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Community Structure and Diversity across Spatial Scales of Macro-benthos in the Hwang River

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Abstract

Biological assessments of the macro-benthos community were carried out in the Hwang River from May 2009 to November 2010. The collected macro-benthos from the surveyed sites (St.) comprised 72 species belonging to 46 families, 17 orders, and four divisions. The emergence of species and individuals were dependent on the type and location of riverbed where they grew. St. 5, St. 7, and St. 9 had similar types of biomass, as their riverbeds were composed of boulders, gravel, etc., whereas St. 5, St. 6, St. 8, and St. 10 were located in sandy beds; therefore, featured similar benthic animals. Biomass tended to decrease on moving downstream along the river. Arthropods dominated the macro-benthos community both numerically (at individual level) and quantitatively (at species level), with a dominance of 84.7 % at the level of species. Mollusca showed the second highest dominance of 8.3 %, while Annelida and Platyhelminthes comprised 5.6 % and 1.4 %, respectively. Eight of every ten sites (80 %) were oligosaprobic according to the saprobic determination. Only two sites, St. 6 and St. 8, were β-mesosaprobic.

Key words: Macro-benthos, Environmental factors, Hwang River, Diversity index

1. Introduction

The study of river populations and communities of diatoms, macro-benthos, and fish facilitates the construction of equality indices and maps that are useful in the evaluation of both the degree of integration in the ecosystem of a river and its pollution levels. These indices and maps are also useful in obtaining direct information about land management (Mancini et al., 2004; Mostert, 1998). The ecosystem of a river refers to the river as a system operating in its natural environment, and it includes the biotic (living) interactions amongst plants, animals, and microorganisms, as well as the abiotic (non-living) physical and chemical interactions between these entities (Hynes, 1963; Kehde et al., 1972).

A river ecosystem shelters animals such as freshwater fish, frogs, salamanders, turtles, and, occasionally, birds. Various insects live in rivers, such as the water strider and the mayfly larva. A healthy river ecosystem has a food chain that provides food for the species inhabiting the river; these include plankton such as
diatoms and heliozoans at the bottom of the chain and ducks and otters at the top. Animals such as the mink and deer, which come to fish and drink, respectively, are also a part of the river ecosystem.

The Hwang River, a tributary of Nakdong River, is located in the southern part of Korea. The length of the river is 111.0 km, and it provides water to the Hapcheon Dam. The investigated watercourses all have shallow beds. Smaller streams often have an extremely low altitudinal gradient, and their riverbeds are composed of fragile materials. The channels of the Hwang River are stable except during flooding seasons. Riparian vegetation is abundant along relatively stable channels, and the majority of channels are devoid of a tree cover. Current velocity varies in the range of 0.2-0.5 m/s for periods of low-water level and in the range of 1-2 m/s during floods.

A critical part of improving river health is the accurate assessment of the current ecological state of river ecosystems (Jawad, 2003). Of the various functional measures available, we have chosen to focus on two that are relatively straightforward to estimate, and which describe fundamental aspects of an ecosystem’s functional health; these are the composition of micro-benthos species in the Hwang River and environmental factors. Data gathered in the Hwang River and overseas indicate that both indicators show considerable differences between upstream and downstream sites; thus, they have the potential to act as good indicators of ecosystem health.

The macro-benthos are mostly non-migrant inhabitants, and they can be used as indices of ecological changes in the water environment (Tabatabai and Amiri, 2010). However, to date, both the ecology and distribution of macro-benthos in Hwang River have been poorly investigated. This paper reports the results of a baseline survey of the benthic macrofaunal community within the Hwang River. Water quality measurements are also compared to assess the impacts of existing water quality in this area.

2. Materials and methods

2.1. Sites and collections

Micro-benthos were collected monthly at stations on the Hwang River from January to November during the period 2009–2010 using a Surber net (30 × 30 cm²) (APHA, 1985; Surber, 1937). Saplings were tested at the ten sites (Table 1). Three replicate samples, randomly taken at each riffle or gliding run within a 100 m reach, were pooled in a 500 mL plastic bottle to which 80% ethanol solution was immediately added. The organisms in these samples were hand-separated from detritus and inorganic materials in the laboratory. Species identification was accomplished by referring to a book (Yoon, 1988). The assessment of species composition, abundance, and the richness of aquatic

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<td>St.8</td>
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</tbody>
</table>
plants and macro-invertebrates is important for determining the nature conservation value of a reach and can be used as indicators of ecosystem health.

2.2. Biotic indices

We were able to analyze the collected data sets to understand trends in the data or statistical differences between rivers and reaches before and after treatments/activities.

The dominance index (DI) was calculated using McNaughton’s dominance index (1) (McNaughton, 1967).

\[
DI = \frac{(n1+n2)}{N} 
\]

\( (N: N \) is the total number of entities in the dataset, \( n1 \) and \( n2: \) the first and second most dominant individuals of the species) \( ) \)

The richness index (RI) of the micro-benthos was calculated by using Margalef’s Index of Richness (2) (Magurran, 1988).

\[
RI = \frac{(S-1)}{\ln(N)} 
\]

Here, \( S \) is the total number of species and \( N \) is the total number of individuals of that species.

2.3. Environmental factors

We examined the effect of environmental factors for macro-benthos using the ESB index (3) (Kong, 1997).

\[
ESB = \sum_{i=1}^{d} (S_i \cdot Q_i) 
\]

Here, ESB is the ecological score of the benthic macro-invertebrate community, \( Q_i \) is the environmental quality score of individual taxa, and \( S_i \) is the species frequency corresponding to \( i \) environmental quality.

3. Results

Water quality is a critical aspect of stream health. One should be aware of the ecological state of the local river because the river ecosystem is the foundation for the existence of many species (Nelson, 1994).

Benthic invertebrates (macro-benthos) collected during the study period in the survey section of this Hwang River comprised 72 species belonging to 46 families, 17 orders, 7 classes, and four divisions (Table 3). Macro-benthos at St. 1 consisted of 3,065 individuals with 46 species and were the most abundant species in the survey area (Table 3). In contrast, the population of macro-benthos at St. 8 was poor, comprising a total of 411 individuals with 15 species. Moreover, the concentration of biomass tended to decrease downstream along the river (Fig. 1).

Table 2. Environmental quality evaluation and saprobic determination by ESB index

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<td>4</td>
<td><em>Hydropsyche</em> KUa 줄날도래 KUa</td>
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<td><em>Hydropsyche</em> KUb 줄날도래 KUb</td>
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Table 3. continued

<table>
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<th>Qi</th>
<th>Scientific name and Korean</th>
<th>Sites</th>
<th>Total</th>
<th>RA (%)</th>
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<td><em>Rhyacophila nigrocephala</em> 검은머리물날도래</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
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<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
</tr>
<tr>
<td>3</td>
<td><em>Hydroptila KUa</em> 애날도래 KUa</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
</tr>
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<td>3</td>
<td><em>Phryganopsyche latipennis</em> 동근날개날도래</td>
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<td>St.2</td>
<td>St.3</td>
</tr>
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<td>3</td>
<td><em>Goera japonica</em> 가시날도래</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
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<td>4</td>
<td><em>Neophylax ussuriensis</em> 가시목말날도래</td>
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<td>St.3</td>
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<td>4</td>
<td><em>Apatania Kub</em> 애우묵날도래 Kub</td>
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<td>St.3</td>
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<td><em>Hydatophylax nigrovittatus</em> 뺨무늬우묵날도래</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
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<td><em>Nothopsyche KUa</em> 갈색우묵날도래 KUa</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
</tr>
<tr>
<td>3</td>
<td><em>Goerodes Kub</em> 네모집날도래 Kub</td>
<td>St.1</td>
<td>St.2</td>
<td>St.3</td>
</tr>
</tbody>
</table>

Number of species 47 45 33 21 29 19 31 15 35 28 71
Number of individuals 3065 2229 1415 1057 892 672 1179 411 762 730 12412

Qi: Environmental quality score of individual taxa, RA: Relative abundance.
Community Structure and Diversity across Spatial Scales of Macro-benthos in the Hwang River

The emergence of species and individuals depended on the type and location of the riverbed. For example, St. 5, St. 7, and St. 9 had similar types of biomass as their riverbeds were composed of boulders, gravel, etc., while St. 5, St. 6, St. 8, and St. 10 consisted of sandy beds; thus, they were populated by similar benthic animals.

Arthropods dominated the macro-benthos community both numerically (at individual level) and quantitatively (at species level), with a dominance of 84.7% at the Table 3. The lists of macro-benthos species and number of individuals at the ten sites during the period 2009-2010 level of species. Mollusca were the second most dominant species at 8.3%, whereas Annelida and Platyhelminthes comprised 5.6% and 1.4%, respectively. The composition of the investigated taxa belonging to each section of the river, was similar. However, flatworms were detected in only St. 1, St. 2, St. 3, and St. 5.

Limnodrilus gotoi was collected in large amounts at St. 4 because water pollution occurred due to domestic sewage flowing from the Hapchen dam. Thus, annelids showed a very high relative abundance in these areas, whereas other taxa, except arthropods, showed very low biomasses.

Investigated species were categorized into non-insects and aquatic insects; majority of the macro-benthos are arthropods. The arthropods of Hwang River consisted mainly of aquatic insects. In this survey, more than 60% of the species were aquatic insects that accounted for above 80% of the species at all sites except at St. 4.

Trichoptera and Ephemeroptera showed high concentrations in the upstream, whereas there were high concentrations of Odonata at the midstream and downstream sections. In particular, Micronecta sedula belonging to the order Hemiptera showed higher biomass concentration and relative abundance than the other species.

A total of 2,268 individuals (18.3%) in this survey belonged to Chironomus sp., which was the dominant species at St. 1, St. 2, St. 5, and St. 9 (Table 4). The rest of the species in order of dominance were Micronecta sedula (13.3%), Ecdyonurus levis (9.2%), Siphlonurus chankae (5.9%), and Goera japonica (5.7%).

Table 4. First and second dominant species at the ten sites

<table>
<thead>
<tr>
<th>Site</th>
<th>First dominant</th>
<th>Second dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. 1</td>
<td>Chironomus sp.</td>
<td>Ecdyonurus levis</td>
</tr>
<tr>
<td>St. 2</td>
<td>Chironomus sp.</td>
<td>Ecdyonurus levis</td>
</tr>
<tr>
<td>St. 3</td>
<td>Ecdyonurus levis</td>
<td>Chironomus sp.</td>
</tr>
<tr>
<td>St. 4</td>
<td>Limnodrilus gotoi</td>
<td>Micronecta sedula</td>
</tr>
<tr>
<td>St. 5</td>
<td>Chironomus sp.</td>
<td>Micronecta sedula</td>
</tr>
<tr>
<td>St. 6</td>
<td>Micronecta sedula</td>
<td>Chironomus sp.</td>
</tr>
<tr>
<td>St. 7</td>
<td>Micronecta sedula</td>
<td>Ecdyonurus levis</td>
</tr>
<tr>
<td>St. 8</td>
<td>Micronecta sedula</td>
<td>Chironomus sp.</td>
</tr>
<tr>
<td>St. 9</td>
<td>Chironomus sp.</td>
<td>Micronecta sedula</td>
</tr>
<tr>
<td>St. 10</td>
<td>Micronecta sedula</td>
<td>Chironomus sp.</td>
</tr>
</tbody>
</table>

Though the overall concentration of species tended to be higher in the fall and spring (Table 5), the biomass concentration of macro-benthos tended to be higher in the fall and winter. The numbers of macro-benthos at St. 1 and St. 5 remained constant throughout the year. Fall was enrichment macro-benthic through the scattering.
Table 5. Lists of macro-benthos according to season at the ten sites

<table>
<thead>
<tr>
<th>Sites</th>
<th>Summer, 2009</th>
<th>Fall, 2009</th>
<th>Winter, 2009</th>
<th>Spring, 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Species</td>
<td>Indiv.</td>
<td>Species</td>
<td>Indiv.</td>
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<td>521</td>
<td>35</td>
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<tr>
<td>St. 2</td>
<td>29</td>
<td>390</td>
<td>35</td>
<td>618</td>
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<tr>
<td>St. 3</td>
<td>23</td>
<td>194</td>
<td>22</td>
<td>348</td>
</tr>
<tr>
<td>St. 4</td>
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<tr>
<td>St. 8</td>
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<tr>
<td>St. 9</td>
<td>17</td>
<td>104</td>
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<td>St. 10</td>
<td>10</td>
<td>65</td>
<td>23</td>
<td>220</td>
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</table>

4. Discussion

Macro-benthos are important food sources for fish (Sheik et al., 1998). Discharge of floodwater from Hapcheon dam in summer leads to decreased average biomass of macro-benthos in the local rivers because the fish inhabiting the released dam water are predators of macro-benthos. During winter, the downstream movement of fish into the Nakdong River leads to a decrease in their number upstream (Fig. 1). During spring, fish move upstream as there is an increase in the biomass quantity due to rain, resulting in an increase in the predation selection pressure. The negative effect of flood on micro-organisms is well documented (Popwer and Stewart, 1987). In addition, macro-benthos actively participate in the biogeochemical cycles because of their consumption and they affect the microbial regime spatially and temporally by affecting the redox boundaries and chemical fluxes in sediments (Shajan, 2001).

Environmental quality and saprobic determination were assessed based on the benthic animals collected from each representative point. The results are as shown in Fig. 1. Six sites exhibited excellent results (60%); the results of two sites were moderate (20%), and that of one site was only satisfactory as it had some defects (10%). Thus, most sites exhibited a good environmental state.

Eight of ten sites (80%) were oligosaprobic according to the saprobic determination. Only two sites, St. 6 and St. 8, were β-mesosaprobic. Thus, Hwang River was assumed to exhibit good environmental condition during the survey interval.

In conclusion, this study showed that seasonal patterns in the community structure of the macro-benthos in the Hwang River depending on the dynamics of the river environment. This was determined by evaluating the environmental quality and by saprobic determination of the water. We hope that the relationship between the macro-benthos community and the environment, as suggested by this fine-scale investigation will contribute to future studies involving long-term changes in community structure and spatial distributions. Biological assessments tend to characterize the current status of stream ecosystems by monitoring changes in the aquatic communities associated with anthropogenic disturbance (de Pauw et al., 2006; Jun et al., 2012). Many studies of aquatic communities have been undertaken to establish effective methods for the assessment of stream water quality such as the Saprobie system.

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References


