Reintroduction (2012) 2: 51 – 55

ORIGINAL ARTICLE

Observation of fish movements through artificial fish passes installed in rice paddy fields near a reintroduction site for Oriental Storks *Ciconia boyciana*

Su-kyung Kim[1], Jongmin Yoon[1] and *Shi-Ryong Park[1,2]

Abstract One of human-managed strategies to improve ecological connectivity between rivers and rice paddy fields for migrating fish is to apply fish passes as an alternative to eco-corridors. We placed three fish passes using a wooden and polyethylene material in the drain of three rice paddy fields to observe fish movements from a stream to rice paddy fields in June-August 2012. The study plot was located in Dae-ri, Gwangsi-myun, Yesan-gun near the future reintroduction sites for Oriental Storks *Ciconia boyciana* foraging freshwater fish as well as other various animals. We captured four fish groups ascending through fish passes, which included muddy loach *Misgurnus* sp., Chinese Minnow *Rhynchocypris oxycephalus*, Pale Chub *Zacco platypus*, and Dark Sleeper *Odontobutis interrupta*. The most abundant group passing through the fish passes was muddy loach, and the medium sized muddy loach (6–8 cm total length) was prevalent from late June to early July and large sized muddy loach (9–11 cm) was dominant in mid August. Overall, the number of captured fish in rice paddy fields was highest in early July and declined through late August. The medium sized muddy loach was prevalent from late June to mid July, and the large sized muddy loach was dominant in mid August in rice paddy fields.

Key words Fish pass, Habitat management, Oriental Stork, Reintroduction, Rice paddy field

Introduction

Rice paddy fields occupy approximately 60% of the Korean agro-ecosystem, and up to date their ecological value and conservation concerns have been paid attention in relation to how to increase biodiversity in rice paddy fields as alternative wetlands (Bang et al. 2009; Kim et al. 2011a). Since the 10th meeting of the Conference of the Parties to the Convention on Wetlands also passed a resolution for enhancing biodiversity in rice paddy fields as wetland systems in 2008, it was noted that rice paddy fields in many parts of the world support important wetland biodiversity and that aquatic biodiversity associated with rice paddy fields can make an important contribution to the nutrition, health and well-being of rural populations. It was also concerned that current and potential threats to the role of rice paddy fields as sustainable wetland systems caused by factors such as inappropriate agricultural practices relating to water management and change of natural flow (Ramsar Convention 2008).

Rice paddy fields have to be irrigated from spring to summer and maintained at relatively warm water temperature, and then those as alternative wetlands can provide good habitats and spawning sites for diverse aquatic animals including freshwater fish (Saito et al. 1988). Specifically, muddy loach *Misgurnus anguillicaudatus*, Far Eastern Catfish *Silurus asotus*, and Asiatic Ricefish *Oryzias latipes* are known to spawn in ditches near rice paddy fields (Katano et al. 2003), which may allow fish that forage diverse invertebrates to inhabit.

In the past, rice paddy fields were formed near naturally shallow-water or flooded wetlands, which characteristics also attracted diverse aquatic animals including freshwater fish. Up to date, the economical productivity of rice paddy fields has to induce many types of land alterations such as land consolidation, irrigation system changed from natural to structured canal, and mechanized farming. These landscape- and fine-scaled modifications in agro-ecosystems resulted in disconnecting ecological corridors, forming dry rice paddy fields, and then limiting the population size of freshwater fish (Lane and Fujioka 1998).

To reconnect the altered hydrology in rice paddy fields,

[1] Korea Institute of Oriental White Stork Reintroduction Research, Korea National University of Education, Cheongwon 363-791, Republic of Korea
[2] Department of Biology Education, Korea National University of Education, Cheongwon 363-791, Republic of Korea
* E-mail: srpark@knue.ac.kr

many researchers have applied a diversity of artificial fish passes for rivers and rice paddy fields (Hata 2000; Wada 2000; Suzuki et al. 2001). One of the studies on fish passes in Republic of Korea includes the application of fish passes in rice paddy fields connected to ditches near Daeho Tide Embankment, Asan, in 2009 (Kim et al. 2011b). The objective of the present study is to document what fish species and how many of them seasonally use our tentatively installed fish passes near one of the reintroduction sites for Oriental Storks (*Ciconia boyciana*; see Park et al. 2011).

Methods

Our study site was located in Dae-ri, Gwangsi-myun, Yesan-gun (126° 32' 39.05" N, 126° 47' 30.88" E) (Fig. 1a), which included three paddy fields: 0.31 ha for paddy field A, 0.26 ha for B, 0.17 ha for C (Fig. 1b). These areas were a part of the region of eco-friendly rice paddy fields with ongoing habitat management after determining the reintroduction sites for Oriental Storks in June 2009 (Park et al. 2011). Running water in the target rice paddy fields ran down to the tributary flowing in Simok stream (dotted arrows in Fig. 1b). In Simok stream, our preliminary fish sampling on 15 June at the three locations captured 9 fish species such as Chinese Minnow *Rhynchocypris oxycephalus*, Pale Chub *Zacco platypus*, Dark Sleeper *Odontobutis interrupta*, muddy loach *Misgurnus sp.*, Korean Rose Bitterling *Rhodeus uyekii*, Korean Slender Gudgeon *Squalidus gracilis majimae*, Crusian Carp *Carassius auratus*, False Dace *Pseudorasbora parva*, and Sand Spine Loach *Cobitis lutheri.* This pre-sampling data allowed us to predict what fish species might migrate from streams to rice paddy fields.

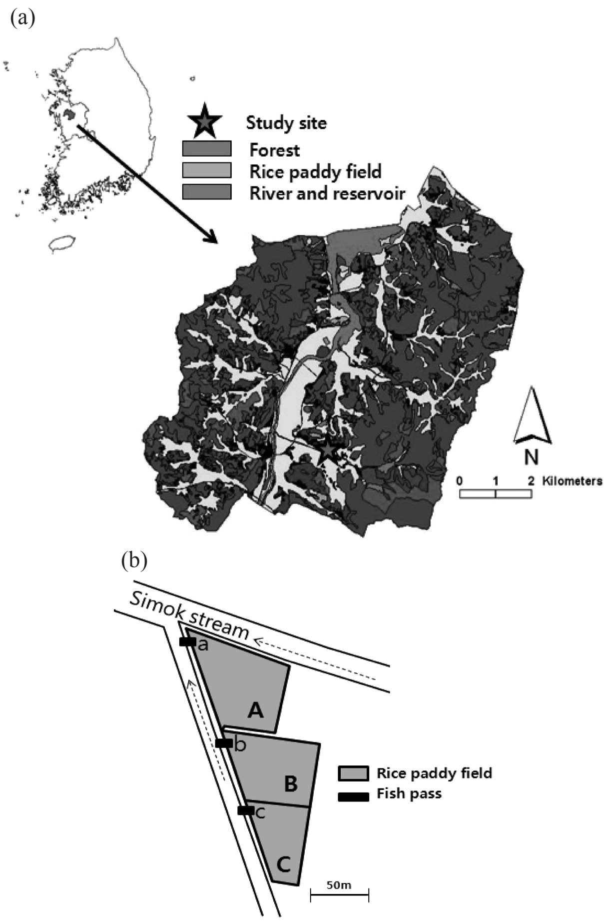

Fig. 1. Reintroduction sites for Oriental Stork *Ciconia boyciana*, Gwangsi myun, Yesan gun, Chungnam, South Korea (a) and the location of fish passes installed in rice paddy fields (A, B, and C) connected to tributary in Simok stream (b). Filled squares indicate fish pass, and dotted arrows indicate water flows.

We installed three fish passes in the drainage of each rice paddy fields on 24 June 2012 to connect the rice paddy fields to the stream (filled squares in Fig. 1b). The structure of fish passes followed the criteria from Kim et al. (2011b) using commercial polyethylene (hereafter PE) and hand-made wooden materials (Fig. 2). PE fish passes were commercial water pipes with a spiral corrugated surface (furrow height 3 cm), which also provided temporary resting pools for migrating fish (Fig. 2b). Similar to PE fish passes, wooden fish passes had partitions (3 cm height) to provide temporary resting pools for migrating fish (Fig. 2a). The conditions of the fish passes were approximately 7–10° in slope, 8.0 m, 14.0 m, 15.3 m in length, and 0.3 m in width.

We conducted fish sampling in three types of locations: one trial in streams, five trials in fish passes, and six trials in rice paddy fields in June-August 2012. All captured fish

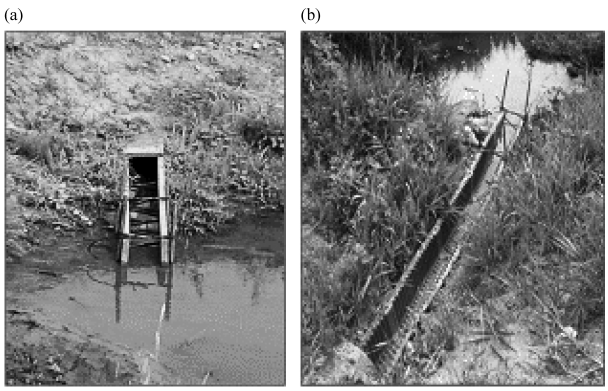

Fig. 2. Examples of the (a) hand-made wooden and (b) polyethylene fish passes installed at the drainage of rice paddy fields.

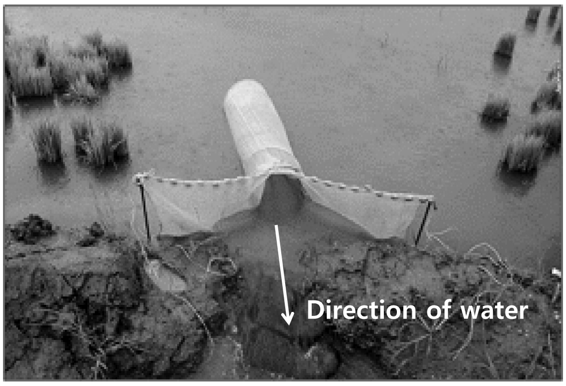

Fig. 3. An example of fish trap installed at the junction of a fish pass in a rice paddy field.

was identified, counted by species, measured total length in size, and released into the site where they were captured. First, we installed a meshed, cylinder-shaped fish trap (height 300 mm × length 1,000 mm, mesh size 5 mm) toward the entrance of fish passes (i.e., inside rice paddy fields) over 24 hr to trap migrating fish in rainy days with 30 mm daily average precipitation when water flows through fish passes (Fig. 3). Second, to compare with the fish number and species captured in the rice paddy fields, we placed four fish traps (height 150 mm × length 280 mm, mesh size 5 mm) per rice paddy field over 24 hr to record the number of individual fish by species (2 sampling trials/month). Lastly, we sampled fish at the three locations in Simok stream once for two hours using hand nets (mesh size 4 mm × 4 mm) on 15 June 2012. We classified captured muddy loach into four categories in relation to total length: ≤ 5 cm for small (juvenile loach), 6–8 cm for medium (sub-adult loach), 9–11 cm for large (adult loach), and > 11 cm for extra-large (adult loach) (see Tanaka 1999). Furthermore, a comparison of the number of captured fish in the three fish passes showed no significant difference (P = 0.45), so we combined the data from the three fish passes.

Results

We captured four fish species passing through the fish passes, which included muddy loach (98.7%), Chinese Minnow (0.6%), Pale Chub (0.34%), and Dark Sleeper (0.36%). The average number of captured fish per trap was 31.9 ± 38.1 individuals (n = 15), and the largest number of fish per trap (113 individuals per trap) was captured over 24 hr on 6 July. Compared to that, 64 individuals per trap were captured on 16 July, followed by 57 individuals per trap on 15 August. Chinese Minnow (1.7%), Pale Chub (1.1%), and Dark Sleeper (1.1%) other than muddy loach (96.1%) were captured only on 15 August in the 8 m PE fish pass, compared to the sampling results in other days and fish passes.

Among captured muddy loaches in the trap of fish passes, the size proportion of muddy loach exhibited total length 6–8 cm (21.6 ± 30.4 individuals; 67.9%), followed by 9–11 cm (7.1 ± 17.2 individuals; 22.2%), ≤ 5 cm (2.6 ± 5.7 individuals; 8.0%), and > 11 cm (0.6 ± 2.1individuals; 1.9%). Sampling from 30 June and 6 July captured 6–8 cm muddy loach at a higher rate, but sampling on 15 August captured 9–11 cm muddy loach at a higher rate, relatively (Fig. 4).

In the rice paddy fields, captured fish included three groups: muddy loach (96.2%), Dark Sleeper (1.1%), and Chinese Minnow (2.7%), and the most abundant fish were also muddy loach. Our fish sampling captured more fish after the completion of fish pass installation (1.3 individuals/trap on 15 June to 7.7 individuals/trap on 30 June). The captured number increased from 32 individuals/trap on 6 July to 21.4 individuals/trap on 15 August, and then that decreased to 9.2 individuals/trap on 28 August. The size proportion of muddy loach was 6–8 cm (10.0 ± 15.0 individuals; 66.5%), 9–11 cm (4.1 ± 6.1 individuals; 27.4%), ≤ 5 (0.6 ± 1.4 individuals; 3.8%),

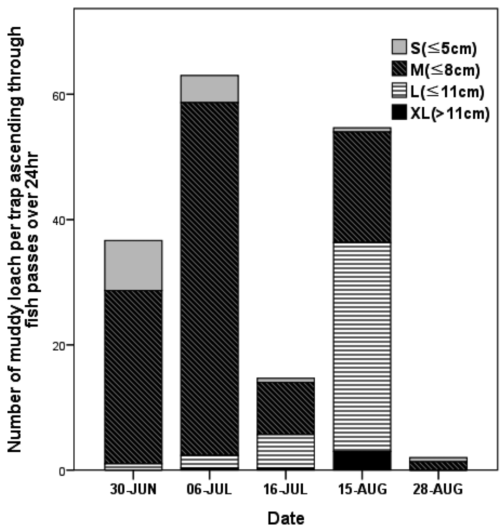

Fig. 4. Seasonal changes in the number of muddy loach (≤ 5 cm for small total length, 6–8 cm for medium total length, 9–11 cm for large total length, and > 11 for extra-large total length) per trap ascending through fish passes from Simok stream and its tributary to rice paddy fields.

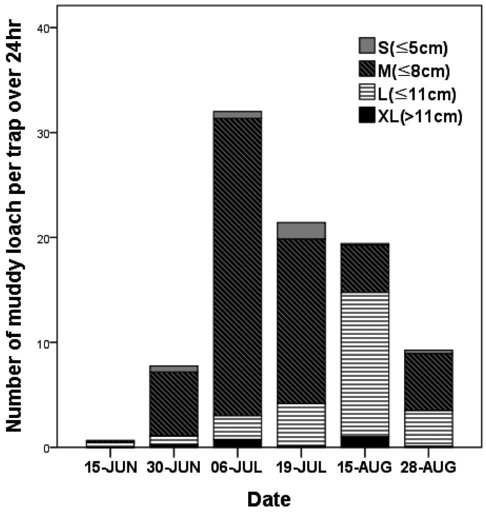

Fig. 5. Seasonal changes in the number of muddy loach per trap over 24 hr in rice paddy fields (fish passes were installed on 24 June 2012).

and > 11 cm (0.4 ± 0.9 individuals; 2.4%). The most common size of muddy loach was 6–8 cm from 30 June to 16 July, but 9–11 cm on 15 August (Fig. 5).

Discussion

The present study documented the seasonal changes in the number of migrating fish by species through recently installed fish passes in rice paddy fields connected to the tributary in Simok stream. We captured four fish species including muddy loach, Chinese Minnow, Pale Chub, and Dark Sleeper ascending through the fish passes and muddy loach was dominant among fish species although 9 fish species including muddy loach, Chinese Minnow, Pale Chub, and Dark Sleeper were captured in Simok stream and its tributary. Our results may be consistent with those from Kim et al. (2011b) using the wooden and PE fish passes with the uneven bottom surface (3.6 m and 4.0 m length) used in Daeho Tide Embankment in which only muddy loach, Chinese Muddy Loach *Misgurnus mizolepis*, and Venus Fish *Aphyocypris chinensis* use the fish passes and muddy loach was prevalent among three species although 9 fish species including crusian carp, false dace, venus fish, muddy loach, and Chinese Muddy Loach are found in ditches near the fish passes.

According to the study of Mizutani (2010), fish with large body height might not properly use fish passes with the uneven bottom surface because they provide temporary resting pools with shallow water levels only for fish with small body height and crawling fish such as the family of Cobitidae. Therefore, muddy loach (i.e., crawling fish with relatively small body height ranging from 1.0 to 1.2 cm) might predominantly migrate through the fish passes with the uneven bottom surface, whereas Chinese Minnow, Pale Chub, and Dark Sleeper (i.e., swimming fish with relatively larger body height ranging from 3.0 to 3.4 cm) migrated through fish passes with uneven bottom surface on 15 August with 70.9 mm daily average precipitation. The results also lead us to conduct future study comparing the effects (i.e., fish migration) of pool type and uneven bottom type of fish passes in same stream.

The number of captured fish in the rice paddy fields increased after the installation of fish passes on 24 June (Fig. 5). This might suggest that fish in the stream migrated to the rice paddy fields through the installed fish passes. However, we could not confirm that this increase in captured fish was solely due to the function of our fish passes, not comparing with the changes in rice paddy fields without fish passes. Thus, further study should consider control sites without fish passes to verify the direct effect of fish passes along the schedule of fish migration.

In the paddy fields, adult or sub-adult muddy loach spawned and reproduced until midseason drainage and an increase in the number of juvenile loaches in the temporary creeks just before midseason drainage. During midseason drainage, the loaches moved primarily towards temporary and permanent creeks, seldom returning to the paddy fields (Tanaka 1999). However, our results showed that high proportion of sub-adult loach (6–8 cm total length) captured by trap at the fish passes migrated from a tributary of Simok stream to rice paddy fields in early July, and adult loach (9–11 cm total length) moved to rice paddy fields in mid August. This might be similar to the study of Kim et al. (2011b), suggesting that sub-adult loaches might be rheotactic towards rice paddy fields rather than adult loaches migrating for spawning.

Future habitat management in the reintroduction sites for Oriental Storks should consider a diversity of fish passes connecting among river systems, ditches, and rice paddy fields, depending upon what fish species as target food resources.

The biological function of fish migration from river systems to rice paddy fields may be limited for reproduction and growth during the early life stage (Hata 2000;

Suzuki et al. 2004). Future studies should examine how fish-refuge ponds or furrow drains with fish passes function to facilitate reproduction and survival of fish populations along the seasonal variation in water level in the rice paddy fields.

Acknowledgements

This study was supported by "Cooperative Research Program for Agriculture Science & Technology Development (project no. PJ007522)", Rural Development Administration, Republic of Korea.

References

Bang HS, Han MS, Na YE, Kang KK (2009) Biodiversity of fauna and flora in Korean paddy field. Marco symposium 2009 'Challenges for agro-environmental research in monsoon asia'.

Hata K (2000) Small fishway to a rice paddy field. Ecol. Civil Eng., 3: 231–234. (in Japanese)

Kantano O, Hosoya K, Iguchi K, Yamaguchi M (2003) Species diversity and abundance of freshwater fishes in irrigation ditches around rice fields. Env. Biol. Fish., 66: 107–121.

Kim JO, Lee SH, Jang KS (2011a) Efforts to improve biodiversity in paddy field ecosystem of South Korea. Reintroduction, 1(1): 25–30.

Kim JO, Shin HS, Yoo JH, Lee SH, Jang KS, Kim BC (2011b) Distribution of fish in paddy fields and the effectiveness of fishways as an ecological corridor between paddy fields and streams. Korean J. Limnol., 44(2): 203–213. (in Korean with English abstract)

Lane SJ, Fujioka M (1998) The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in the rice fields of central Japan. Biol. Conservation, 83: 221–230.

Mizutani M (ed) (2010) Guidelines for fish passes installed in rice paddy fields. The Japan Association of Rural Solutions for Environmental Conservation and Resource Recycling, Tokyo, 71 p. (in Japanese, title was translated by the authors)

Park SR, Yoon JM, Kim SK (2011) Captive propagation, habitat restoration, and reintroduction of Oriental White Storks (*Ciconia boyciana*) extirpated in South Korea. Reintroduction, 1: 31–36.

Ramsar Convention (2008) Resolution X 31 'Enhancing biodiversity in rice paddies as wetland systems'. 10th meeting of the conference of the parties to the convention on wetlands.

Saito K, Katano O, Koizumi A (1988) Movement and spawning of several freshwater fishes in temporary waters around paddy fields. Jpn. J. Ecol., 38: 35–47. (in Japanese with English abstract)

Suzuki M, Mizutani M, Goto A (2001) Trial manufactures and experiments of small-scale fishways to ensure both upward and downward migration of freshwater fishes in the aquatic area with paddy fields. Ecol. Civil Eng., 4(2): 163–177. (in Japanese with English abstract)

Suzuki M, Mizutani M, Goto A (2004) Effects of connection of paddy fields, ditch and stream through small scale fishways on fish fauna. Irrigation, Drainage and Rural engineering Journal, 234: 59–69. (in Japanese)

Tanaka M (1999) Influence of different aquatic habitats on distribution and population density of *Misgurnus anguillicaudatus* in paddy fields. Japan. J. Ichthyol., 46(2): 75–81. (in Japanese with English abstract)

Wada Y (2000) For a knowledge of fishway designs. Ecol. Civil Eng., 3: 225–230. (in Japanese)

(Accepted: 15 December 2012)