The Current Study for the Management and Restoration of Paddy Ecosystem to enhance Biodiversity in Korea

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1. Introduction

As the conservation of agricultural ecosystem becomes more important in the aspects of the enhancement of biodiversity as well as the construction of healthy ecosystem for sustainable production, the development of technologies or practices for the restoration of agro-ecosystem is needed. Therefore, the assessment of the effects of some management technologies and practices on biodiversity in paddy ecosystem were undertaken to find ways to enhance the biodiversity in the paddy and the surrounding environment. As attempts to enhance biodiversity in the paddy ecosystem, we surveyed biodiversity which was focused on benthic macroinvertebrates with and without irrigation ponds across the country during 2010-2012. In Korea also many irrigation ponds were destructed by various development projects since the 1950s [1]. Nowadays, with increasing concerns about biodiversity in rice paddy, we reconsidered the restoration of irrigation ponds in the several local governments in Korea. Ecological functions of irrigation ponds were well known fact that important for biodiversity conservation in agricultural ecosystem. Irrigation ponds play an important role in the life cycle of benthic macroinvertebrates, because of the benthic macroinvertebrates completes their life cycle over moving among paddy field, irrigation pond, and ditch [2]. As the paddy field are drier and have longer dry periods, the irrigation ponds can hopefully also serve as a compensation for the lost water habitats. In this study, to verify the biodiversity enhancement effect of irrigation ponds we surveyed benthic macroinvertebrates with and without irrigation ponds linked to rice paddy field.

2. Materials and Methods

2.1 Study sites and Sampling of benthic macroinvertebrates

The study sites were located in paddy fields in five regions, South Korea (Fig. 1). Field surveys on each survey region were conducted in paddy fields with and without an irrigation pond. The paddy fields without pond were selected within a 0.1 km radius from the paddy fields with pond to minimize the effect of different environmental factors between two paddy types. The land use cover within a 0.5 km radius of each site center was determined using ArcGIS (ver.10.0, Esri Korea).

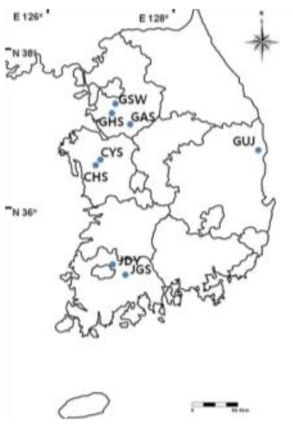

Fig. 1. The location of survey irrigation ponds in Korea (GHS, GyeongGi-Hwaseong; CYS, ChungNam-Yesan; CHS, ChungNam-Hongseong; GUJ, GyeongNam-Uljin; JDY, JeonNam-Damyang)

Field surveys of benthic macroinvertebrates were conducted from 2010 to 2012 at all sampling. Samples in the pad dy fields were collected randomly using quadrat samplers. The quadrat method was performed using a rectangular pl astic quadrat (height 20 cm, base 50×20 cm inside dimensions). Three replicates were randomly collected from each sampling site. The samples were stored in a cooler and transported to the laboratory, and then benthic macroinvertebr ates were sorted and preserved in 70% ethanol. Benthic macroinvertebrates were identified to the species level by usi ng available references [3].

2.2 Data analysis

The differences among regions and taxonomic groups in benthic macroinvertebrate communities were assessed using species richness (the total number of species) and density (total number of individuals per 100cm2). Density data was converted into log10(density + 1) transformed sampling data for normalization and comparison among regions and taxonomic groups.

The potential positive/negative effect of ponds on macroinvertebrates living in paddy fields was calculated by conversion of species richness and density data figures into a new type of numerical data, expressed by Equation 1. In this study, the converted numerical data was defined as the biodiversity enhancement effect degree (BEED).

$$BEED = \log_{10}\left\{(\sum_{i=1}^{n} A_i + 1) \times (\frac{1}{S_n+1})\right\} \quad (1)$$

Where, Ai is the ratio of the number of the ith species that occurred in paddy fields with irrigation pond (Ti) to the number of the ith species that occurred in paddy fields without irrigation pond (Ci), and can be expressed as $\frac{T_i+1}{C_i+1}$. Sn is the total number of all species that occurred in two types of paddy fields. If the density of i species in the paddy field with a pond was higher than that in a paddy field without a pond, then the value of Ai exceeds 1 (Ai> 1) and vice versa (Ai< 1). If the density of i species is same in the two types of paddy fields, then Ai is equal to 1 (Ai = 1). That is, when the Ai values of all species are 1, the sum of the Ai values is equal to the total number of species (Sn) in two types of paddy fields. This also indicates that there is no difference of biodiversity due to irrigation ponds, because the total number of individuals from all species in both types of paddy fields is equal. The calculated values convert using the log10 transformation for normal distribution, and that result defined as the BEED. Case of BEED > 0 indicates that the irrigation pond has a positive effect on the enhancement of benthic macroinvertebrates diversity. On the other hand, the BEED ≤ 0 indicates that irrigation pond do not impart a positive effect on the biodiversity enhancement of benthic macroinvertebrates communities. In addition, a high BEED value has a more significant effect of biodiversity improvement than a low BEED value.

3. Result and Discussion

3.1 Characteristics of survey regions

We identified seven categories for the characteristics of irrigation ponds and survey regions: area of pond, altitude of pond, depth of pond, % forest, % agricultural land, % urban land, and minimum distance from forest (MDF) (Table 1). The ponds ranged from 10.0 to 207.5 m^2 for surface area, from 52 to 143 m for altitude, and from 0.31 to 1.2 m for depth. Unlike the ponds of other regions, the JDY region had the highest (area and depth) and the lowest (altitude) values for above three categories. The JDY region showed the highest % agricultural land (81.24%) among the study regions. whereas in the other regions, the percentages of forest land (46.15~83.58%) were higher than agricultural land (16.22~42.62%). MDF ranged from 2 m (CHS region) to 264 m (JDY region).

Table 1. Characteristics of landscapes and ponds in survey regions.

Region		GHS	CYS	CHS	GUJ	JDY
[1]Land Use Cover (%)	Forestry	83.58	46.15	58.32	66.08	13.17
	Agriculture	16.22	42.62	35.15	26.30	81.24
	Urban	0.20	8.92	6.53	5.35	3.48
[2]MDF (m)		18	51	2	7	264
Pond	Area (m^2)	21.20	10.00	33.20	37.80	207.50
	Altitude (m)	120	67	93	143	52
	Depth (m)	0.83	0.46	0.48	0.31	1.20

[1]Within a 0.5 km radius of survey region center
[2]MDF: Minimum Distance from Forest.

3.2 Comparisons of benthic macroinvertebrate communities in paddy field with/without a pond

During the study period, 61 species of benthic macroinvertebrates were identified from the paddy fields in five regions. The paddy field ecosystem showed a high species number for Mollusca (9) among non-insecta and Coleoptera (16) among insecta. The total number of species and individuals of benthic macroinvertebrates were showed respectively 59 and 50,274 in paddy field with irrigation pond, whereas paddy fields without irrigation pond were showed 50 and 18,662, respectively. The number of species (species richness) and individuals (density) of benthic macroinvertebrates were higher in the paddy field with an irrigation pond than that in a paddy field without a pond (Fig. 2). In taxonomical perspective, species richness of Mollusca (P < 0.001), Ephemeroptera (P < 0.05), Odonata (P < 0.05), and Coleoptera (P < 0.01) were higher in paddy fields with pond than in paddy fields without pond (Fig. 3). However, in the rest taxonomic groups (Annelida, Crustacea, Hemiptera, and Diptera), species richness were not significantly different between paddy fields with and without pond.

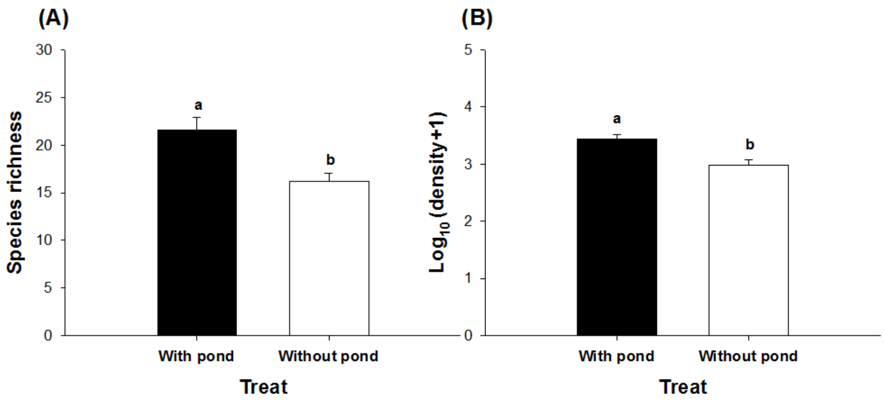

Figure 2. Comparison of (A) the species richness and (B) $\log_{10}$ transformed density of benthic macroinvertebrates according to the existence of irrigation ponds (Tukey HSD test, *P*<0.05).

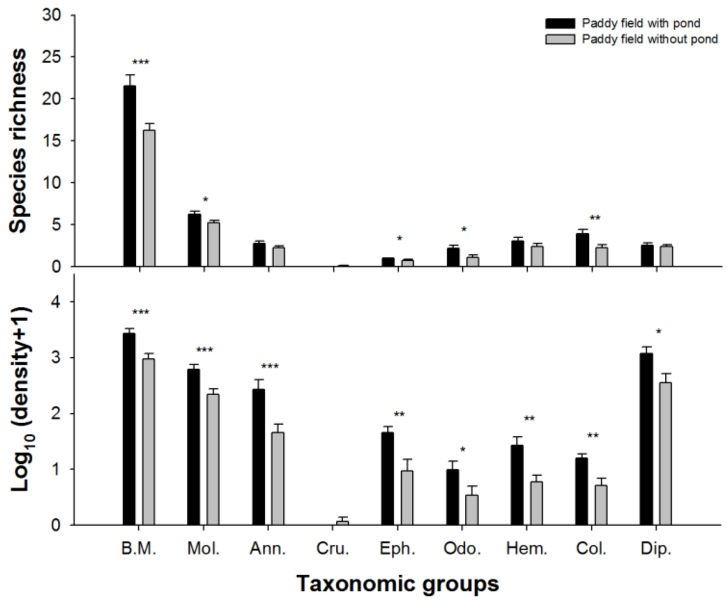

Figure 3. Species richness and density ($\log_{10}$ transformation) in paddy fields with irrigation ponds and paddy fields without irrigation ponds according to taxonomic groups (*t*-test, **P* < 0.05, ***P* < 0.01, ****P* < 0.001; B.M.: Benthic macroinvertebrates; Mol.: Mollusca; Ann.: Annelida; Cru.: Crustacea; Eph.: Ephemeroptera; Odo.: Odonata; Hem.: Hemiptera; Col.: Coleoptera; Dip.: Diptera).

3.3 Effect of irrigation ponds for biodiversity enhancement in paddy fields

The mean *BEED* values of each taxonomic group could be arranged in the following order: Mollusca (1.03 ± 0.14) > Annelida (0.70 ± 0.15) > Hemiptera (0.53 ± 0.08) > Ephemeroptera (0.52 ± 0.15) > Diptera (0.42 ± 0.10) > Coleoptera (0.36 ± 0.05) > Odonata (0.34 ± 0.06) > Crustacea (-0.02 ± 0.02). All taxonomic groups, excluding

Crustacea, showed the positive *BEED* values (*BEED* > 0) (Fig. 4). The *BEED* values calculated by using benthic macroinvertebrates occurred at each survey region. The mean *BEED* values of five survey regions could be arranged in the following order: CYS (0.58 ± 0.12) > GUJ (0.57 ± 0.10) > GHS (0.55 ± 0.11) > CHS (0.36 ± 0.07) > JDY (0.33 ± 0.07).

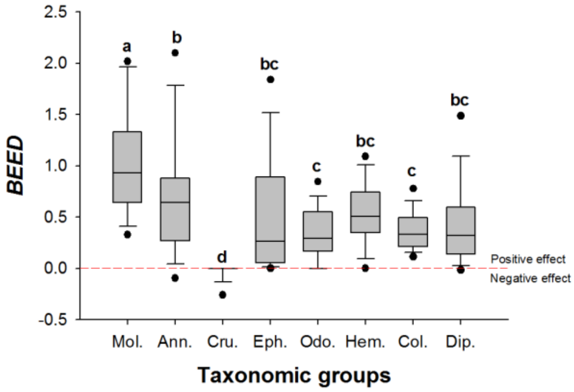

Figure 4. Biodiversity enhancement effect degree (*BEED*) comparison according to taxonomic groups (Tukey HSD test, *P* < 0.05; Mol.: Mollusca; Ann.: Annelida; Cru.: Crustacea; Eph.: Ephemeroptera; Odo.: Odonata; Hem.: Hemiptera; Col.: Coleoptera; Dip.: Diptera).

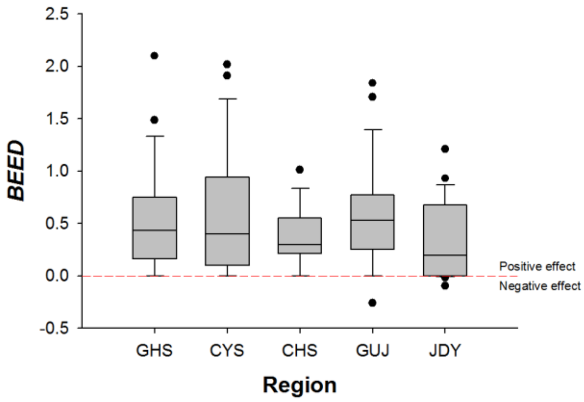

Figure 5. Biodiversity enhancement effect degree (*BEED*) comparison according to regions (Tukey HSD test, *P* < 0.05).

Biodiversity enhancement effect degree (*BEED*) of irrigation pond showed positive values in all survey regions and did not differ among survey regions (P > 0.05)(Fig. 5). The results indicate that *BEED* is related to the dispersal abilities of each taxonomic group, and an irrigation pond increases biodiversity in a paddy field in all regions. Therefore, the irrigation pond is one of the methods that can be immediately applied in paddy fields to improve the biodiversity of agricultural ecosystem.

4. Conclusions

This study was conducted to determine the distribution characteristics and biodiversity of benthic macroinvertebrates according to the existence of irrigation ponds in paddy field ecosystems. The distribution of benthic macroinvertebrates in the paddy field ecosystem was similar to the patterns in natural wetlands, and the biodiversity was affected by regions as well as by the existence of irrigation ponds. On the other hand, the biodiversity enhancement effect of irrigation ponds based on *BEED* varied according to taxonomic groups rather than region. This indicates that the biodiversity enhancement effect of irrigation ponds is related to the dispersal ability of taxonomic groups and that the biodiversity enhancement effect can be expected when irrigation ponds are created, irrespective of regions. Consequently, this study confirmed that the creation of irrigation ponds is an effective method for maintaining and enhancing the biodiversity in the paddy field ecosystem.

References

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