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연구논문

# Stream Corridor Ecological Restoration by Small Dam Removal

## - Removals of Gongreung2 & Gotan Small Dams in Korea -

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# 보 철거를 통한 하천 생물이동통로의 생태적 복원

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## Abstract

하천 수위를 유지하거나 농업용수를 취수 할 목적으로 조성되는 크고 작은 보는 용수공급 시설로 이용되고 있으나, 하천 생물이동의 차단, 보 상류부의 수질악화, 수변 생물서식처의 변화, 하천경관 훼손과 같은 환경적 문제를 초래하고 있다. 더욱이 도시화가 진행됨에 따라 토지이용의 변화, 시설의 노후화 등으로 매년 50~150개 정도의 보가 폐기되고 있는 현실이다. 본 연구는 하천에 설치되었으나 용도와 기능이 상실된 보를 철거하여 생태적 연속성을 확보하고 하천 본래의 모습으로 되돌려 주며, 하천의 생태적 건강성을 회복 및 향상 시키고자 하였다. 보 철거 시범사업으로 공릉천에 설치된 길이 76m, 높이 1.5m의 공릉2보와, 한탄강에 설치된 길이 190m, 높이 2.8m의 고탄보를 철거하였고, 각 시범사업 대상지의 물리/화학/생태특성 모니터링 분석을 수행하였다. 그 결과 철거 직후 보의 직 상류부에 전체적으로 침식이 발생하고, 보 하류부는 여울, 하중도, 사주, 침식 등 다양한 지형으로 변모되었다. 본 연구를 통하여 하천복원의 취지에 맞는 하천 본래의 모습에 가까운 하천으로 복원하기 위해서는 기능 및 용도가 상실된 보의 경우는 기존의 보체를 개량하거나 어도를 설치하여 주는 것 보다 구조물 자체의 완전철거를 통한 생물 이동통로 조성이 바람직하다고 판단된다.

주요어 : eco corridor, habitat change, river restoration

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# I. Introduction

About 34,000 stream crossing structures including small dams and drop structures constructed in the course of streams to maintain the level of water, protect structures and get drinking and agricultural water are installed nationwide(KRA, 2005).

These stream crossing structures remarkably affect not only river discharge and water quality, but riparian organisms, as the height of the structures and the size of reservoirs become larger. Moreover the cross structures greatly change time and spatial distribution characteristics of flow duration and temperature(OGURA, 2005), and also cause river habitat changes and stream scenery damages by interrupting stream eco corridors through small dam installation.

In addition, 50-150 small dams that lost functions are annually abandoned, due to urbanized farm land, changes in farming land including change from rice farming to vinyl house farming, integration of water collection facilities deriving from large reservoirs construction and pumping stations installation, and aging facilities(KRC, 2001). For the abandoned small dams, the structures are not completely removed out of the streams, but most still remain in the streams, or eco corridors like fishways are artificially installed in minimal number of small dams. Therefore, those abandoned small dams continuously cause problems including the interruption of stream eco corridors and deterioration of water quality and the habitat of riparian organisms.

Foreign countries generally promote restoring of streams, including stream eco corridor restoration, by removing even stream crossing structures with some remaining useful functions, as well as small dams without useful functions.

In the United States, 467 small dams have been removed, since 1912(ASCE, 1997; NANAMI, 2001). Of the 364 removed small dams whose specifications are known, the small dams with less than 15m in height equivalent to Korean small dams or small dams are 338 or 93%.

In Japan, according to a survey result in April 2001, 326 small dams for collecting agricultural water were removed, due to aging facilities and integration of water collection facilities and so on. Most of the removed facilities were small dams or small dams with less than 15m in height(WRETC, 2000).

In case of Korea, about 18,000 small dams are located nationwide. Among them, the small dams with 1.0m or lower in height accounts for 70%. About 25% of them shows 1.0-2.0m in height and about those with higher than 2.0m in height takes up 5%(KRC, 2001).

However, no cases of stream structure removal like small dams, due to restoration of stream eco corridors and safety, along with removal of small dams and small dams with no useful functions, have been found. In this context, relevant studies or technology development can be hardly found.

Studies on small dam removal are mostly those in the civil engineering field: *A Study on the change in river discharge and earth and sand movement model deriving from control of earth and sand movement due to small dam installation*(Fang Cheng, 2005; Gary, 2004; Yantao Cui, 2006), *A study of economic benefits arising from small dam removal* (William, 2002) and *A study of fish movement disorder and the designed flow velocity for fish movement* (Douglas, 2000; Thomas, 2000).

Meanwhile, in the ecological field, a study of the *Impacts on organisms by installation of stream*

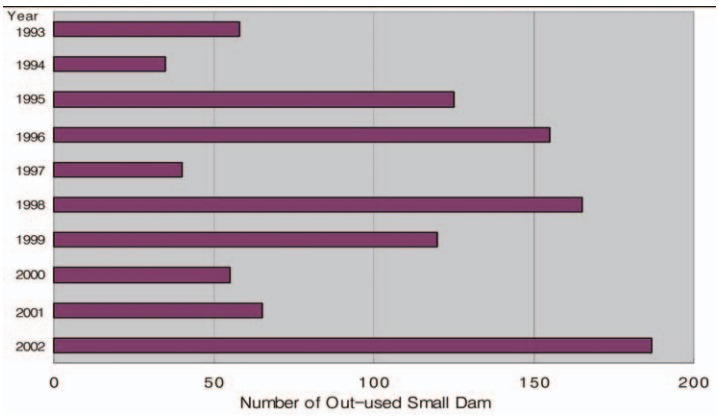


Fig. 1. Number of Out-used Small Dam by year in Korea

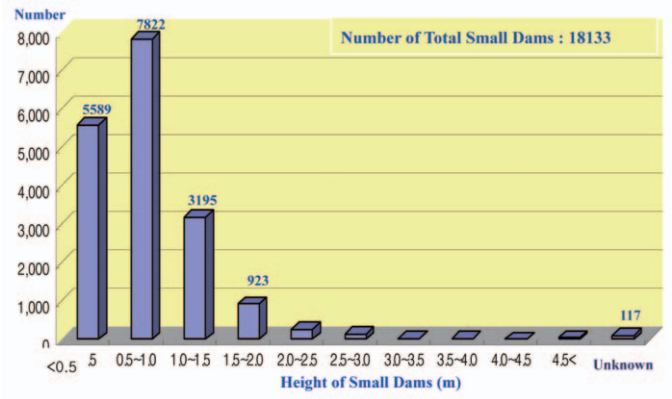


Fig. 2. Number of Korea's Current Small Dams by Height

*structures*(Maitland and Morgan, 1997; Giller and Malmqvist, 1998), and a study on *Change phases of large invertebrate animals after small dam removal* (Hye Kyung Kill *et. al*, 2007), which is the only study in Korea, can be found. However, there are some limitations in that monitoring before small dam removal was omitted, and only a fragmental analysis on some organism groups was conducted.

A study on the *Water temperature in the lower reach of small dams affecting organisms and spatial features according to small dam removal*(Allan, 1997; Moss, 1998; Cowx and Welcomme, 1998) can also be found. In Korea, though, studies on ecological responses according to small dam removal are very rare.

This study analyzed physical features(river bed change), chemical characteristics(water quality analysis) and ecological changes(fishes, benthic animals, vegetation) before and after small dam removal for smooth restoration of stream eco corridors.

## II. Materials and methods

### 1. Study sites

The study chose Gongreung2 small dam (length: 76m, height: 1.5m) in the upper reach of the Gongreung Stream located in Goyang City and Gotan small dam(length: 190m, height: 2.8m)


Fig. 3. Study sites

located in the Hantan River, Yeoncheon-gun, Gyeonggi-do as study sites.

Gongreung2 small dam was built to supply agricultural water in the 1970s, and was reinforced in several occasions. However, it lost its use, because of changed water collection method, deriving from the conversion of surrounding farming land into vinyl house complexes starting the 1990s. The basin area of Gongreung stream is 253.1 $km^2$ and river bed slope is 1/200(Gyonggi-do, 2002).

Gotan small dam was installed in order to supply water for local residents in 1991, but lost its function as a small dam to collect water, since water supply source was relocated, due to pollution of water in the upper reach of the small dam. The basin area of the Hantan River is 2,436.4 $km^2$ and river bed slope is 1/950 (Gyonggi-do, 1998).

## 2. Methods

In carrying out this study, the structures of Gongreung2 and Gotan small dams were completely removed in early May in 2006 and early June in 2007, respectively. The physical, chemical and ecological monitoring was conducted from early April in 2006 before the small dam removal to December 2007.

For physical impact comparative analysis before and after the small dam removal, we conducted river bed measurement and analyzed river bed materials; for chemical impact comparative analysis, water quality(BOD, SS, TN and TP) was measured; and for ecological impact comparative analysis, plants, benthic animals and fishes were analyzed.

### 1) The analysis of physical characteristics

As to the Gongreung 2 small dam, a traversal measurement was performed in April, before the removal of the small dams, in June, immediately after the removal of the small dams, and in August, during which time there was a flood, at a total of 14 points throughout the 600m long lower stream section of the small dam from a point on the 420m upper stream, beginning at the Gongreung 2 small dam. As to the Gotan small dam, the traversal measurement was undertaken in May, before the removal of the small dams, in June, immediately after the removal of the small dams, and in October, during which time there was a flood, at a total of 19 points in the 400m long lower stream section of

the small dam from the 600m of the upper stream beginning at the Gotan small dam. Through these traversal measurements, the changes in the deepest riverbed were analyzed with the removal of the small dams. Also, the grain sizes of riverbed materials, which were collected in the upper stream and the lower stream section of the dams before the removal of the dam, were analyzed. Then, the changes in grain sizes were analyzed by collecting riverbed materials again in the same places after their removal and analyzing them again.

2) The analysis of chemical characteristics

In order to analyze chemical characteristics according to the removal of the small dams, the analysis was conducted in April and June(twice) before the removal of the small dams, and during four seasons(July, October, April, and June: four times) after the removal of the small dams on chosen dates when no changes occurred in the flux. In the fields, the measurement of water temperature, pH, EC, and the flux as well as DO fixation were done, and collected samples were promptly delivered to a testing lab and measured with a water quality process testing method and a standard method for items to measure(DO, SS, COD, T-N, T-P, T-P, F) in the testing lab.

Items that require a long time went through an appropriate pre-treatment, and they were kept in a cold place at less than 4℃ before the analysis. Then, they were analyzed with a water quality process testing method. Regarding the analysis method, SS used a Vacuum Filtration(Glass Fiber Filters, GF/C) method, BOD used an Azide Modification, DO Meter Method(YSI Mo.58), T-N used an Ultraviolet Spectrophotometric Screening Method(UV-1601PC, Shimadzu, Japan), and T-P used an Ascorbic Acid Method.

3) The analysis of ecological characteristics

In order to analyze ecological characteristics, it was decided to conduct the testing on the same day when the analysis of chemical characteristics was done. Then, the analysis was performed in April before the removal of the small dams, in June, after the removal of the small dams(twice), and throughout the four seasons(July, October, April, and June: four times) after the removal of the small dams on chosen dates when no changes occurred in the flux, and additional investigations were undertaken only for insufficient parts.

(1) Vegetation

For the flora research, the upper stream and lower stream sections of the small dams were distinguished, and species that appear in those sections were confirmed. Then, the names of the species were recorded and they were listed up. After that, the major plant community in the sections subject to research were prepared as a vegetation mapping. Also, the representative cross sections of the upper stream and the lower stream sections after the removal of the small dams of the rivers subject to research were selected, and were shown in a mimetic diagram.

(2) Large benthic invertebrates

It was anticipated that the feasibility that large benthic invertebrates will live in the upper stream and the lower stream basin in which there were small dams would be high or the fauna would be enriched before and after the removal of the small dams, and some points and peaks that may sufficiently represent the characteristics of the fauna in the target water system were randomly selected and collected a total of six times.

(3) Fish

The research referenced mainly the river edition of the national censuses on river environments research manual(the edition of research into organisms) of the riverfront(Foundation for Riverfront Improvement and Restoration in Japan, 1997), and it was made to be quantified by using devices below. The species that could be identified on the spot were immediately identified, and then, were released after measuring their body lengths and weight. As to rarely appearing fish or species of which identity were unclear, they were classified in a testing lab by fixating them in 10% formalin.

## III. Results

### 1. Analysis of physical impacts(short-term change of riverbed)

We selected Gongreung2 small dam in the Gongreung Stream and Gotan small dam in Hantan river where a demonstration project was

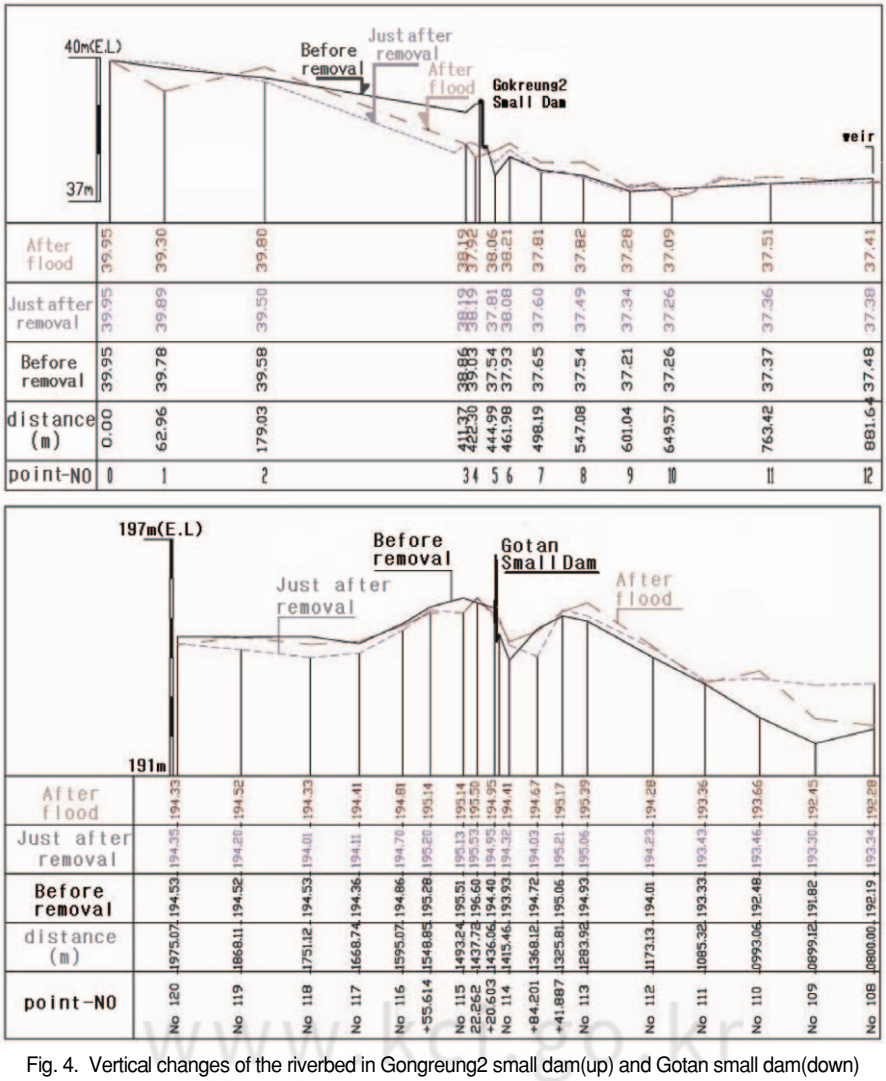


Fig. 4. Vertical changes of the riverbed in Gongreung2 small dam(up) and Gotan small dam(down)

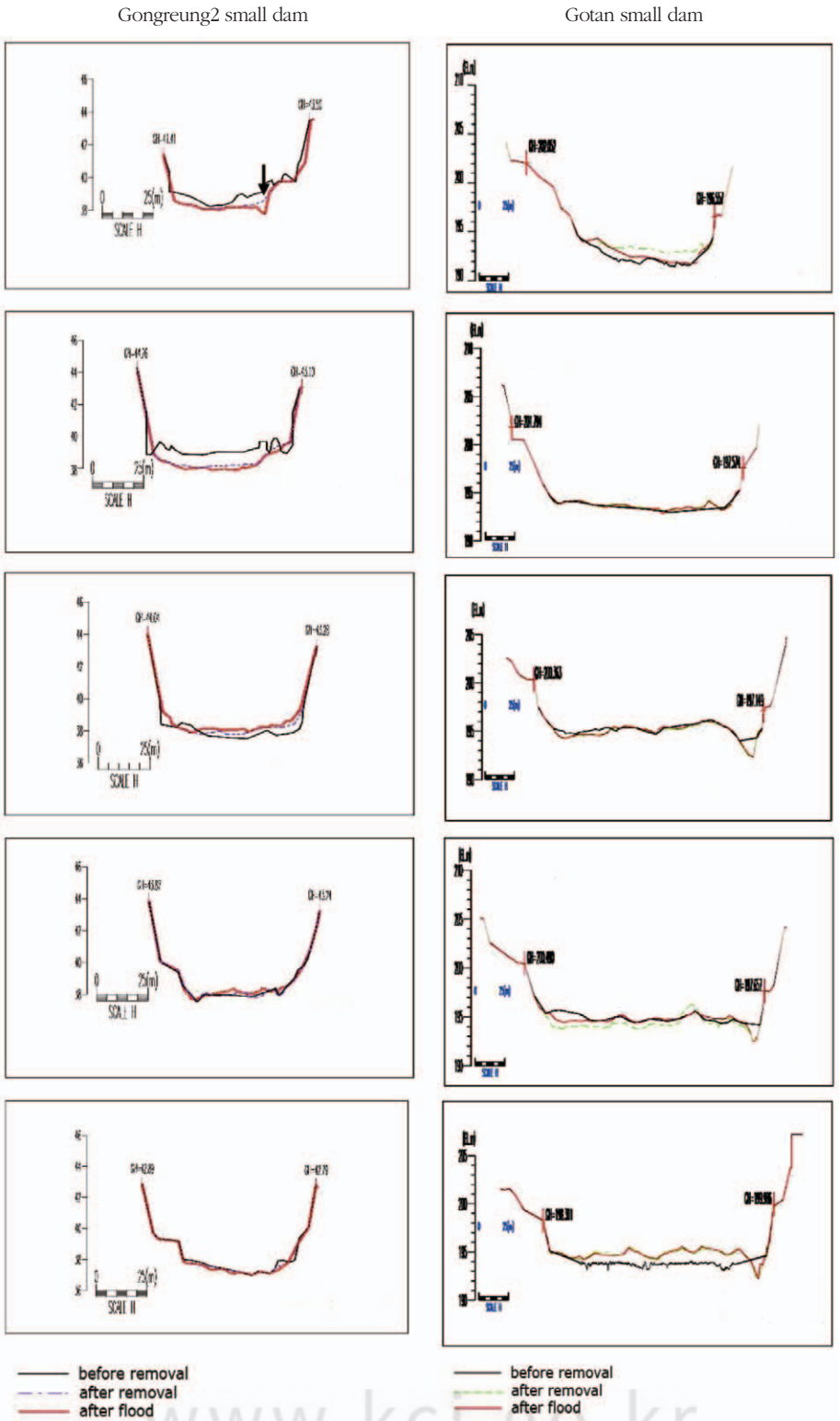


Fig. 5. Change of bed elevation in Gongreung2 small dam(left) and Gotan small dam(right)

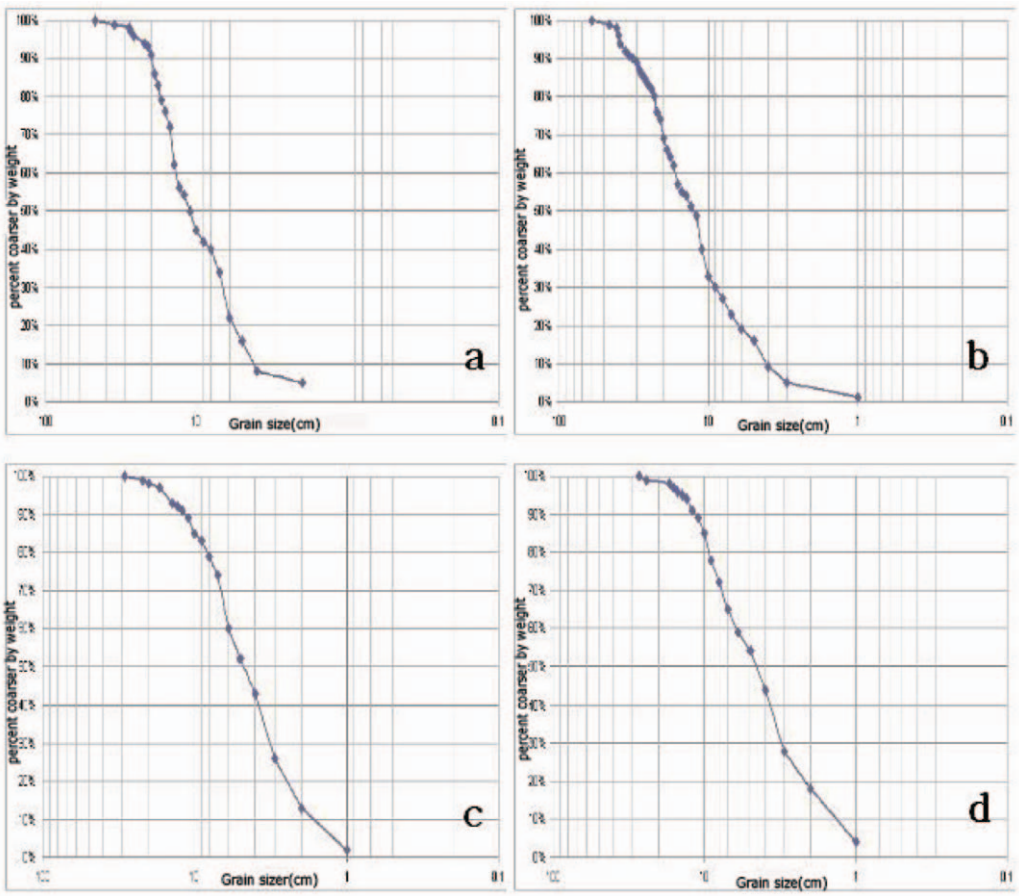


Fig. 6. Grading curve(upstream of before removal and after flooding: a, b, downstream of before removal and after flooding: c, d)

conducted in early April 2006 and Jun 2007, and analyzed the data from monitoring.

1) Riverbed variation

The comparison of the riverbed before and after the flooding showed that the upper reaches of the small dam degraded early after the removal and aggraded again, while sediments continued to accumulate in the immediate lower reaches of the both of dam after the removal and the riverbed continued to aggrade in Gongreung2 small dam.

Conversely, although the flooding occurred, there were not any significant changes in the riverbed after the removal of the Gotan small dam in Hantan River. This seems to be the result that the riverbed consists of large particle stones and the change in the riverbed is happening slowly.

2) Grain size distribution of the measured cross section

The analysis of the grain size distribution based on the analysis of the riverbed materials showed that, in the upper reaches of the small dam, the grain size of the riverbed materials increased as the riverbed, which used to be a sedimentary layer, was eroded, while in the immediate lower reaches of the small dam, sediments accumulated during the removal work was all washed away during the flooding, and the riverbed was full of cobbles, medium-to-fine

gravels and coarse sands. In this sector the erosion due to the flooding abruptly changed the riverbed materials, but is quickly stabilizing and returning to the original riverbed.

## 2. Analysis of chemical impacts

The analysis of the mean concentration of BOD, SS and TN and TP showed that the concentration of SS was lower after the dam removal than before the dam removal except for in the uppermost reaches of the small dam, and that of BOD had significant lower values of both of the after the dam removal than before the dam removal.

These results indicate that the water quality got better after the small dam removal than before the dam removal. However, as the monitoring was conducted over a short period of tine after the dam removal, it is too early to come to any quantitative conclusion, and a longer-term monitoring is in order.

## 3. Analysis of ecological characteristics

### 1) Vegetation

In this area there used to be a swamp in the upstream. What used to be a detention pond before the small dam removal showed the characteristics of a detention pond after the small dam removal as well. As the water was drained from the ex-detention pond in the upper reaches of the small dam, the part newly out of the water became a new habitat for plants, but only pioneer plants inhabit there in the early stage. In July there was a flood after the small dam removal, and the topography of the low-flow riparian area was changed a great deal, and the habitat of the water-caltrop, a submerged plant, shrunk. As for new habitats emerging after the small dam removal, in the early stage annual

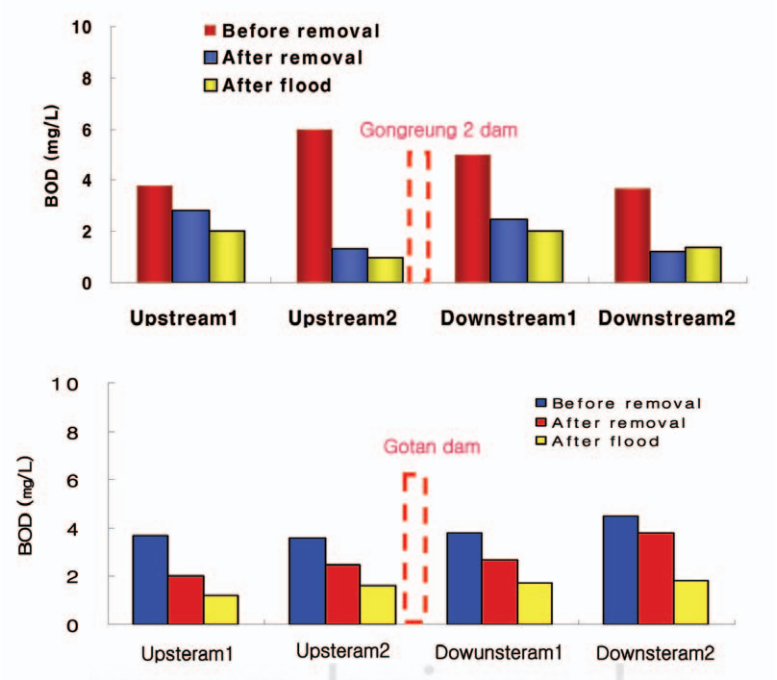


Fig. 7. Changes in BOD and SS concentration of Gongreung2 small dam(up) and Gotan small dam(down) before and after small dam removal


Fig. 8. Changes of vegetation illustrated in the vegetation cross section after the removal of Gongreung2 small dam(up) and Gotan small dam(down)

zone-of-disturbance vegetation appear in most cases, and as time passes, perennial vegetation is expected to succeed to the annual vegetation.

2) Large benthic invertebrates

After the removal the static waters of the upstream changed to flowing waters, and as diverse particles form the riverbed materials, dragonflies and melanian snails, which used to be there, were not discovered, whereas trichoptera, which did not used to be there prior to the small dam removal, appeared. There was some change to the species. Before the small dam removal chironomids and tubifexes were dominant, but chironomids and mayflies were dominant after the small dam removal.

3) Fish

The dominant species was the pale chub, and the next dominant species was the goby minnow.

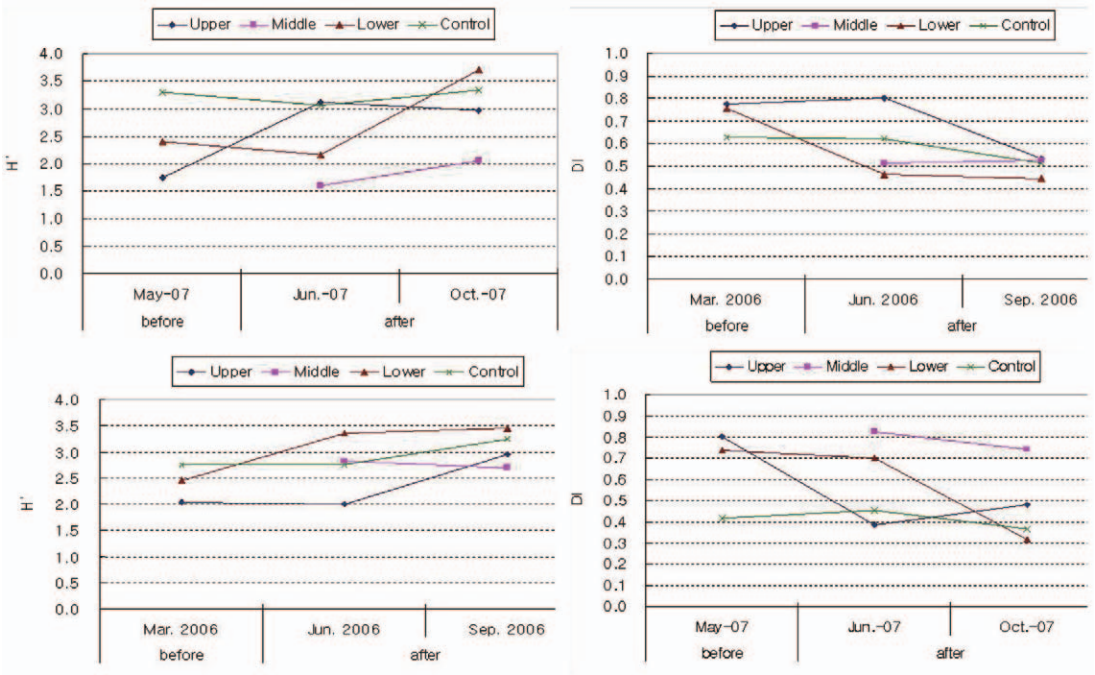


Fig. 9. Comparison of diversity indices(H') and dominant indices(DI) of large benthic invertebrate after the removal of Gongreung small dam(up) and Gotan small dam(down)

Table 1. Comparison of species diversity indexes before and after the dam removal of Gongreung2 and Gotan small dam

| Fish community patterns | Before vs after removal | downstream | | upstream | |
|---|---|---|---|---|---|
| | | Gongreung2 small dam | Gotan Small dam | Gongreung2 small dam | Gotan Small dam |
| Species number | Before removal | 8 | 10 | 8 | 16 |
| | After removal | 9 | 12 | 12 | 26 |
| Species diversity(H') | Before removal | 1.53 | 1.88 | 1.02 | 0.98 |
| | After removal | 1.97 | 1.63 | 1.97 | 1.97 |
| Evenness (E') | Before removal | 0.74 | 0.90 | 0.49 | 0.71 |
| | After removal | 0.90 | 0.67 | 0.79 | 0.83 |
| Species richness(R') | Before removal | 1.80 | 1.53 | 1.49 | 1.00 |
| | After removal | 2.25 | 1.84 | 2.55 | 1.99 |

After the small dam removal Far Eastern catfish and Chinese mitten crab, which used to be found in the downstream area only, were seen in the upstream area as well. We could confirm the details of the changes in fishes after the small dam removal. A look at the changes of the species index before and after the small dam removal shows that most indexes rose after the small dam removal. As the small dam removal secured the eco-corridor, most indexes increased. However, fishes seem to need a longer-term monitoring as well.

## IV. Conclusions

This study is to analyze the changing phase in the habitat of organisms after the removal of

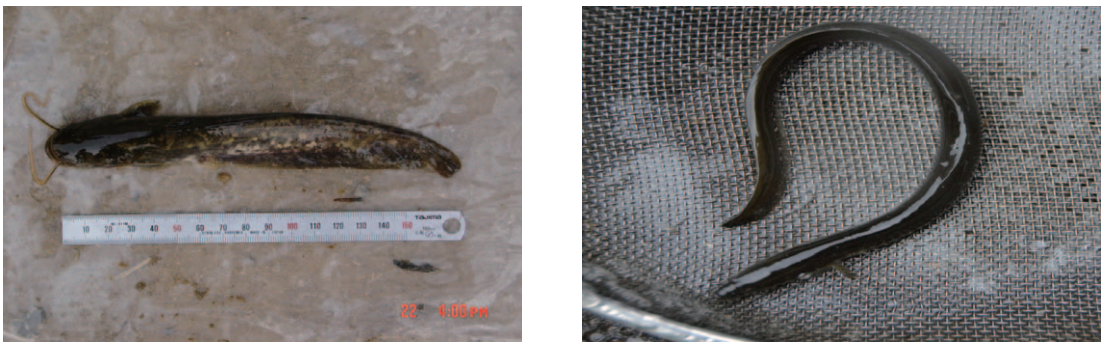

Fig. 10. The photo of the Far Eastern Catfish(left:Gongreung2 small dam) and eel(right:Gotan small dam) be found in the upstream after the dam removal

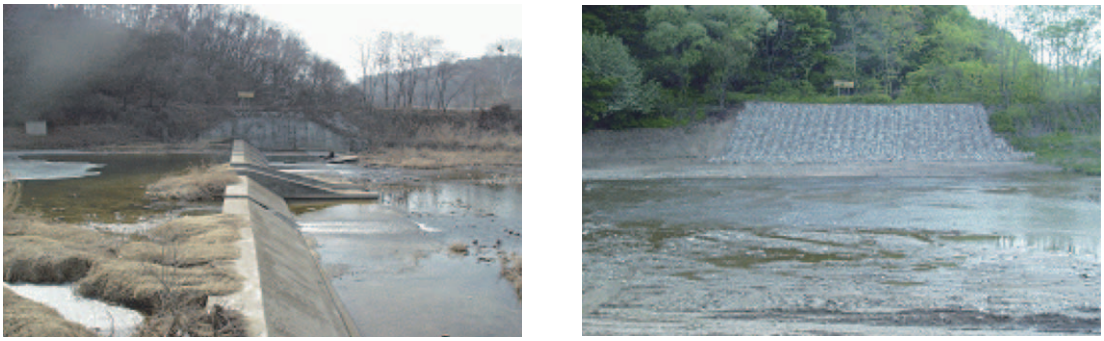

Fig. 11. The photo of Gongreung2 small dam before(left) and after(right) the dam removal(opposing the left bank of the small dam)

Fig. 12. The photo of Gotan small dam before(left) and after(right) the dam removal(opposing the right bank of the small dam)

small dams which used to block streams.

For the analysis of the changing phase in the habitat of organisms, the physical impacts such as the changes of the riverbed caused by the removal of the small dam, chemical impacts such as changes of the water quality before and after the removal, and biological impacts due to changes in the habitat were examined.

In the Gongreung2 small dam in the Gongreungcheon whose riverbed was made up with sand, swamps in the upper and lower reaches of the small dam quickly changed to rapids after the removal of the small dam whereas swamps in the Gotan small dam in the Hantan River whose riverbed consists of gravel is very slowly changing to rapids.

As the density of BOD decreases through the removal of the small dams, the water quality has improved in the two areas.

In terms of biological impacts, there were changes in the habitats as the two streams changed from lentic ones(swaps) to lotic ones (rapids).

These biological changes in the habitats brought the creation of vacant lands right after the removal of the small dam and noticeable invasion of introduced plants, but it is likely that the introduced varieties will be succeeded by indigenous ones in the future and caddisflies appeared which had not inhabited in the areas before the removal of the small dams.

Also, fish such as catfish and eels whose movements were obstructed by structures such as small dams before are discovered now in the upper reaches of the small dams.

The result of this study to analyze the changes in organisms' habitats before and after the removal of the two small dams show that the removals were substantially helpful for recovering of ecological functions of rivers.

The analysis of biological impacts, however, seems to need a further long-term monitoring.

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