM were detected and their endemicity was very low, 0.70. More than 6 species, i.e., *C. sinensis*, *Echinostoma* spp., *Metorchis orientalis*, *Clinostomum complanatum*, *Diplostomum* spp. and *C. orientalis*, of DTM were found in the fishes from Woopo-neup, and their endemicity was low, 5.16. In the fishes from Yangcheon, more than 8 species, i.e., *C. sinensis*, *Metagonimus* spp., *Centrocestus armatus*, *C. complanatum*, *C. orientalis*, *M. orientalis*, *Echinostoma* spp., and *Diplostomum* spp., of DTM were detected, and their endemicity was relatively high, 95.48. The percentages of avian trematode metacercariae (ATM) were 99.6% and 94.7% in fishes from Junam-jeosuji and Woopo-neup whereas it was 74.1% in the control site, Yangcheon. The above findings suggested that migratory birds partly affect in endemicity of DTM in the fish in the 2 visiting sites in Gyeongsangnam-do, Korea.

Key words: Migratory bird, digenetic trematode, metacercariae, Junam-jeosuji, Woopo-neup, Yangcheon

INTRODUCTION

Numerous species of avian trematodes have been reported in the Republic of Korea (Korea). Most of them are the members of family Echinostomatidae, Microphallidae, and Gymnophallidae. More than 14 species of echinostomatid flukes, i.e., *Acanthoparyphium marilae*, *A. tyosenense*, *Echinochasmus japonicus*, *Echinoparyphium recurvatum*, *Echinostoma gotoi*, *E. miyagawai*, *E. revolutum*, *Himasthla kususigi*, *Patagifer bilobus*, *Petasiger neocomense*, *Saakotrema metatestis*, *Pegosomum bubulcum*, *Nephrostomum ramosum* and *Chaunocephalus ferox*, were detected from the various species of bird in Korea [1-10]. Total 6 species of microphallid (*Microphallus koreana*, *Gynaecotyla squatarolae*, *Maritrema jebuensis*, *M. obstipum*, *Endocotyle incana*

and *Spelotrema pseudogonocotyla*) [11-14], and 4 species of gymnophallid flukes (*Gymnophalloides seoi*, *Gymnophallus macrostoma*, *Parvatrema duboisi* and *P. homoeotecnium*) [15-17] were reported as avian trematodes in Korea. On the other hand, it has been known that several species of avian trematode, i.e., *Centrocestus armatus*, *Cyathocotyle orientalis*, *Holostephanus nipponicus*, *Clinostomum complanatum*, *Metorchis orientalis*, *M. taiwanensis* and *Diplostomum* spp., metacercariae are frequently detected in the freshwater fishes in Korea [18-21].

Junam-jeosuji (a reservoir in Dong-eup, Changwon-si) and Woopo-neup (a swamp in Changnyung-gun) in Gyeongsangnam-do, are famous as the visiting sites of migratory birds in Winter season. More than 20 species of migratory birds from China, Siberia and so on winter until late in March [22]. The specific ecological condition, such as the massive visiting of various migratory birds, may be affected the avian trematode fauna in 2 sites. On the other hand, many Korean workers have been investigated the infection status with digenetic trematode metacercariae (DTM) including *Clonorchis sinensis* in fishes from various ecological environments, such as river,

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stream, lake, pond, swamp and even coast, to estimate the DTM endemicities [18-21,23-29]. Most of these studies were performed on the specific trematode species related with human infections, such as *C. sinensis*, heterophyid including *Metagonimus yokogawai* and echinostomatid flukes, in Korea [23-29]. However, there have been not so many studies on the avian trematode metacercariae (ATM) in fishes from the visiting sites of migratory birds in Korea. Moreover, the infection status of DTM in fishes from Junam-jeosuji and Woopo-neup was surveyed in a long time ago [30-32]. Therefore, we are going to focus on the infection status of ATM in 2 representative visiting sites of migratory birds, Junam-jeosuji and Woopo-neup, with a comparison of that in control site, Yangcheon, in Gyeongsangnam-do, Korea.

MATERIALS AND METHODS

Main survey (fish collection) sites were Junam-jeosuji in Dong-eup (eup=town) (35.313588; 128.666354), Changwon-si (si=city), Gyeongsangnam-do (do=province), and Woopo-neup in Ibang-myeon (myeon=township) (35.566238; 128.408215), Changnyeong-gun (gun=county), Gyeongsangnam-do, Korea. Total 220 fishes (7 spp.) from Junam-jeosuji were examined in June and October 2017. Fish species (No. of fish) examined were *Erythroculter erythropterus* (52), *Lepomis macrochirus* (52), *Hemiculter eigenmanni* (46), *Cyprinus carpio* (26), *Acanthorhodeus gracilis* (20), *Carassius auratus* (12), *Micropterus salmoides* (12). A total of 127 fishes (7 spp.) from Woopo-neup were examined in October 2017. Fish species (No. of fish) examined were *Pseudorasbora parva* (40), *L. macrochirus* (28), *C. auratus* (20), *E. erythropterus* (16), *M. salmoides* (15), *H. eigenmanni* (6), *C. carpio* (2).

As the control group, total 312 fish (22 spp.) from Yangcheon in Saengbiryang-myeon (35.355960; 128.056635), Sanchong-gun, Gyeongsangnam-do were also examined in June and October 2017. Fish species (No. of fish) examined were *M. salmoides* (36), *Acheilognathus yamatsutae* (31), *Acheilognathus majusculus* (30), *Zacco platypus* (27), *L. macrochirus* (25), *C. auratus* (21), *Zacco temminckii* (20), *A. gracilis* (20), *Zacco koreanus* (20), *Pseudogobio esocinus* (15), *Squalidus japonicus coreanus* (15), *Pungtungia herzi* (12), *Coreoperca herzi* (9), *Acheilognathus rhombus* (7), *Hemibarbus labeo* (6), *Hemibarbus longirostris* (5), *Odontobutis platycephala* (4), *Squalidus gracilis majimae* (3), *Acheilognathus koreensis* (2), *Acanthorhodeus macropterus* (2), *Sarcocheilichthys nigripinnis morii* (1), *Sarcocheilichthys variegatus*

wakiyae (1).

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. Each ground fish meat was mixed with artificial gastric juice and the mixture was incubated at 36°C for about 2 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. Digenetic trematode metacercariae (DTM) except for 3 species, i.e., *Metacercaria hasegawai*, *Exorchis oviformis* and *Pseudoexorchis major*, were separately collected by the general features [33], and they were counted to get hold of infection rates (%) and intensities (No. of DTM per fish infected) by fish species.

The endemicity of DTM was calculated by the Positive Rate in Fish Species (PRFS: No. of fish species infected/Total No. of fish species examined) × the Positive Rate in Positive Fish Species (PRPFS: No. of positive fish/total No. of fish in positive fish species examined) × the Intensity of Metacercariae Per a Positive Fish (IMPPF: Total No. of metacercariae detected/total No. of positive fish). The endemicity of avian trematode metacercariae (ATM) was calculated by the endemicity of ATM/total endemicity of DTM by the surveyed site × 100. More than 7 species, i.e., *C. armatus*, *C. complanatum*, *C. orientalis*, *M. orientalis*, *M. taiwanensis* *Echinostoma* spp. and *Diplostomum* spp., of DTM were treated as the ATM in this study.

RESULTS

In fishes from Junam-jeosuji, more than 4 species, i.e., *C. sinensis*, *Echinostoma* spp., *Diplostomum* sp. and *C. orientalis*, of DTM were detected, and their infection status by the fish species is detailedly shown in Table 1. More than 6 species, i.e., *C. sinensis*, *Echinostoma* spp., *Diplostomum* spp., *C. orientalis*, *M. orientalis* and *C. complanatum*, of DTM were found in fishes from Woopo-neup, and their infection status by the fish species is detailedly designated in Table 2. Unidentified echinostomatid metacercariae were dominant and commonly detected in all 7 fish species from 2 survey sites. Most of them were elliptical, 138-210 (162) × 103-150 (127) μm in size and had a head crown equipped with 27 collar spines including 4 end-group ones in each side like those of *Isthmiophora hortensis* (Fig. 1).

In fishes from Yangcheon (control site), more than 8 spe-

Table 1. Infection status of trematode metacercariae by fish species caught from Junam-jeosuji (reservoir) in Changwon-si, Gyeong-sangnam-do, Korea

Trematode Fish sp. infected	No. of fish examined	No. of fish infected (%)	No. of metacercariae detected	
			Range	Average
<i>Clonorchis sinensis</i>				
<i>Hemiculter eigenmanni</i>	46	1 (2.2)	-	1.0
<i>Echinostoma</i> spp.				
<i>Erythroculter erythropterus</i>	52	7 (13.5)	1-103	16.6
<i>Lepomis macrochirus</i>	52	19 (36.5)	1-10	2.6
<i>Hemiculter eigenmanni</i>	46	8 (17.4)	1-7	2.6
<i>Cyprinus carpio</i>	26	4 (15.4)	1-6	2.3
<i>Acanthorhodeus gracilis</i>	20	19 (95.0)	1-49	10.7
<i>Carassius auratus</i>	12	9 (75.0)	1-14	8.3
<i>Micropterus salmoides</i>	12	11 (91.7)	1-103	8.7
Subtotal	220	77 (35.0)	1-103	8.7
<i>Diplostomum</i> spp.				
<i>Erythroculter erythropterus</i>	52	5 (9.6)	1-3	1.6
<i>Lepomis macrochirus</i>	52	1 (1.9)	-	1.0
<i>Hemiculter eigenmanni</i>	46	10 (21.7)	1-16	3.6
<i>Acanthorhodeus gracilis</i>	20	1 (5.0)	-	1.0
Subtotal	170	17 (10.0)	1-16	2.7
<i>Cyathocotyle orientalis</i>				
<i>Hemiculter eigenmanni</i>	46	2 (4.3)	1-2	1.5

Table 2. Infection status of trematode metacercariae by fish species caught Woopo-neup (swamp) in Changnyung-gun, Gyeongsang-nam-do, Korea

Trematode fish sp. infected	No. of fish examined	No. of fish infected (%)	No. of metacercariae detected	
			Range	Average
<i>Clonorchis sinensis</i>				
<i>Pseudorasbora parva</i>	40	11 (27.5)	1-17	4.6
<i>Hemiculter eigenmanni</i>	6	2 (33.3)	-	1.0
Subtotal	46	13 (28.3)	1-17	4.1
<i>Echinostoma</i> spp.				
<i>Pseudorasbora parva</i>	40	38 (95.0)	1-145	25.7
<i>Lepomis macrochirus</i>	28	20 (71.4)	1-9	3.1
<i>Carassius auratus</i>	20	18 (90.0)	1-58	17.4
<i>Erythroculter erythropterus</i>	16	13 (81.3)	1-25	10.2
<i>Micropterus salmoides</i>	15	13 (86.7)	1-23	10.1
<i>Hemiculter eigenmanni</i>	6	4 (66.7)	1-6	3.0
<i>Cyprinus carpio</i>	2	2 (100)	125-132	128.5
Subtotal	127	108 (85.0)	1-145	17.5
<i>Metorchis orientalis</i>				
<i>Pseudorasbora parva</i>	40	30 (75.0)	1-11	2.7
<i>Micropterus salmoides</i>	15	1 (6.7)	-	2.0
Subtotal	55	31 (56.4)	1-11	2.7
<i>Clinostomum complanatum</i>				
<i>Pseudorasbora parva</i>	40	3 (7.5)	1-2	1.7
<i>Diplostomum</i> spp.				
<i>Pseudorasbora parva</i>	40	28 (70.0)	1-7	2.4
<i>Lepomis macrochirus</i>	28	1 (3.6)	-	2.0
<i>Carassius auratus</i>	20	3 (15.0)	1-4	2.3
<i>Erythroculter erythropterus</i>	16	8 (50.0)	1-5	2.4
<i>Hemiculter eigenmanni</i>	6	2 (33.3)	-	1.0
<i>Cyprinus carpio</i>	2	1 (50.0)	-	6.0
Subtotal	112	43 (38.4)	1-7	2.4
<i>Cyathocotyle orientalis</i>				
<i>Pseudorasbora parva</i>	40	40 (100)	7-252	60.1
<i>Micropterus salmoides</i>	15	3 (20.0)	1-6	2.7
<i>Hemiculter eigenmanni</i>	6	1 (16.7)	-	1.0
Subtotal	61	44 (72.1)	1-252	54.8

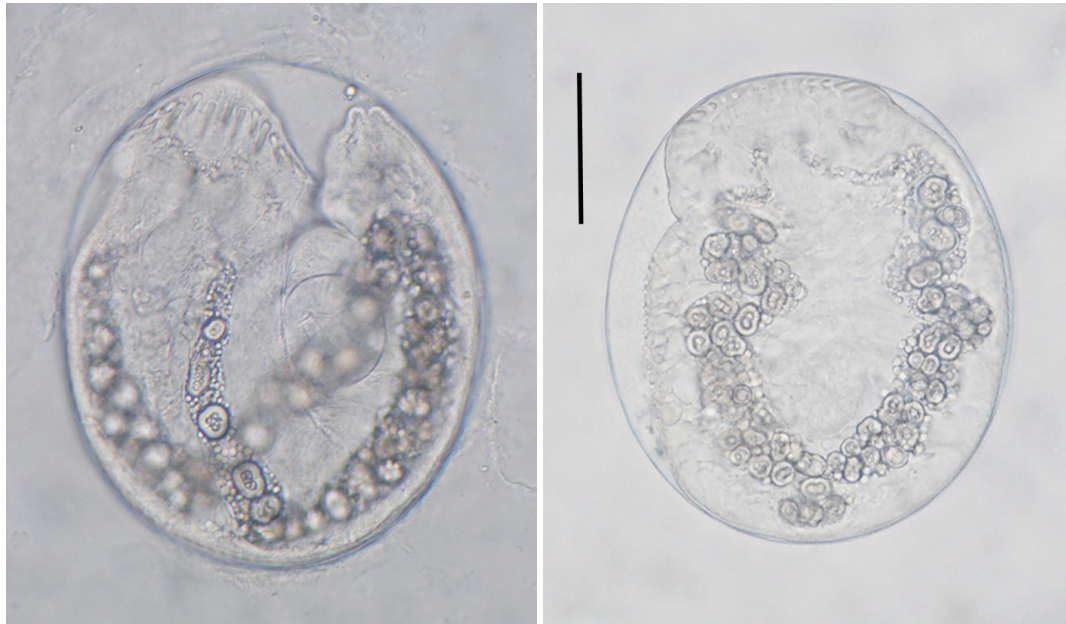


Fig. 1. Two echinostomatid metacercariae detected in a false dace, *Pseudorasbora parva*, from Woopo-neup in Changnyeong-gun, Gyeongsangnam-do, Korea. They were elliptical, 138-210 (162) × 103-150 (127) μm in size and had a head crown equipped with 27 collar spines including 4 end-group ones in each sides. Scale bar is 50 μm.

cies, i.e., *C. sinensis*, *Metagonimus* spp., *C. armatus*, *C. complanatum*, *C. orientalis*, *M. orientalis*, *Echinostoma* spp., and *Diplostomum* spp., of DTM were detected, and their infection status by the fish species is detailedly revealed in Table 3.

The overall DTM endemicities were 0.70 and 5.16 in fishes from Junam-jeosuji and Woopo-neup, whereas it was 95.48 in the control site, Yangcheon. In Junam-jeosuji, the endemicity of *Echinostoma* spp. (3.045) was most high and those of remains were relatively very low. In Woopo-neup, the endemicities of *C. orientalis* (16.950) and *Echinostoma* spp. (14.875) was relatively high and those of remains were below 1.0. Whereas in Yangcheon, the endemicity of *C. armatus* (531.311) was very high, those of *C. sinensis* (23.408) and *C. orientalis* (21.028) were moderate levels and those of remains were relatively low. The endemicities with DTM by the surveyed localities are detailedly designated in Table 4. The percentages of ATM were 99.6% and 94.7% in fishes from Junam-jeosuji and Woopo-neup, whereas it was 74.1% in the control site, Yangcheon.

DISCUSSION

The number of fish species examined were not so enough to evaluate DTM infections in 2 survey sites in this study. Among 7 fish species (total No. of fish) examined in each surveyed

sites, 6 ones, i.e., *L. macrochirus* (80), *E. erythropterus* (68), *H. eigenmanni* (52), *C. auratus* (32), *C. carpio* (28), and *M. salmoides* (27), were commonly investigated, and remain each one was *A. gracilis* (20) in Junam-jeosuji and *P. parva* (40) in Woopo-neup. Therefore, in this study, we examined total 347 fish in 8 species from 2 visiting sites of migratory birds and a total of 312 fish in 22 species from the control site, Yangcheon, in Sancheong-gun, Gyeongsangnam-do. The smaller number of fish species in the 2 main survey sites than in the control site is strongly suggested that the ecology for fish is not so good in 2 survey sites, Junam-jeosuji and Woopo-neup. The bad condition of fish ecology was revealed in the previous studies. Han et al. [30] examined total 7 fish species, *P. parva* (301), *E. erythropterus* (113), *Rhodeus uyekii* (44), *Rhodeus ocellatus* (9), *Gnathopogon atramaculatus* (= *G. striatus*) (6), *C. carassius* (= *C. auratus*) (2) and *Acanthorhodeus taenianalis* (= *A. macropterus*) (2), from Junam-jeosuji in 1992. Kong and Choi [31] investigated DTM infections in 8 fish species, *G. atramaculatus* (61), *A. taenianalis* (33), *P. parva* (29), *C. carassius* (22), *Zacco platypus* (20), *Microphysogobio koreensis* (19), *R. uyekii* (16) and *Zacco temminckii* (8), from Woopo-neup. Sohn and Choi [32] also examined on the infection status of DTM in 5 fish species, *H. eigenmanni* (45), *P. parva* (25), *E. erythropterus* (20), *A. macropterus* (20), and *C. auratus* (20), from Junam-jeosuji. The exotic

Table 3. Infection status of trematode metacercariae by fish species caught from Yangcheon (stream) in Sancheong-gun, Gyeongsang-nam-do, Korea

Trematode fish sp. infected	No. of fish examined	No. of fish infected (%)	No. of metacercariae detected	
			Range	Average
<i>Clonorchis sinensis</i>				
<i>Acheilognathus yamatsutae</i>	31	21 (67.7)	1-12	3.3
<i>Acheilognathus majusculus</i>	30	16 (53.3)	1-10	2.6
<i>Zacco platypus</i>	27	4 (14.8)	1-2	1.8
<i>Lepomis macrochirus</i>	25	1 (4.0)	-	1.0
<i>Acanthorhodeus gracilis</i>	20	18 (90.0)	1-59	17.1
<i>Pseudogobio esocinus</i>	15	15 (100)	11-124	37.9
<i>Squalidus japonicus coreanus</i>	15	15 (100)	15-364	133.7
<i>Pungtungia herzi</i>	12	12 (100)	40-45	40-451
<i>Acheilognathus rhombeus</i>	7	6 (85.7)	1-34	11.8
<i>Hemibarbus labeo</i>	6	5 (83.3)	1-6	2.4
<i>Hemibarbus longirostris</i>	5	4 (80.0)	1-8	2.8
<i>Squalidus gracilis majimae</i>	3	3 (100)	32-195	86.7
<i>Acheilognathus koreensis</i>	2	2 (100)	1-3	2.0
<i>Acanthorhodeus macropterus</i>	2	2 (100)	4-7	5.5
<i>Sarcocheilichthys nigripinnis</i>	1	1 (100)	-	172.0
<i>Sarcocheilichthys variegatus</i>	1	1 (100)	-	208.0
Subtotal	202	126 (62.4)	1-451	51.6
<i>Metagonimus</i> spp.				
<i>Micropterus salmoides</i>	36	2 (5.6)	-	1.0
<i>Acheilognathus yamatsutae</i>	31	4 (12.9)	-	1.0
<i>Zacco platypus</i>	27	15 (55.6)	1-17	3.2
<i>Lepomis macrochirus</i>	25	13 (52.0)	1-11	2.5
<i>Carassius auratus</i>	21	21 (100)	2-39	14.4
<i>Zacco temminckii</i>	20	11 (55.0)	1-3	1.6
<i>Acanthorhodeus gracilis</i>	20	5 (25.0)	1-2	1.4
<i>Zacco koreanus</i>	20	15 (75.0)	1-10	3.8
<i>Squalidus japonicus coreanus</i>	15	6 (40.0)	1-4	1.8
<i>Pungtungia herzi</i>	12	7 (58.3)	1-6	1.9
<i>Hemibarbus longirostris</i>	5	2 (40.0)	1-3	2.0
<i>Squalidus gracilis majimae</i>	3	3 (100)	1-7	3.3
<i>Sarcocheilichthys nigripinnis</i>	1	1 (100)	-	1.0
<i>Sarcocheilichthys variegatus</i>	1	1 (100)	-	1.0
Subtotal	237	106 (44.7)	1-39	4.8
<i>Centrocestus armatus</i>				
<i>Micropterus salmoides</i>	36	1 (2.8)	-	1.0
<i>Acheilognathus yamatsutae</i>	31	6 (19.4)	1-2	1.2
<i>Zacco platypus</i>	27	27 (100)	526-9,860	3,330
<i>Carassius auratus</i>	21	7 (33.3)	1-6	2.7
<i>Zacco temminckii</i>	20	20 (100)	252-7,315	2,738
<i>Acanthorhodeus gracilis</i>	20	6 (30.0)	1-17	5.3
<i>Zacco koreanus</i>	20	20 (100)	1,030-17,330	5,555
<i>Squalidus japonicus coreanus</i>	15	1 (6.7)	-	1.0
<i>Acheilognathus rhombeus</i>	1 (14.3)	1 (14.3)	-	1.0
Subtotal	197	89 (45.2)	1-17,330	2,874
<i>Echinostoma</i> spp.				
<i>Micropterus salmoides</i>	36	10 (27.8)	1-16	4.0
<i>Acheilognathus yamatsutae</i>	31	2 (6.5)	-	1.0
<i>Acheilognathus majusculus</i>	30	1 (3.3)	-	2.0
<i>Acanthorhodeus gracilis</i>	20	8 (40.0)	1-6	1.9
<i>Pseudogobio esocinus</i>	15	1 (6.7)	-	5.0
<i>Squalidus japonicus coreanus</i>	15	2 (13.3)	2-4	3.0
<i>Pungtungia herzi</i>	12	3 (25.0)	2-12	6.7
<i>Acheilognathus rhombeus</i>	7	2 (28.6)	-	1.0
<i>Hemibarbus longirostris</i>	5	3 (60.0)	1-2	1.3
Subtotal	171	32 (18.7)	1-16	3.0

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Table 3. Continued

Trematode fish sp. infected	No. of fish examined	No. of fish infected (%)	No. of metacercariae detected	
			Range	Average
<i>Clinostomum complanatum</i>				
<i>Acheilognathus yamatsutae</i>	31	23 (74.2)	1-28	5.6
<i>Acheilognathus majusculus</i>	30	23 (76.7)	1-52	17.1
<i>Zacco platypus</i>	27	6 (22.2)	1-15	7.7
<i>Carassius auratus</i>	21	1 (4.8)	-	1.0
<i>Zacco temminckii</i>	20	5 (25.0)	1-7	2.6
<i>Acanthorhodeus gracilis</i>	20	10 (50.0)	16-253	57.1
<i>Zacco koreanus</i>	20	9 (45.0)	1-14	7.7
<i>Squalidus japonicus coreanus</i>	15	15 (100)	1-108	31.4
<i>Pungtungia herzi</i>	12	11 (91.7)	1-73	19.2
<i>Acheilognathus rhombeus</i>	7	3 (42.9)	4-50	24.0
<i>Hemibarbus labeo</i>	6	2 (33.3)	2-5	3.5
<i>Hemibarbus longirostris</i>	5	3 (60.0)	-	1.0
<i>Squalidus gracilis majimae</i>	3	1 (33.3)	-	1.0
<i>Acheilognathus koreensis</i>	2	2 (100)	7-33	20.0
<i>Acanthorhodeus macropterus</i>	2	2 (100)	8-9	8.5
Subtotal	221	116 (52.5)	1-253	17.6
<i>Metorchis orientalis</i>				
<i>Acheilognathus majusculus</i>	30	2 (6.7)	1-2	1.5
<i>Acanthorhodeus gracilis</i>	20	1 (5.0)	-	1.0
<i>Pseudogobio esocinus</i>	15	2 (13.3)	-	1.0
<i>Pungtungia herzi</i>	12	9 (75.0)	1-8	3.4
Subtotal	77	14 (18.2)	1-8	2.6
<i>Diplostomum</i> spp.				
<i>Acheilognathus yamatsutae</i>	31	5 (16.1)	1-2	1.2
<i>Acheilognathus majusculus</i>	30	3 (10.0)	1-2	1.3
<i>Zacco temminckii</i>	20	1 (5.0)	-	1.0
<i>Acanthorhodeus gracilis</i>	20	1 (5.0)	-	1.0
<i>Pseudogobio esocinus</i>	15	5 (33.3)	1-5	2.8
<i>Squalidus japonicus coreanus</i>	15	4 (26.7)	1-6	3.0
<i>Acheilognathus rhombeus</i>	7	1 (14.3)	-	1.0
<i>Acheilognathus koreensis</i>	2	2 (100)	-	1.0
Subtotal	140	22 (15.7)	1-6	1.9
<i>Cyathocotyle orientalis</i>				
<i>Acheilognathus yamatsutae</i>	31	22 (71.0)	1-46	7.5
<i>Acheilognathus majusculus</i>	30	23 (76.7)	1-35	8.4
<i>Zacco platypus</i>	27	6 (22.2)	1-4	2.5
<i>Lepomis macrochirus</i>	25	1 (4.0)	-	1.0
<i>Zacco temminckii</i>	20	18 (90.0)	1-10	3.3
<i>Acanthorhodeus gracilis</i>	20	13 (65.0)	1-24	7.2
<i>Zacco koreanus</i>	20	20 (100)	1-93	31.2
<i>Pseudogobio esocinus</i>	15	11 (73.3)	1-17	5.7
<i>Squalidus japonicus coreanus</i>	15	14 (93.3)	1-57	13.6
<i>Pungtungia herzi</i>	12	12 (100)	3-1,698	440.3
<i>Acheilognathus rhombeus</i>	7	5 (71.4)	2-30	10.4
<i>Hemibarbus labeo</i>	6	2 (33.3)	1-2	1.5
<i>Hemibarbus longirostris</i>	5	3 (60.0)	1-86	29.3
<i>Acheilognathus koreensis</i>	2	2 (100)	1-7	4.0
<i>Sarcocheilichthys nigripinnis</i>	1	1 (100)	-	1.0
<i>Sarcocheilichthys variegatus</i>	1 (100)	1 (100)	-	5.0
Subtotal	237	154 (65.0)	1-1,698	44.5

predatory fish, *L. macrochirus* and *M. salmoides*, and the big-sized fish, *E. erythropterus* and *H. eigenmanni*, were dominant in this study. Whereas, all fish examined were the native fish species and *P. parva* and *E. erythropterus* were dominant in the previous studies [30-32].

In the calculating formula of DTM endemicity, PRFS (the positive rate in fish species) was originated without the consideration of host-specificity between trematode larvae (cercariae) and fish species. The list of fish host for each DTM has not been known yet in Korea except some human trematodes in-

Table 4. Endemicity of digenetic trematode metacercariae in fishes from 3 subjected sites in Gyeongsangnam-do, Korea

Locality/Trematode metacercariae	PRFS ^a	PRPFS ^b	IMPPF ^c	Endemicity ^d
Junam-jeosuji				
<i>Clonorchis sinensis</i>	0.143	0.022	1.0	0.003
<i>Echinostoma</i> spp.	1.0	0.35	8.7	3.045
<i>Diplostomum</i> spp.	0.57	0.10	2.7	0.154
<i>Cyathocotyle orientalis</i>	0.143	0.043	1.5	0.009
Subtotal	0.46	0.201	7.4	0.70
Woopo-neup				
<i>Clonorchis sinensis</i>	0.286	0.283	4.1	0.332
<i>Echinostoma</i> spp.	1.0	0.85	17.5	14.875
<i>Diplostomum</i> spp.	0.857	0.384	2.4	0.790
<i>Cyathocotyle orientalis</i>	0.429	0.721	54.8	16.950
<i>Metorchis orientalis</i>	0.286	0.564	2.7	0.436
<i>Clinostomum complanatum</i>	0.143	0.075	1.7	0.018
Subtotal	0.50	0.549	18.8	5.16
Yangcheon				
<i>Clonorchis sinensis</i>	0.727	0.624	51.6	23.408
<i>Metagonimus</i> spp.	0.636	0.447	4.8	1.365
<i>Centrocestus armatus</i>	0.409	0.452	2,874	531.311
<i>Echinostoma</i> spp.	0.409	0.187	3.0	0.229
<i>Clinostomum complanatum</i>	0.682	0.525	17.6	6.302
<i>Metorchis orientalis</i>	0.182	0.182	2.6	0.086
<i>Diplostomum</i> spp.	0.364	0.157	1.9	0.109
<i>Cyathocotyle orientalis</i>	0.727	0.650	44.5	21.028
Subtotal	0.52	0.445	412.6	95.48

^aPRFS (Positive Rate of Fish Species/100: No. of fish species positive/total No. of fish species examined).

^bPRPFS (Positive Rate in Positive Fish Species/100: No. of positive fish/total No. in positive fish species examined).

^cIMPPF (Intensity of Metacercariae Per a Positive Fish: Total No. of metacercariae detected/total No. of positive fish).

^da × b × c.

cluding *C. sinensis*. In this study, we evenly applied PRFS as a factor of all DTM endemicity regardless of the host-specificity. The DTM endemicity, PRFS×PRPFS×IMPPF, is thought to be the more reasonable index to compare the endemicities of individual trematode species and specific trematode groups in a certain survey site. Undoubtedly, it is not to be an absolute index, shows a kind of trend for DTM infections, and its standard is changeable according to the trematode species.

Among the 24 avian trematodes reported in Korea, microphallid and gymnophallid flukes have no possibility to infect via the consumption of freshwater fish. Microphallid flukes, i.e., *M. koreana*, *G. squatarolae*, *M. jebuensis*, *M. obstipum*, *E. incana* and *S. pseudogonocotyla*, are to be mainly infected with the eatings of crustacean intermediate hosts like crabs [11-14]. Gymnophallids, i.e., *G. seoi*, *G. macrostoma*, *P. duboisi* and *P. homoeotectum*, are mainly infected in clam-eating birds [15-17]. However, echinostomatid ones are known to be infected with the consumption of fish and molluscs including snails [1-10]. In this study, unidentified echinostomatid metacercariae were dominantly detected in all fish species from 2 survey sites. They were elliptical, 162×127 μm in average size and morphologically very similar with those of *I. hortensis*. The

metacercariae of *I. hortensis* previously reported were globular or elliptical, 143-165 (154) by 128-158 (144) μm in size, and have 27 collar spines including 4 end group ones in each side of the head crown [29]. However, most of echinostomatid metacercariae detected were inactive in the cyst wall, and then we could not obtain the adult worms from hamsters experimentally infected with them. Reason why the echinostomatid metacercariae are dominant in fishes from 2 survey sites should be clarified with the recovery and identification of adults in near future.

The metacercariae of *C. sinensis* (CsMc) were detected in only 2 fish species, *P. parva* and *H. eigenmanni* from the 2 main survey sites and their prevalence and intensity were very low in this study. Han et al. [30] found them in 2 fish species, *G. atromaculatus* and *P. parva*, from Junam-jeosuji, Kong and Choi [31] detected CsMc in 4 fish species, *G. atromaculatus*, *P. parva*, *M. koreensis* and *A. taenianalis*, from Woopo-neup and Sohn and Choi [32] also found them in 4 fish species, *H. eigenmanni*, *P. parva*, *E. erythropterus* and *A. macropterus*, from Junam-jeosuji. In previous studies, there are some differences in prevalences and intensities of CsMc, but their endemicity is not so high in fishes from 2 survey sites.

Conclusively, it was confirmed by the present study that the proportions of ATM are higher in fishes from 2 visiting sites of migratory birds, Junam-jeosuji and Woopo-neup, in Gyeongsangnam-do, Korea. However, overall DTM endemicities were very low in fishes from 2 survey sites when we compared with that in fishes from the control site, Yangcheon. These findings partly suggested that the specific ecological condition, the massive visiting of migratory birds, is to be affected the endemicity of avian trematodes. However, some environmental factors, i.e., the bad fish ecology with agitating of exotic fish species like blue gill and large mouth bass, a long-lasting drought and a remarkable propagation of water plants, may be acted as the limited points in this study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

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