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NOTE

Ecological Studies of Epizoic Algae Attached on the Freshwater Fishes in a Small Stream (Ian Stream), South Korea

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Most of the surveys of periphyton carried out for environmental and ecosystem health assessment of streams have considered the impact made on their fixative substrates (stones, rocks, sand, silt, clay and other abiotic matters), but there has been virtually no research that considered moving substrates. This study attempted to make an analysis and assessment of the habitat environments of the microalgae attached to the skin surfaces of fish living in small streams, with a focus on their species composition and community structure. The dominant fish in the this survey were *Zacco temmincki* and *Zacco platypus*, which are usually found in the streams, and rivers, and they accounted for 62% and 19%, respectively, in relative abundance. Substrates of fish, a representative organism with the trait of moving a long distance, show a marked contrast with those of organisms fixed at a certain place. Characteristics of both the upstream and the downstream reach well reflected in the microalgae attached to the skin surface of fishes, of which diatoms took the major composition. The result of this observation is considered to be useful to provide basic data in assessment of stream health. Also it may be suggested as a biological tool for the assessment of aquatic environment in the future.

Key words: periphyton, epizoic algae, moving substrate, stream, fish, water quality assessment

The microcosms of periphyton rather than phytoplankton are well developed in wadeable streams and small rivers that are not deep and maintain a certain level of water current (Allan, 1995). Periphyton that form biofilms by attaching themselves to a variety of substrates play an important role in matter cycling of a stream, as they, along with phytoplanktons and macrophytes, form the basis of the food chain as crucial producers of organisms in the aquatic ecosystem (Bold and Wynne, 1985). As well, periphytons are widely used in assessment of the healthiness of a stream, as they, along with their floating cousins, are highly valuable indicators of water pollution by being sensitively responsive to physical and chemical changes in the aquatic environment while attaching themselves to substrates for a long time (Horne and Goldman, 1994; Allan, 1995).

Periphyton surveys have been carried out chiefly toward fixative substrates, such as stones, sands, mud, plants or artificial substrates. This study attempts to make assessment of aquatic environment, using microalgae attached to fishes, one of the moving substrates, for which not many research activities have been carried out (Patil and Anil, 2000). It also attempts to provide basic materials concerning the river ecology that can help explain the habitat environment and various disturbance in the ecosystems based on the distribution of microalgae in diverse aquatic environments, i.e. from the upstream of small streams

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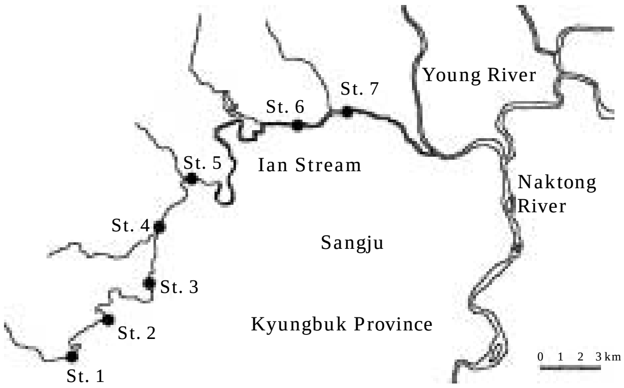

Fig. 1. Map showing sampling locations of freshwater fishes and epizoic algae in the Ian Stream.

to the downstream, which shows a stronger trait of the river ecosystem.

This study was conducted in the 0.5 km reach both in the upstream and downstream of each station in the Ian Stream in April 2004. It is a typically small stream, which the Young River, a tributary of the Naktong River (Fig. 1). The stream flows more smoothly at the downstream and gets wider toward the downstream. There are many weirs built across it. Out of the seven stations selected from the about 25 km-long stream, a mine are located between station 4 and station 5 in the midstream, and wastewater flow in from small towns between station 6 and station 7 in the downstream.

The survey was made in different locations toward downstream from each designated station to evaluate the community structure. For a quantitative survey, about ten trials were made for collection of fishes, using two kinds of cast net (mesh size 5×5 mm and 8×8 mm) at each station. For a qualitative survey, dip net (mesh size 5×5 mm) was additionally used at the streamside or around rocks. The number of the fishes collected was counted after identifying them right on the *in situ*. Those difficult to be identified were fixed, using 10% formalin solution for final classification at the laboratory. Fish samples approximately 20-30 were collected to be used for analysis of periphyton. They were washed with distilled water right on the *in situ* to prevent contamination from impure materials and carried to the laboratory with formalin fixation in a plastic bag. Classification of the fish species was carried out using the illustrated fauna book edited by Kim (1997), in accordance with the classification system of Nelson (1994).

Samples of the survey of periphyton were prepared by scrapping fish skin surfaces with a plastic brush. In order to elucidate the species composition of diatoms, part of the samples were made as permanent specimens, using a photomicroscopy of 1,000 magnification and imbading by Pleurax media after acid (HNO_3, $K_2Cr_2O_7$) treatment. Fixed samples were used as they were for other than diatoms.

In periphyton, relative abundance of diatoms was calculated in percentages based on the mean value of 500-1,000 individual numbers per samples of diatoms counting them twice. As for diatoms, cell frustules for specifies were counted to check their dominance (i.e. the share of 10% or more) in their species. As quantitative analysis on substrates per unit area was difficult to carry out, so relative abundance was calculated. Concerning blue-green algae and green algae, they were observed with a microscope without pretreatment. What could be done was to check composition of species and their abundance as the situation did not allow quantitative analysis to be done. In sampled periphytons, literatures of Jensen (1984), Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b) were referred to for diatoms, and literatures of Hegewald and Silva (1988), Hirose *et al.* (1977) and Prescott (1982) for others than diatoms. Assessment of aquatic environment of the stream using diatoms within the species of periphyton was carried out by biological indices of DAIpo of Watanabe *et al.* (1990) and TDI, %PTV of Kelly (1998).

The fish species collected from the upstream and downstream stations of the stream were classified into 7 families, 15 genera and 17 species (Table 1). Among them, Cyprinidae was the dominant family with 58.8% relative abundance, followed by Cobitidae (11.7%), Amblycipitidae (5.9%), Centropomidae (5.9%), Odontobutidae (5.9%), Gobiidae (5.9%), and Centrarchidae (5.9%). The Genus of Hemibarbus (*H. labeo*, *H. longirostris*) and Zacco (*Z. platiypus*, *Z. temmincki*) comprised two or more species. Considering the differences between stations five of the most abundant species based on relative abundance were *Z. temmincki* (1.3-84.5%), *Z. platypus* (1.1-58.5%), *C. splendidus* (2.1-15.4%), *M. yaluensis* (1.3-14.9%) and *S. gracilis_majimae* (0.6-16.7 %).

Table 1. A list and relative abundance of freshwater fish fauna observed in running water ecosystem of the Ian Stream from April 2004. rr: very rare (<0.5%), r: rare (0.5%-1.0%), +: common (1.1%-5.0%), ++: abundant (5.1%-10.0%), +++: very abundant (>10.0%)

Fish fauna\Sampling stations	Upstream 1	2	3	4	5	6	Downstream 7
Cyprinidae							
Coreoleuciscus splendidus	·	·	·	·	++	+	+++
Hemibarbus labeo	·	·	·	·	·	·	+
Hemibarbus longirostris	+	r	·	+	+	+	·
Microphysogobio yaluensis	+++	+	+	++	+	+	·
Pseudogobio esocinus	·	·	r	++	+	·	+
Pungtungia herzi	r	+	+	+	+	+	++
Rhynchocypris oxycephalus	+	·	·	·	·	·	·
Squalidus gracilis majimae	++	+	+	+	r	+	+++
Zacco platypus	+	++	+++	+	·	+++	+++
Zacco temmincki	+++	+++	+++	+++	+++	+++	+
Cobitidae							
Cobitis sinensis	·	·	r	+	·	+	·
Niwaella multifasciata	r	·	·	·	·	·	·
Amblycipitidae							
Liobagrus mediadiposalis	r	·	·	·	·	·	·
Centropomidae							
Coreoperca herzi	·	·	·	r	·	r	·
Odontobutidae							
Odontobutis platycephala	r	·	·	·	·	·	·
Gobiidae							
Rhinogobius brunneus	·	·	·	·	·	·	+
Centrarchidae							
Micropterus salmoides	·	·	·	·	·	·	+

Freshwater algae attached to fishes were classified into 26 genera and 93 species (Table 2), in which diatoms accounted for 83.9%, followed by blue-green algae (4.3%) and green algae (11.8 %). In diatoms, pennate types take the major component, and individual species, for which five or more types were found, include the Genus of *Cyclotella, Fragilaria, Achnanthes, Cymbella, Gomphonema, Navicula* and *Nitzschia*, with *Achnanthes* leading the others by a wide margin (Fig. 2). Also, phyla found in all stations were seven species and their relative abundance are as follows: *A. alteragracillima* (9.2-45.4%), *A. convergens* (1.7-16.7%), *A. minutissima* (22.9-50. 8%), *C. placentula* var. *lineata* (0.5-4.2%), *C. affinis* (0.8-15.8%) and *C. sinuata* (0.8-2.5%). It appears that *M. glaucum* and *O. limosa* that belong to blue-green algae, and *H. juliana*, *L. martensiana*, *Spirogyra* sp., and *Zygnema* sp. that belong to green algae are abundant in downstream reach.

As a factor characteristic of small streams,

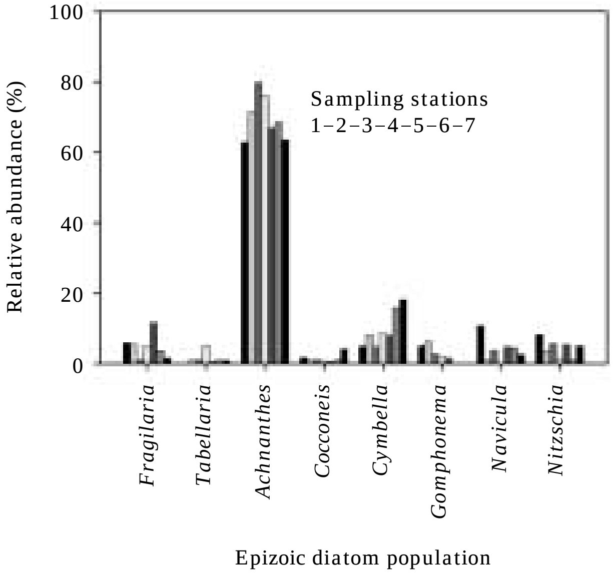

Fig. 2. Spatial distribution of the relative abundance (%) of major epizoic diatom populations in the Ian Stream from April 2004.

Table 2. The composition and their relative abundance (percentage, %) of epizoic algae attached on skin surface of fishes in the Ian Stream ecosystem, South Korea. r: rare, +: observation only, ++: abundant and +++: very abundant, respectively.

Species composition \Sampling stations	Upstream 1	2	3	4	5	6	Downstream 7
BACILLARIOPHYTA							
Order Centrales							
Family Thalassiosiraceae							
Aulacoseira ambigua	·	·	·	·	·	r	r
Cyclotella meneghiniana	·	r	·	·	·	·	r
Cyclotella pseudostelligera	·	·	·	r	·	·	3.3
Cyclotella stelligera	·	·	·	·	·	·	r
Cyclotella spp.	·	·	·	·	·	5.3	·
Family Melosiraceae							
Melosira varians	0.8	r	·	r	0.5	·	·
Order Pennales							
Family Fragilariaceae							
Fragilaria arcus	r	0.9	·	·	·	·	·
Fragilaria capucina var. *capitellata*	0.8	r	r	1.4	3.2	·	·
Fragilaria capucina var. *rumpens*	·	·	r	3.6	6.3	1.8	0.8
Fragilaria capucina var. *vaucheriae*	2.5	0.9	·	·	·	·	·
Fragilaria crotonensis	·	·	·	·	·	r	·
Fragilaria inaequalis	r	·	r	·	r	r	·
Fragilaria pinnata	·	·	·	·	0.5	·	0.8
Fragilaria sp. 001	2.5	2.8	0.9	·	1.1	·	·
Fragilaria sp. 002	r	·	·	·	·	·	·
Fragilaria ulna	r	0.9	·	r	0.5	1.8	r
Fragilaria ulna var. *acus*	·	·	·	·	·	r	r
Meridion circulare var. *constrictum*	·	·	0.9	·	·	·	·
Tabellaria flocculosa	·	0.9	0.	5.1	0.5	0.9	0.8
Family Eunotiaceae							
Eunotia minor	·	·	·	·	r	·	·
Eunotia muscicola var. *tridentula*	·	·	·	·	r	·	·
Family Achnanthaceae							
Achnanthes alteragracillima	15.7	33.9	45.4	25.4	19.5	24.6	9.2
Achnanthes convergens	15.7	11.9	6.5	15.2	8.4	16.7	1.7
Achnanthes delicatula	r	·	·	·	·	·	·
Achnanthes laevis	·	·	·	r	·	·	·
Achnanthes lanceolata	0.8	0.9	·	·	0.5	1.8	1.7
Achnanthes lanceolata var. *dubia*	r	0.9	·	·	·	·	·
Achnanthes lanceolata var. *frequentissima*	·	0.9	·	·	·	·	·
Achnanthes lanceolata var. *rostrata*	·	·	·	·	2.6	·	·
Achnanthes minutissima	30.6	22.9	27.8	35.5	35.8	25.4	50.8
Cocconeis placentula	r	·	·	·	·	·	r
Cocconeis placentula var. *lineata*	1.7	0.9	0.9	0.7	0.5	0.9	4.2
Family Naviculaceae							
Amphora pediculus	·	0.9	·	·	·	·	·
Cymbella affinis	0.8	4.6	1.9	2.9	2.6	11.4	15.8
Cymbella delicatula	·	0.9	·	3.6	0.5	2.6	r
Cymbella leptoceros	·	·	·	r	·	·	·
Cymbella minuta	0.8	0.9	·	·	·	·	·
Cymbella pusilla	·	·	r	·	·	·	·
Cymbella silesiaca	0.8	·	·	·	·	·	·
Cymbella sinuata	2.5	0.9	1.9	2.2	1.1	0.9	0.8
Cymbella tumida	r	·	0.9	·	1.6	0.9	0.8
Cymbella ventricosa	r	0.9	·	r	2.1	·	0.8
Gomphonema angustum	·	1.8	·	0.7	r	·	·

Table 2. Continued

Species composition \Sampling stations	Upstream 1	2	3	4	5	6	Downstream 7
Gomphonema clevei	1.7	1.8	0.9	·	·	·	·
Gomphonema minutum	1.7	0.9	0.9	·	·	r	·
Gomphonema parvulum	0.8	0.9	0.9	0.7	1.1	r	·
Gomphonema pseudoaugur	·	·	r	·	·	·	·
Gomphonema quadripunctatum	0.8	0.9	·	0.7	0.5	r	·
Navicula bacillum	·	r	·	·	0.5	r	·
Navicula capitata	·	·	·	·	r	·	·
Navicula capitatoradiata	0.8	·	r	r	·	0.9	·
Navicula cryptocephala	3.3	0.9	·	r	1.6	·	2.5
Navicula cryptotenella	·	·	·	·	1.1	0.9	·
Navicula decussis	0.8	·	1.9	·	r	1.8	·
Navicula duerrenbergiana	1.7	·	·	·	·	·	·
Navicula gregaria	·	·	·	r	1.1	0.9	·
Navicula minima	4.1	·	1.9	·	·	·	·
Navicula neoventricosa	·	·	·	·	·	·	r
Navicula protracta	·	·	r	·	·	·	·
Navicula pupula	·	·	·	r	·	·	·
Navicula sp. 001	·	r	·	·	·	·	·
Navicula sp. 002	·	·	·	·	0.5	·	·
Stauroneis phoenicenteron	·	·	·	0.7	·	·	·
Family Bacillariaceae							
Bacillaria paradoxa	·	·	·	·	·	r	r
Nitzschia acicularis	·	·	·	·	·	·	r
Nitzschia amphibia	4.1	·	r	1.4	4.2	·	1.7
Nitzschia bryophila	·	·	·	·	·	r	·
Nitzschia diversa	1.7	·	2.8	·	·	·	r
Nitzschia fruticosa	r	·	·	·	·	·	·
Nitzschia frustulum	·	·	·	·	·	·	r
Nitzschia intermedia	r	3.7	1.9	r	·	0.9	·
Nitzschia microcephala	0.8	·	0.9	·	·	·	r
Nitzschia palea	·	·	·	·	1.1	·	3.3
Nitzschia perminuta	·	r	·	·	·	·	·
Nitzschia recta	0.8	·	·	·	·	·	r
Nitzschia sp. 001	0.8	r	·	·	·	r	r
Family Surirellaceae							
Surirella angusta	·	0.9	·	·	·	·	·
Surirella minuta	·	·	·	·	0.5	·	0.8
CYANOPHTA							
Merismopedium glaucum	·	·	·	·	·	++	·
Oscillatoria irrigua	+	·	·	+	·	·	·
Oscillatoria limosa	·	·	·	·	·	+++	+
Oscillatoria neglecta	·	+	·	·	·	·	·
CHLOROPHYTA							
Cosmarium depressum f. *minuta*	·	·	·	·	+	·	·
Cosmarium sp. 001	+	·	·	+	·	·	·
Cosmarium sp. 002	·	·	·	·	+	·	·
Homoeothrix juliana	·	+	+	·	+	+++	·
Lyngbya martensiana	·	·	·	·	·	+++	+
Pediastrum duplex var. *reticulatum*	·	·	·	·	·	+	·
Scenedesmus acutus	·	+	+	·	·	·	·
Scenedesmus acutus f. *costulatus*	·	·	·	+	+	+	·
Scenedesmus ecornis var. *ecornis*	·	+	·	+	·	·	·
Spirogyra sp.	·	·	·	·	·	·	++
Zygnema sp.	·	·	·	·	·	·	++

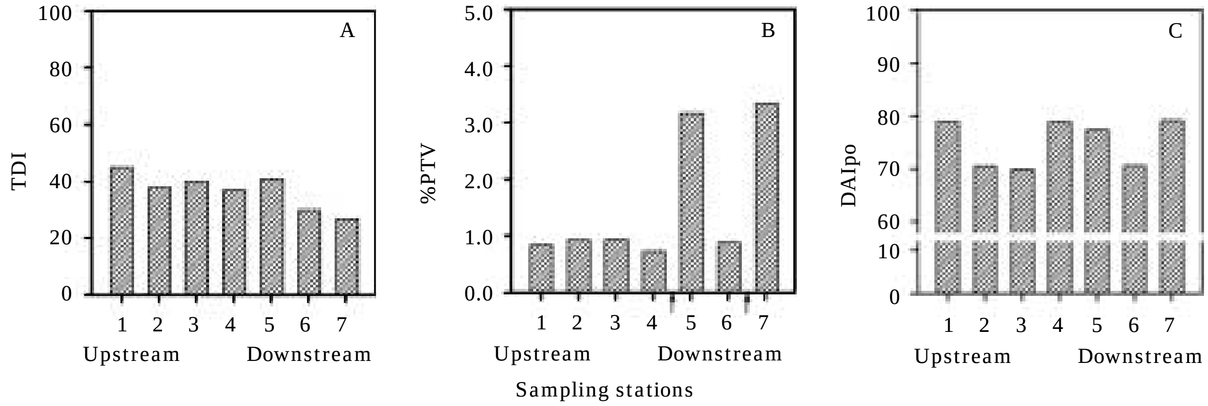

Fig. 3. Quality assessment of flowing habitat by the biological indices in the Ian Stream from April 2004.

there were small-sized fishes and periphytons, unlike the large river ecosystem. Looking at the distribution of fishes, there were a smaller number of *Z. temmincki* near the upstream, whereas there were a larger number of *Z. platypus* near the downstream (Table 1). As for distribution of periphytons, *A. alteragracillima* which is a diatom was mostly observed in middle stream reach, while much of *A. minutissima* and *C. affinis* were found in the downstream reach, and *A. convergens* was found more in the upstream reach than elsewhere (Table 2).

As a result of the water quality assessment based on biological indices, it appears that the level of organic pollution was very low, and the water fertility decreased foward the downstream. The mean value and the range of TDI were 1.54 and 0.72–3.33, respectively, with the value at upstream, midstream and downstream reach were 0.88, 0.83 and 2.42, respectively (Fig. 3). DAIpo appears to be in excess of 70% in whole reach, with the mean value and the range were 75.1 and 69.9–79.2, respectively (Fig. 3).

Looking at the pollution tolerant species, the %PTV value was below 20 in all stations, which shows that the area is affected very little by organic pollution. The %PTV reading of 3.16 and 3.33, respectively, i.e., a little higher than the mean value, at station 5 and station 7 are attributable to possible water discharge from a mine and the wastewater inflow from adjacent small rural towns.

As a result, the following conclusions could be made on the basis of the bioassessment of periphytons attached to moving substrates, such as fishes: First, fishes cannot move easily due to weirs built across the stream. Second, the composition of epizoic algae attached to fishes are more responsive to the spatial effects in an area than to the species characteristics of the fishes that offer substrates to them.

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<국문적요>

소하천에서 담수어류 표피에 부착된 미세조류의 생태학적 연구

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하천의 환경성 평가에서 부착조류 조사는 주로 비이동성 기질(돌, 식물, 모래, 점토 및 식물체 등)에 누적된 영향을 반영한 반면에 이동성 기질을 이용한 연구는 전무한 실정이었다. 본 연구는 소하천 생태계에서 어류 표피에 부착된 미세조류의 종조성과 군집구조를 파악하여 서식처 환경을 분석 평가하고자 시도하였다. 현장 조사에서 우점한 어류는 계류성 어종에 속하는 갈겨니(*Zacco temmincki*)와 피라미(*Zacco platypus*)이었고, 상대도수는 각각 62%, 19%를 차지하였다. 어류는 광역 이동의 대표적인 생물로서 기존의 한 장소에 고정된 부착생물의 기질과는 비교가 될 수 있었고, 어류에 부착된 미세조류의 구성으로 볼 때 하천 상하류 구간의 현재 특성을 잘 반영하였다. 부착 미세조류는 규조류가 주류를 이루었고, 다른 분류군도 소수 관찰되었다. 또한, 생태학적 측면에서 하천의 건강성을 평가하는데 유용한 기초자료로 활용될 수 있을 것으로 판단되며 향후 수환경 평가의 생물학적 도구로 제시하고자 한다.