INTRODUCTION

Members in the genus *Metagonimus* Katsurada, 1912 (Digena: 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 ([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), Chungcheongbuk-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 crucian 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].

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.), Songdaechean 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 Nampancheon (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. Endemities 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

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intermediate hosts of *M. miyutai*, many species of fish, including the sea rondeal, 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]. Only few studies were performed on the infection status of *ZT* metacercariae in freshwater fish from the water systems of Hantan-gang and Imjin-gang located in relatively northern regions of Korea. Sohn et al. [27] investigated the infection status of *ZT* metacercariae in freshwater fish from the upper reaches of 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 Insil-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 Nam-sancheon (35.095020; 127.798093) in Hadong-gun, Gyeng-sangnam-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 (2012-2016) and total 517 fishes (17 species) in the lower reaches of Tamjin-gang in Gangjin-gun (Latitude: 34.830531; Longitude: 126.485115), Jeollanam-do, Korea in 2014 and 2017.

**Fishes examined in the upper reaches of Seomjin-gang**

Total 236 freshwater fish (11 species) from Osucheon in Insil-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* (11) 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), *Coreleuciscus splendidus* (4), *Acheilognathus yamatsutae* (3), *Abbottina springeri* (3), *Cobitis tetralini-

**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 |
|-----------------------|-----------------------|--------------------------|----------------------|
| **Osucheon in Insil-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 |
| *Opsanichthys 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 |
| *Opsanichthys uncirostris* | 14 | 14 (100) | 1-45 | 9.9 |
| *Carassius auratus* | 14 | 1 (7.1) | - | 5.0 |
| *Sarcochilichthys vanegatus* | 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 majmae* | 6 | 1 (16.7) | - | 1.0 |
| *Acanthorhodeus gracilis* | 6 | 5 (83.3) | 7-40 | 16.2 |
| *Granhoplogen striatus* | 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 |
| *Plecostomus altivelis* | 3 | 3 (100) | 282-6,750 | 3,146 |
| *Cyprinus carpio* | 2 | 1 (50.0) | - | 1.0 |
| *Hemiculter leuciscus* | 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), Acanthorhodes 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), Ilsookimia longicorpus (1), and Lepomis macrochirus (1) including 8 ones with MsMc in Table 2. Total 289 freshwater fish (15 species) from Seomjingang

Table 2. Infection status of Metagonimus spp. metacercariae in freshwater fish from the middle reaches of Seomjingang (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  |         |
| Rhyynochopris oxycephalus | 21               | 1 (4.8)                    | -                    | 1.0   |         |
| Microphysogobio koreensis | 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 majumae | 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   |         |
| Sarcocelichthys variogatus | 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 koreensis | 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   |         |
| Plectoglossus altivales | 2                   | 2 (100)                    | 1,370-4,380          | 2,875 |         |
| Hemibarbus labo        | 2                    | 2 (100)                    | 2-9                  | 5.5   |         |
| Opsarichthys amurenensis | 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  |         |

in Gokseong-gun, Jeollanam-do were examined in 2015 and 2016. Fish species (No. of fish) examined were Lepomis macrochirus (1) including 14 ones with MsMc in Table 2.

Fishes examined in the lower reaches of Seomjingang

Total 183 freshwater fish (21 species) from Seomjingang in Gurye-gun, Jeollanam-do were examined in 2014. Fish species (No. of fish) examined were C. herzi (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 (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 until 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.
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., Songdacheon 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, Hoengcheon and Namsancheon in Hadong-gun, Gyeongsangnam-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.

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)                 | 1-520 126.3          |
| 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 nigripinis | 14           | 13 (92.9)                | 1-52 13.6            |
| Opsariichthys uncirostris | 13               | 13 (100)                 | 52-495 143.8         |
| Acheilognathus rhombesus | 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 majinae | 8                | 5 (62.5)                 | 1-2 1.4              |
| Pseudogobio esocinus | 7                    | 7 (100)                  | 6-62 28.1            |
| Micropterygobio koreanus | 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                |
| Pseudogobio esocinus | 3                    | 3 (100)                  | 6,280-10,750 8,727   |
| Subtotal              | 170                  | 134 (78.8)               | 1-10,750 246.5       |
| Hoengcheon in Hadong-gun |                      |                          |                      |
| Zacco platypus       | 27                   | 27 (100)                 | 2-1,510 115.3        |
| Acheilognathus coreanae | 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 korensa        | 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 splendicus | 4               | 3 (75.0)                 | - 1.0                |
| Squalidus gracilis majinae | 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 | 52                   | 4 (8.7)                  | 1-2 1.3              |
| Zacco platypus       | 42                   | 41 (100)                 | 3-101 27.4           |
| Pungtungia herzi     | 35                   | 7 (20.0)                 | 1-7 2.3              |
| Hemibarbus longirostris | 35               | 14 (7.1)                 | - 1.0                |
| Zacco temminckii     | 14                   | 11 (100)                 | 2-580 104.5          |
| Squalidus gracilis majinae | 3              | 3 (33.3)                 | - 1.0                |
| Subtotal              | 207                  | 122 (58.9)               | 1-2,860 67.5         |
| Total                 | 523                  | 363 (69.4)               | 1-10,750 165         |

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 (90.9)                | 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        |
| Opsariichthys amurensis | 21                 | 21 (100)                 | 2-580 129.2          |
| 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.

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

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**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 temmincki       | 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     | 54                   | 17 (31.5)                | 1-7                  | 2.0   |
| variatus               |                       |                          |                      |       |
| 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      | 29                   | 6 (13.3)                | 1-32                 | 8.3   |
| nigripinnis            |                       |                          |                      |       |
| 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 scherzi      | 6                    | 1 (16.7)                | -                    | 1.0   |
| Hemiculter eigenmanni  | 6                    | 2 (33.3)                | -                    | 4.0   |
| Squalius gracilis majiiae| 3              | 3 (100)                 | 1-5                  | 2.7   |
| Subtotal               | 1,155                | 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      | 33                   | 14 (42.4)               | 1-17                 | 3.2   |
| nigripinnis            |                       |                          |                      |       |
| Acanthorhodeus macropterus| 28             | 12 (42.9)               | 1-10                 | 3.2   |
| Zacco temmincki        | 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      | 20                   | 3 (15.0)                | 2-4                  | 3.0   |
| variatus               |                       |                          |                      |       |
| 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   |

**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 temmincki       | 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 temmincki       | 26                   | 25 (96.2)               | 1-875                | 110.3 |
| Carassius auratus     | 62                   | 54 (87.1)               | 1-924                | 126.6 |
| 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   |
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 Tamjin-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 1,004 (30.9%) rasborinids 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 rasborinids 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

### Table 7. Comparison of the infection status 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. (%) 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        | 611.1 |

*Positive rate: No. of fish infected/No. of fish examined × 100; metacercarial density: mean No. of MsMc per fish infected. No. of rasborinid fish/Total No. of fish examined × 100.*
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 Nam-sancheon in Hadong-gun, O. uncirostris amarenis 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. tabahashii 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 corveana 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. tabahashii [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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