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# Ecological Impact Analysis of a Stream on the Dam Construction Using Species Biotic Index (SBI) as a Tool of Ecosystem Health Assessment

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**Species biotic index (SBI), based on a fish assemblage, was applied to a stream assessment using long-term ecological fish dataset (1996 to 2001) in Boryong dam area, which is located in the mainstream of Ungchun Stream of Chungnam province, Korea. According to the methods of Hilsenhoff (1988), the scores of tolerance guild assigned 10 classes to each species by its habitat and feeding guild, but modified current 7 criteria to 5 scoring standards due to unclear borderline among species. Relative abundance in the species number of upper stream guilds was only 7% of the total, whereas the abundance in the species number of middle to downstream upper stream guilds was 64%. Mean SBI, based on dataset in Site 1 during 1995-2001 averaged 5.10, which was judged as a "good" condition by the rank criteria of SBI. Before the dam construction, mean SBI in the Site 1 was 4.61, indicating a "good" condition, but after the dam construction, mean SBI was 5.60, indicating a "fair" condition. Trajectory analysis in the Site 1 showed significantly (One-way ANOVA, $F_{6,21}$=3.26, $p$= 0.02) different among years, reflecting the changes of fish composition and population density by the dam construction, whereas Site 2 showed no significant changes ($F_{6,21}$=1.00, $p$=0.45) difference among years. Mean SBI prior to the dam construction in the Site 3 was 4.52 but after the construction, the value was 6.30, indicating a distinct difference between the pre- and post-dam construction. Trajectory analysis at the Site 3 supported this fact: Values of SBI showed significantly ($F_{6,21}$=14.37, $p$< 0.01) different. Mean SBI was 4.67 in the Site 4, indicating a "good" condition in the health and the health rank was same as the sampling sites 1, 2, and 4. Trajectory in the Site 4 showed no significant ($F_{6,21}$=2.35, $p$=0.07) difference among the years. Overall, our trajectory analysis indicated that three of four sampling sites (sites 1, 3, 4) showed significant decreases (n=7, $p$<0.05) and that the proportions of sensitive species declined evidently in the sites 1 and 2 and the tolerant species increased in the dam sites. Our outcomes may be used as a key data for diagnosis of the long-term ecological impact in the future in the watershed.**

**Key words : Species Biotic Index, ecological assessment, fish, SBI, stream**

## INTRODUCTION

Recently, various aquatic taxa have been used for ecological and biological assessments of aquatic environments (US EPA, 1988; Barbour *et al.*, 1999). One of the major popular trophic levels for the assessments was fish, which is a long-lived

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species in the water and has high sensitivity to habitat degradations as well as water pollutions (Karr, 1991). In Korea, freshwater fish is known as about 200 species (including North and South Korea) and about 150 species among them are habited in the southern part of Korea. These fishes have adapted their own habitat environments during long periods (Choi *et al.*, 1990; Kim, 1995; Kim 1997), so fishes have their own unique ecological niche and distributed widely depending on types of watersheds or rivers, water quality, and physical habitats. Major primary factors influencing the fish distribution and the number of species have been identified as modifications of physical habitats by dam construction, sediment dredging, and channelization and water pollutions by nutrient loadings and toxic chemical inputs (Barbour *et al.*, 1999; An *et al.*, 2001). In addition, exotic species such as large mouth bass caused decreases of the population size of Korean endemic fish species. Such various disturbances resulted in massive ecological disturbance by trophic unbalance in the aquatic environments.

Under these circumstances, regional ecological assessments using various methodology are so important for species conservation, protection of water resources, and efficient watershed managements. For these reasons, various approaches have been applied using fish assemblage (Yang and Chae, 1994; Song *et al.*, 1995; Choi *et al.*, 1997), aquatic macroinvertebrate (Bae and Park, 1992; Kim *et al.*, 1995; Youn and Jeon, 1999), and algae (Kim *et al.*, 1995; Cho *et al.*, 1998; Shin *et al.*, 2000). One of the problems in uses of such biological indicators, however, was lack of the stream order concept in their assessments (especially, in fish). These problems were largely overcame by US EPA's methodology, which is known as rapid bioassessment protocol (RBP, Barbour *et al.*, 1999) and uses a multi-metric model based on the Index of Biological Integrity (IBI). Also, biological criteria by Hilsenhoff (1988) and Putten (1989) have been widely applied as a tool for evaluations of aquatic environments. Especially, Species Biotic Index reflect organic pollution and conditions of physical habitats in aquatic ecosystems (SBI, Hilsenhoff, 1988), so the index were widely applied in more than 20 countries for evaluations of aquatic ecosystems.

The objective of our study was to apply Species Biotic index (SBI), based on a fish assemblage and tolerance score, for determining the impact of dam construction on a regional watershed. We applied the model to the values for long-term ecological fish dataset (1996 to 2001) in Boryong Dam area, which is located in the mainstream of Ungchun Stream of Chungnam province, Korea. In this study, we tested how the ecosystem responded to the dam construction over the long-term period and analyzed how the dam construction influence trophic compositions and tolerance guilds of fish.

## MATERIALS AND METHODS

### 1. Sampling sites and sampling methods

Fish collections were conducted in four sampling sites of Boryong dam watershed, which is located in the mainstream of Ungchun Stream of Chungnam province, Korea. Locations of the sampling sites are as follows: Site 1: Dowhadam bridge, Dowhadam-ri, Mitan-myon, Boryong City, Chungnam Province, Site 2: Nuckjin bridge, Nuckjin-ri, Mitan-myon, Boryong City, Chungnam Province, Site 3: Pyungna-ri Mitan-myon, Boryong City, Chungnam Province (the inside of the dam, and Site 4: Whasan bridge, Dongho-ri, Jusan-myon, Boryong City, Chungnam Province.

All habitats such as riffle, run, and pool were included in the sampling and the sampling were conducted upstream direction using casting nets (mesh size: $4 \times 4$ mm) and kick nets (mesh size: $2 \times 2$ mm). The distance and time sampled was at least 150-200 m and 60-70 minutes, respectively at each site for the catch per unit efforts (CPUE). Fish species collected were identified and then were released to their habitats sampled. Some ambiguous specimens, however, were preserved in 10% formalin to identify the taxa in the laboratory.

### 2. Calculation of Species Biotic Index (SBI)

Species Biotic Index (SBI), based on a fish assemblage and tolerance score, was developed in this study and applied the values for long-term ecological fish dataset (1996 to 2001). Tolerance ranks on each fish species were empirically obtained from personally Dr. Ki-Chul Choi in 2001 (before he died) according to the approach of Species Biotic Index (Hilsenhoff, 1988). In this study, we included fish tolerant scores (FTSs) of fauna collected in our study, but the FTS for all other species distributed in Korea were summerized by Drs. An and Choi. The equation of SBI is as follows:

Species Biotic Index (SBI) $= 1/N\ \Sigma n_i * t_i$

($N$=total number of individual; $n_i$=total number of each species; $t_i$=tolerance value of each species)

Each value was categorized as 7 criteria, which is based on the rank values of Hilsenhoff (1988). The ranks of 0.00-3.75, 3.76-4.25, 4.26-5.00, 5.01-5.75, 5.76-6.50, 6.51-7.25, and 7.26-10.00 were classified as "Excellent", "Very good", "Good", "Fair", "Fairly poor", "Poor" and "Very poor", respectively.

### 3. Comparisons of percent similarity

Current conditions were compared using percent similarity values among the stream sites. One of the advantages in the approach was to compare the conditions of water pollution between past and present dataset. When the percent similarity values were >85%, the condition is judged as "no significant difference between the past and present condition". Similarly, when the percent similarity is less than 50%, it means that the condition was very severely changed between the past and present condition. Percent similarity of 84-70% and 69-50% indicates slight difference and large difference, respectively. The percent similarity in the SBI follows the approach of Plafkin (1989) and the equation is calculated as follows:

Percent Similarity (%)
=(SBI in the past/SBI in the present) × 100

## RESULTS AND DISCUSSION

Total number of fish species was 31 in four sampling sites of Boryong dam watershed, which is located in the mainstream of Ungchun Stream, Chungnam province. We classified the reach guilds along the axis of the longitudinal gradients, based on approach of Kim (1995) and the guilds divided into five categories of upper stream, mid-upper stream, middle stream, mid-down stream, and downstream (Table 1). Relative abundance in the species number of upper stream guilds (U) was only 7% of the total, whereas the abundance in the species number of middle to downstream upper stream guilds (MD, D) was 64%. This phenomenon was accord with the midstream characteristics in the watershed. Trophic guild analysis showed that omnivores and insectivores were 39% and 42%, respectively. US EPA (1993) pointed out that high proportion of omnivores in a stream or rivers indicates a degradation of water quality, and vise versa in insectivores (US EPA, 1993). Based on these results, our watershed was composed of mixed guilds with no-food specificity and food specificity (aquatic macroinvertebrate). In contrast, the relative proportion of herbivores was very low (3%), indicating that primary production may not enough to support the herbivore fish in this watershed. In fact, periphyton was rarely observed in the watershed, and in spite of the dominance of benthic species such as run benthic, pool benthic, and riffle benthic species, the feeding of herbivores was low. Based on these dataset, values of fish tolerant species (FTS) were estimated after the approach of Species Biotic Index (Hilsenhoff, 1988). Values of FTS ranged from 10 in the species of *Cyprinus carpio, Carassius auratus*, and *Channa arga* to 1-2 in the species of *Coreoleuciscus splendidus, Rhynchocypris oxycephalus, Zacco temmincki, Pseudobagrus koreanus, Pseudobagrus koreanus*, and *Odontobutis platycephala* (Table 1). Values of FTS $\leq 4$ were 45% of the total, indicating that sensitive species dominated the community in the watershed.

Long-term variation of Species Biotic Index (SBI) was evaluated in the stream, and one of the main purposes of SBI was to identify the impact of the dam (constructed in 1998) on the stream ecosystem. Mean SBI, based on dataset in Site 1 during 1995-2001 averaged 5.10 (Fig. 1A), which was judged as a "good" condition by the rank criteria of SBI. Before the dam construction, mean SBI in the Site 1 was 4.61, indicating a "good" condition, but after the dam construction, mean SBI was 5.60, indicating a "fair" condition (Fig. 1A). This means that biological health condition in 2001, based on SBI, got worse after the dam construction. Thus, trajectory in the Site 1 showed significantly (One-way ANOVA, $F_{6,21}=3.26$, $p=0.02$) different among years (Fig. 1A), reflecting the changes of fish composition and population density by the dam construction.

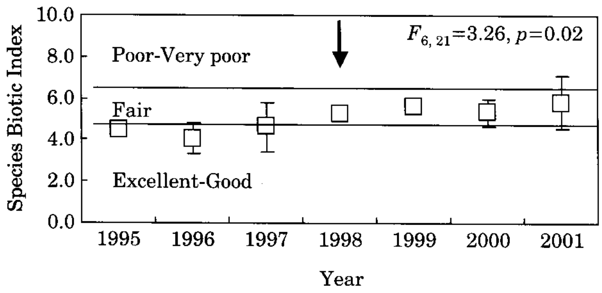
**Table 1.** Reach guilds, trophic guilds, habitat guilds, and tolerance guilds observed in the sampling site along with fish tolerant scores (FTSs). In reach guild, the letters of U, MU, M, MD and D mean upper stream, mid-upper stream, middle stream, mid-downstream and downstream, respectively. The characters of RB, rB, W and PB in the habitat guild represent run-benthic species, riffle-benthic species, water column species and pool-benthic species, respectively. The characters of S, I, and T indicate sensitive, intermediate and tolerant species that classified by many fish scientists, respectively.

| No | Species | Reach guild | Trophic guild | Habitat guild | Tolerance guild | FTSs |
|---|---|---|---|---|---|---|
| 1 | *Cyprinus carpio* | D | O | RB | T | 10 |
| 2 | *Carassius auratus* | D | O | W | T | 10 |
| 3 | *Rhodeus ocellatus* | MD | O | W | I | 4 |
| 4 | *Rhodeus uyeckii* | MD | O | W | T | 7 |
| 5 | *Acheilognathus lanceolatus* | M | O | W | S | 4 |
| 6 | *Acheilognathus yamatsutae* | M | O | W | I | 4 |
| 7 | *Acanthorhodeus macropterus* | MD | O | W | I | 4 |
| 8 | *Pseudorasbora parva* | D | O | W | T | 9 |
| 9 | *Puntungia herzi* | MU | I | rB | S | 3 |
| 10 | *Coreoleuciscus splendidus* | MU | I | rB | S | 2 |
| 11 | *Sarcocheilichthys nigripinnis morii* | MD | I | PB | I | 5 |
| 12 | *Gnathopogon strigatus* | M | I | PB | T | 9 |
| 13 | *Squalidus gracilis majimae* | MD | I | W | I | 6 |
| 14 | *Hemibarbus labeo* | MD | I | RB | T | 8 |
| 15 | *Hemibarbus longirostris* | MU | I | rB | S | 3 |
| 16 | *Pseudogobio esocinus* | MD | I | PB | I | 5 |
| 17 | *Microphysogobio yaluensis* | M | O | RB | I | 5 |
| 18 | *Rhynchocypris oxycephalus* | U | O | rB | S | 1 |
| 19 | *Aphyocypris chinensis* | MU | O | rB | T | 9 |
| 20 | *Zacco temmincki* | MU | I | rB | S | 2 |
| 21 | *Zacco platypus* | MD | H | rB | I | 6 |
| 22 | *Opsariichthys bidens* | M | P | RB | T | 8 |
| 23 | *Iksookimia koreensis* | MU | I | rB | S | 3 |
| 24 | *Cobitis lutheri* | MU | I | RB | S | 3 |
| 25 | *Pseudobagrus koreanus* | U | P | rB | S | 2 |
| 26 | *Odontobutis platycephala* | MU | P | RB | S | 2 |
| 27 | *Odontobutis interrupta* | M | P | RB | S | 3 |
| 28 | *Chaenogobius urotaenia* | D | I | rB | I | 6 |
| 29 | *Tridentiger obscurus* | D | O | RB | T | 8 |
| 30 | *Rhinogobius brunneus* | MU | I | RB | I | 5 |
| 31 | *Channa arga* | MD | P | PB | T | 10 |

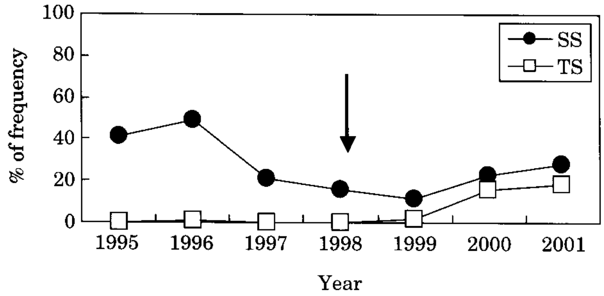
Tolerant guild analysis in the Site 1 showed that the proportion of sensitive species was 40% prior to the construction of the dam, but it declined by 2 fold in 1999, immediately after the dam construction. In contrast, tolerant species showed the significant difference ($p<0.05$) between pre-dam and post-dam construction. As shown in the Fig. 1B, the percent frequency of tolerant species increased by 20% in 2001.

The population density of *Zacco temmincki*, based on the percent of number per $m^2$, was not significant ($r$=0.68, $p>0.05$) in the Site 1 over the study period of 1995-2001 (Fig. 1C), indicating that the population did not change in spite of the dam construction of 1998. These outcomes indicate that trophic compositions of the sensitive species in the community level changed, but the specific population did not change regardless of the dam construction.

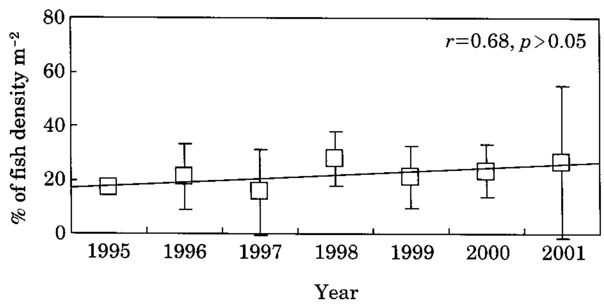
Species Biotic Index (SBI) averaged 4.80 in the Site 2 (Fig. 2A) and this was judged as a "good" condition in the health by the rank criteria of SBI. Thus, the health condition in the Site 2 did not differ, compared with the average in the Site 1. In the Site 2, mean SBI prior to the dam construction of 1998 was 4.80, and the SBI after the dam construction was 5.1, resulting in little difference between the period. Trajectory in the Site 2 showed no significant (One-way ANOVA, $F_{6,21}$= 1.00, $p$=0.45) difference among years (Fig. 2A).




(A) Trajectory of SBI

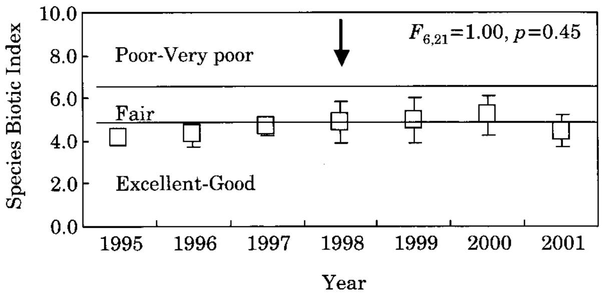



(B) Trophic composition

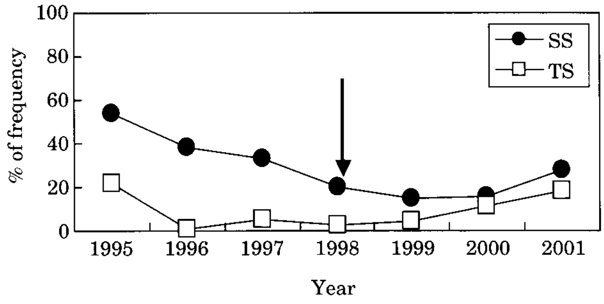



(C) *Zacco temmincki*

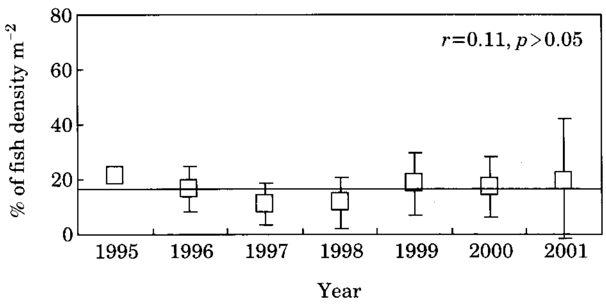
**Fig. 1.** Interannual variations of Species Biotic index (SBI) at Site 1 (A). The trajectory showed significantly different among years, reflecting the changes of fish composition and population density by the dam construction (One-way ANOVA, $F_{6,21}$= 3.26, $p$=0.02). The slope of sensitive group was steeply declined before the dam construction and positively increased after that time, while that of tolerant group was gradually increased after dam construction (B). The population density of *Zacco temmincki* was not varied ($r$=0.68, $p>0.05$; C) among sampling years.




(A) Trajectory of SBI




(B) Trophic composition




(C) *Zacco temmincki*

**Fig. 2.** Interannual variations of SBI at Site 2. The trajectory showed no difference ($F_{6,21}$=1.00, $p$=0.45) among years. The slopes of both sensitive and tolerant groups were steeply declined before the dam construction and positively increased after that time (B). The density of *Zacco temmincki* was not significantly varied ($r$=0.11, $p>0.05$; C) among sampling years.

Thus, the site variation was evident, compared with the two sites. Tolerant guild analysis showed that the proportion of sensitive species was >30% in 1995, 1996, and 1997, while the proportion was <30% after the dam construction (1999, 2000, 2001, Fig. 2B). Thus, sensitive species declined continuously over the study period during 1995-2001 and this pattern was similar to the tolerant species (Fig. 2B). The decreasing slope in the sensitive species, however, was greater than the slope of tolerant species. The population density of *Zacco temmincki*, expressed a percent of number per m$^2$, was not significant ($r$=0.11, $p>0.05$) over the study period. These results indicate that specific sensitive population did not

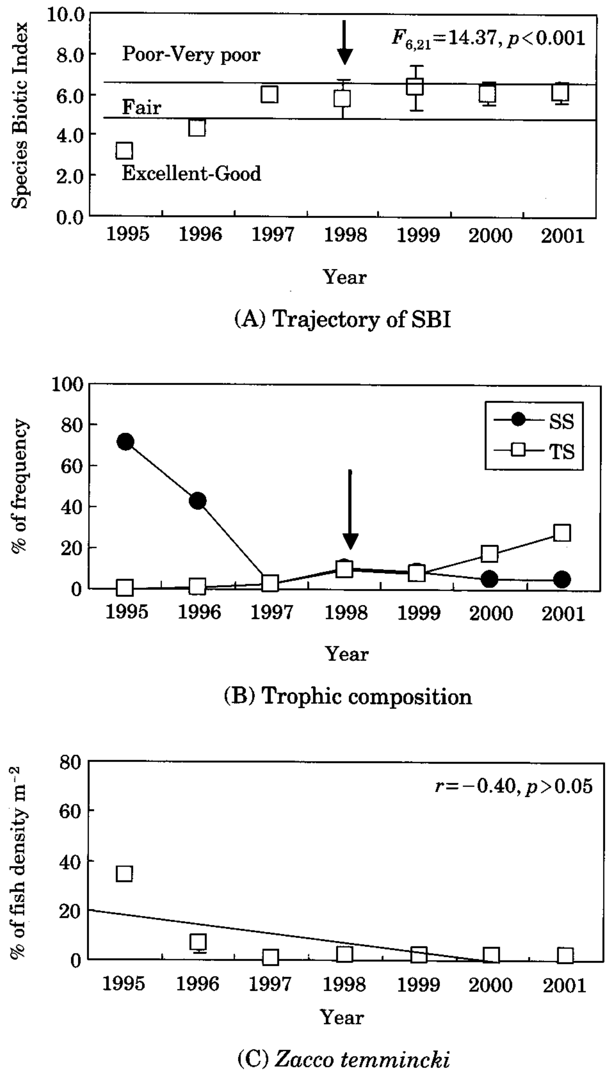



**Fig. 3.** Interannual variations of SBI at Site 3 (A). The trajectory showed significantly different ($F_{6,21}$= 14.37, $p<0.001$) among years. The slope of sensitive group was steeply declined with dam construction and no recovery was observed after that time, while that of tolerant group positively increased after dam construction (B). The population density of *Zacco temmincki* was not varied ($r=-0.40$, $p>$ 0.05; C) among sampling years, but correlated negatively.

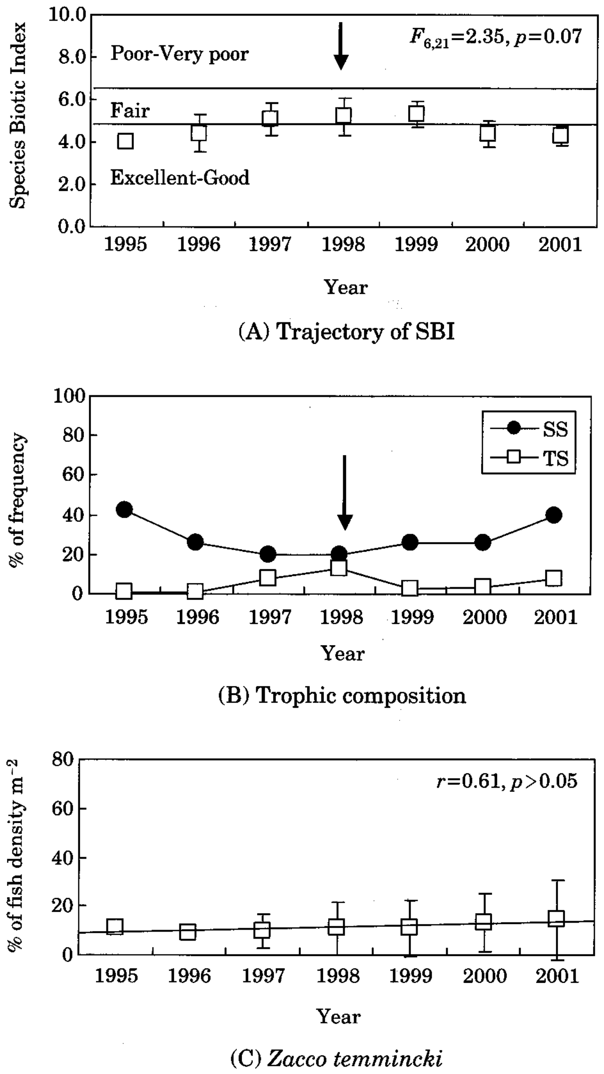



**Fig. 4.** Interannual variations of SBI at Site 4 (A). The trajectory was significantly different ($F_{6,21}=2.35$, $p=0.07$) among years. The slopes of sensitive group was declined, while the tolerant group were increased before dam construction (B). The population density of *Zacco temmincki* was not varied ($r=0.61$, $p>0.05$; C) among sampling years.

change the density, in spite of the decreasing of sensitive species over the time.

Species Biotic Index (SBI) in the Site 3 during 1995-2001 averaged 5.48 (Fig. 3A), which was judged as a "fair" condition by the rank criteria of SBI. Thus, this value was higher than any other sites, indicating a worst condition of the biological health and largest impacts of the dam construction among the sites. In fact, mean SBI prior to the dam construction in the Site 3 was 4.52 but after the dam construction, the mean SBI was 6.30 (Fig. 3A). Thus, there was a distinct difference between the pre- and post-dam construction. Trajectory analysis at the Site 3 over 1995-2001 supported the fact: Values of SBI showed significantly (One-way ANOVA, $F_{6,21}=14.37$, $p<0.01$) different among years (Fig. 3A). This means that the dam construction in 1988 resulted in the biological degradation, based on the fish index. One of the important characteristics was shown in the decreasing trends in the number of sensitive species (Fig. 3B) and this phenomenon was supported by remarkable decreases in the population density of *Zacco temmincki* after 1998, although the long-term was not significant ($r=-0.40$, $p>0.05$; Fig. 3C). Also, tolerant species increased continuously from 1995 to 2001 (Fig. 3C), indicating a degradation of the health condition, and the sentinel species did not observed after the dam construction during the study period (Fig. 3C), the potential impacts of the dam construction.

Mean Species Biotic Index (SBI) was 4.67 in the Site 4 (Fig. 4A), indicating a "good" condition in the health by the rank criteria of SBI. Thus, the health standard (rank) in the Site 4 was same as the sampling sites 1, 2, and 4. In the Site 4, mean SBI prior to the dam construction of 1998 was 4.50, and the SBI after the dam construction was 4.63, resulting in little difference between the period. At this site, values were highest in 1998 and then declined slightly after the dam construction. Trajectory in the Site 4 showed no significant ($F_{6,21}=2.35$, $p=0.07$) difference among years (Fig. 4A). Percent of sensitive species declined by 1998, and then increased slightly over the period of 1999-2001 (Fig. 4B). Conversely, the tolerant species slightly increased by 1998, and then decreased over the period of 1999-2001 (Fig. 4B). In the mean time, in the Site 4 there was no significant change ($r=0.61$ $p>0.05$) in the population density of *Zacco temmincki* (Fig. 4C).

Overall, our trajectory analysis indicated that three of four sampling sites (Sites 1, 3, 4) showed significant decreases ($n=7$, $p<0.05$) of Species Biotic Index (SBI). Also we found that changes of trophic compositions was evident, even though the state varied depending on the sampling locations. Thus, the proportions of sensitive species declined evidently in the Sites 1 and 2, and the proportions of tolerant species increased evidently in the Sites 1 and 2. In the mean time, specific sentinel species using *Zacco temmincki* did not showed statistical differences. These results indicates that three years after the dam construction may not enough for variation in the population of specific species. In contrast, the health condition, based on the SBI, evidently declined from a "good" in the pre-dam construction to "fair" in the post-dam construction. Such biological health impact on the dam construction was hypothesized by the serial discontinuity concept of artificial dam by Ward and Stanford (1983). The disruptions of dam construction resulted in compositional changes of biota such as a fish, top trophic level of the aquatic ecosystem, in the waterbody, in the end resulted in changes of functions of aquatic ecosystems. Therefore, our results may be used as a basic data for diagnosis of the long-term ecological impact in the future in the watershed.

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