Impact of fishways in the Miyanaka Intake Dam area on fish diversity in the Shinano River, Japan

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Fishways are an important facility for securing continuity between upstream and downstream of a dam. The continuity should be secured as efficiently as possible. In this paper, we will introduce an effective case of an improved fishway for 16 fish types, including *Oncorhynchus keta, Plecoglossus altivelis altivelis*, and *Cottus pollux* for the Miyanaka Intake Dam in Japan. The study investigated the effects of combining three fishways based on the results of a survey that captured fish upstream and downstream of the dam.

1 INTRODUCTION

Continuity of river channels is an essential requirement for migrating fish in rivers. However, continuity is often lost as a result of the construction of dams and weirs. Thus, fish passes have been developed to solve this problem [1, 2]. However, most fishways are for the benefit of anadromous salmonids, such as *Salmo salar, Oncorhynchus gorbuscha*, *Oncorhynchus spp*, *Salmo trutta*, because they are commercially important in many areas in the world, rather than for the purpose of preserving fish communities in general [3,4].

In this study, we investigate a combination of a traditional Ice-Harbor and a natural-shaped fishway to increase fish diversity in the Shinano River. Regarding the fishway of the Shinano River, only a few cases [5, 6] are discussed in English, and efficiency improvement by combining fishways is rarely mentioned in Japan. This is one of the few peer-reviewed English-language studies that assess the efficiency of fishways in Asia.

Where dams have interrupted a river's continuity, the restoration of continuity is a particularly important issue [1, 2, and 7]. To ensure the sustainability of fishery resources, commercially valuable fish species alone are often considered as a preservation target [3, 4, and 8]. *Plecoglossus altivelis altivelis* is a major target in Japan.

It is important to evaluate the efficiency of fishways so that the optimum biodiversity of rivers can be realized. The objective of this study is to assess the efficiency of a combination of different types of fishways: the Ice-Harbor fishway, the stair-type fishway, and the natural-shaped fishway for preserving fish diversity. This was done by comparing the number of species upstream with the number of species downstream.

2 STUDY SITE

Miyanaka Intake Dam was built in 1951 and rehabilitated in 1986. It is located on the middle of the Shinano River in central Japan, 134 km upstream from the river mouth. Its purpose is to provide water for a power station 35 km downstream. Two different-sized stair-type fishways were installed in 1951. Their purpose was to compensate for the elevation gap between the upstream and the downstream parts of the dam. The fishway was modified in 2012 to enhance the occurrence of a wider range of fish species. Table 1 shows the 16 species that were targeted (Table 1).

Table 1. Target fish species: Fish species were determined based on literature review and interviews with local fishermen.

1 Anguilliformes	2 Carassius auratus langsdorfii	3 Cottus pollux
4 Cyprinus carpio	5 Hemibarbus barbus	6 Lethenteron spp
7 Liobagrus reini	8 Oncorhynchus keta	9 Oncorhynchus masou
10 Oncorhynchus mykiss	11 Opsariichthys platypus	12 Plecoglossus altivelis altivelis
13 Rhinogobius kurodai	14 Salvelinus	15 Tribolodon hakonensis
16 Tribolodon nakamurai		

The existing stair-type fishways were modified into a large Ice-Harbor fishway and small stair-type fishway. Then, a natural-shaped fishway (Figure 1) was installed parallel to the existing ones.

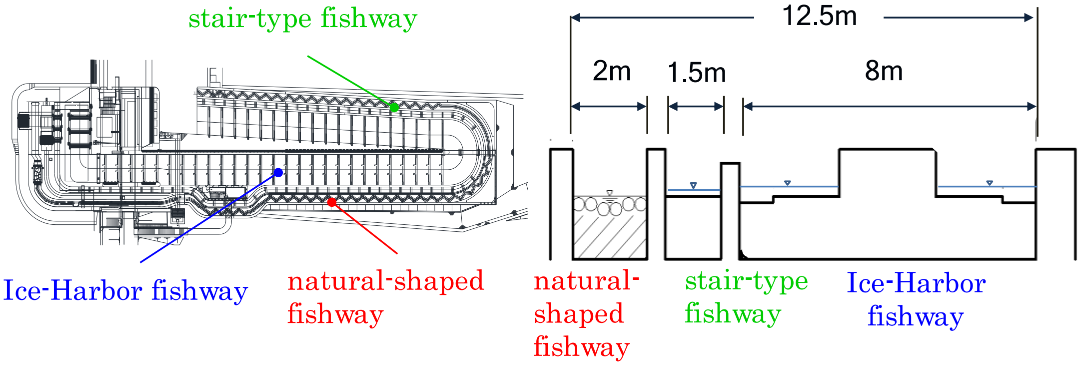

Figure 1. Outline of fishway: The width of the Ice Harbor fishway was reduced from 10 m to 8 m to suppress the generation of transverse waves. The small stair-type fishway was relocated and a natural-shaped fishway for bottom type fish with less swimming mobility was created. Newly established natural shaped fishway: The fishway (with a water depth of 15 cm and a flow rate of 0.022 m3/s) is adapted to the requirements of the biodiversity of the Shinano River and allows the upstream and downstream movement of bottom fish, crustaceans, and small fish.

3 METHODOLOGY AND STATISTICS

Velocities were measured using an electromagnetic current meter (TK-105x made by the Toho Dentan Co. Ltd in Tokyo, Japan). For the Ice-Harbor fishway velocities were measured at six places, 193 cm above the bottom of the four centrals and at the two notches (Figure 2).

For the stair-type fishway, velocities were measured at two places (171 cm above the bottom). For the natural-shaped fishway, one velocity was measured (3 cm above the bottom).

The electromagnetic current meter was attached to a hand frame and placed in a predetermined position in the overflow part of the fishway. A measurement was taken when the flow velocity became stable. Two readings were taken at each measurement site (one with a net basket and one without) and the average value obtained.

The large Ice-Harbor fishway had three traps on the left side and three traps on the right side of the non-flowing areas. The six traps had frames with angled material and a basket that captured fish underwater. The stair-type fishway had two traps. These were the same as the traps of the large Ice-Harbor fishway. Because the cross-sectional shape of the natural-shaped fishway is different from the other fishways, a trap used by the local fishery cooperative to catch *Cottus pollux* was employed. Baskets were placed in the Ice-Harbor fishway and in the stair-type fishway at the beginning of each monitoring period and removed every hour. In 2010, before starting the investigation, passing fish were counted every hour for over 24 hours. It was found that there were no fish passes during the night. Thus, fish passes were counted from 6:00 to 19:00 in 2011–2014, and from 9:00 to 17:00 in 2015–2016.

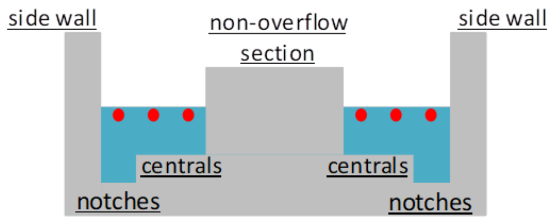

Figure 2. The electromagnetic current meter measured the flow velocities at a total of six places, four at the centrals and two at the notches in the IceHarbor-type fishway.

The effects of moving water and depth of water on biodiversity were investigated by comparing, the relationships for different species of swimming fish, different species of swimming and bottom fish, and different species of bottom fish. The relationship between *P. altivelis* and *Tribolodon hakonensis*, *Opasariicthys platypus*, and *Oncorhynchus masou* were analyzed using a 2-sample t-test. In addition, the relationships between *P. altivelis* and *C. pollux*, *Rhinogobius kurodai*, and the relationship between *C. pollux* and *R. kurodai*, was analyzed using a 2-sample t-test.

4 RESULTS

As shown in Figure 3, most of the types identified at the downstream site were identified in the fishways and at the upstream site (Figure 3). At the upstream site, only two to four species were identified annually. Overall, only eight species were identified upstream.

However, five species (*Cyprinus carpio*, *Carassius auratus buergeri*, *Pseudorasbora parva*, *Micropterus salmoides*, and *Misgurnus angillicaudatus*) were identified in one year. As shown in Figure 4, about 60% of fish species found upstream were observed at downstream sites, and about 30% of fish species were only observed in each fishway (Figure 4). More than 10% of the fish species were captured at the upstream site only.

Figure 3. Number of fish species observed upstream and downstream of the dam, and in the fishway. There were more species identified in the upstream than in the downstream.

Figure 4. Rate of species observed upstream and downstream of the dam, and in the fishway. About 60% of fish species were observed both upstream and downstream.

5 DISCCUSSION

To take into account the background geomorphology of this river reach, two different types of fishways (large-type and small-type) have already been constructed. However, these fishways have not been sufficient to maintain the biodiversity of the reach. The newly added natural-shaped fishway, with a cobble and gravel bottom, has helped restore biodiversity.

The results of the t-tests showed a significant difference in the fishway chosen by some of the fish, and that this difference was based on their body length (an indicator of swimming ability). Differences were detected between swimming fish such as *P. altivelis*, *T. hakonensis*, and *O. platypus*, and between swimming and bottom fish such as *C. pollux* and *R. kurodai*. However, there was no significant difference between the bottom fish. Part of the wall at the entrance between each fishways in the Miyanaka Intake Dam has been removed, and the fishway has been designed so that fish entering the fishway can be selected according to their body length (swimming ability).

The results of this t-test show that the bottom fish selected the natural-shaped fishway and moved according to their body length (swimming ability). This suggests that the newly constructed natural-shaped fishway contributes to maintaining and improving the moving environment of the bottom fish.

The overflow water depth of the natural-shaped fishway, established in 2012, was 8 cm. Subsequently, based on their results, opinions from the fishermen's cooperative, and the local situation at the time of monitoring, the overflow depth was increased to 15 cm in December 2014. Subsequent monitoring results showed an increase in the species of swimming fish such as *P. altivelis*, *T. hakonensis*, and *O. masou* without decreasing the number of species of bottom fish such as *Cobityis biwae*, *R. kurodai*, and *C. pollux*. The swimming fish moving in or inhabiting the natural-shaped fishway were immature fish or juveniles with limited swimming power. Therefore, the increase in the number of species of swimming fish in the natural-shaped fishway showed that immature fish and juveniles could move easily upstream and downstream of the dam.

6 CUNCLUSION

Although the fishways were functioning from the time the dam was built, there have been recommendations that the fishways should be improved so that salmon can more easily ascend them..

The fishways of the Miyanaka Intake Dam were improved for *Oncorhynchus keta*, and also for 16 other species including swimming fish such as *P. altivelis* and bottom fish such as *C. pollux*. The improvements involved adopting the Ice Harbor type and “Seseragi Fishway”.

Monitoring surveys were carried out in the fishways before and after improvement to the fishway structure. Investigations of the use of the Ice-Harbor and stair-type fishways by *T. hakonensis* revealed that it selected a fishway according to its body length (swimming ability). In addition, it was confirmed that for *T. hakonensis*, which has a small body length (weak swimming ability), a fishway with weaker flows is required. It seems that the newly established natural-shaped fishway is having a positive effect because 13–23 fish species were identified at the upstream site and 19–24 fish species were identified in the fishways of the Miyanaka Intake Dam.

Monitoring surveys were also conducted upstream and downstream of the dam. Common fish were found upstream and downstream of the dam, as were migratory fish and other fish moving between the upstream and downstream. Thus, the fishways are functioning effectively. The results show that the fish can select one of the fishways according to their body length (swimming ability). This provides evidence that the combination of the three types of fishways for the Miyanaka Intake dam is more efficient.

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