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Alpha and Beta Diversity of Kingdom Animalia at the Hari River, Uiryeong-gun, Korea

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ABSTRACT

The purpose of this study was investigated the ecological biodiversity of animals and environmental factors at the Hari River in Korea during 2014 season. The fauna of four surveyed stations was a total of 62 taxa, representing five classes. Invertebrates exhibited the greatest species diversity with 19 taxa identified, followed by birds (Aves) (15 taxa); mammals with 9 taxa, reptiles/amphibians (Sauropsida/Amphibia) with 8 taxa, and fish represented by 11 taxa. Berger-Parker's index (BPI) for mammals was varied from 0.222 to 0.308. Shannon-Weaver indices (H´) for mammals and invertebrates also varied among the stations and seasons. Although evenness indices for five animal kingdoms during seasons were different from each other, there were not shown significant differences (P<0.05). The portions of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in the river increased exponentially along the upper-down gradient. The ranges of total phosphorus were varied from 0.028 mg/L to 0.106 mg/L and total nitrogen were 0.18~0.116 mg/L. Total phosphorus and total nitrogen from the Hari River is found to be within the limit (Current National Recommended Water Quality Criteria). The Bray-Curtis' distances were calculated from differences in abundance of each species according to geographic distances among four stations at the Hari River. The relationship between a distance matrix and a quantitative environmental variable was shown very strong. The Hari River has received increasing levels of nutrients through sewage discharge and fertilizer runoff from agriculture fields.

Keywords: *Fauna, BOD, COD, spatial patterns, Hari River*

INTRODUCTION

An ecosystem is all the living organisms along with their environment and environmental elements in an area. A river ecosystem also consists of inter-related living & non-living parts. For example, a river ecosystem includes all the mammals, birds, reptiles, amphibians, fish, invertebrates, algae and bacteria living in that river, as well as the rocks, sand, soil, and water in that river. Diversity of Kingdom Animalia in a river is comprised of individual organisms such as vertebrates and invertebrates. These organisms work together and interact with non-living systems to form larger ecosystems: e.g. floodplains, riparian areas, wetlands, and the river itself.

Much of the ecology downstream depends on habit is happening upstream. The water carries nutrients and other chemicals downstream with its flow making rivers very dynamic streams to study and a particular conservation challenge[18]. Nutrient levels in the river have an important influence on the community that develops. Low-nutrient (oligotrophic) rivers may have a low biomass, but high species richness. Whereas high nutrient (eutrophic) rivers may have a high biomass, but be dominated by a few competitive species which thrive under these conditions.

The degradation of freshwater in a river has been of the two important characters. One is water pollution. If pollution can be significantly reduced or eliminated by technical process, dirty water is the world's biggest health risk yet and continues to threaten both quality of life and public health[6]. The other is disruption of long established water and biogeochemical cycles in the landscape.

Alpha (α), beta (β), and gamma (γ) diversities are among the fundamental descriptive varieties of ecology, but their quantitative definition has been controversial[9]. Whittaker proposed measuring β as the ratio between regional diversity or γ and αsuch that $H\gamma = H\alpha \times H\beta$[24]. An alternative approach consists in measuring β diversity with an additive model such as $H\gamma = H\alpha + H\beta$[9,20]. Most diversity indices may be considered generalized measures of uncertainty[20].

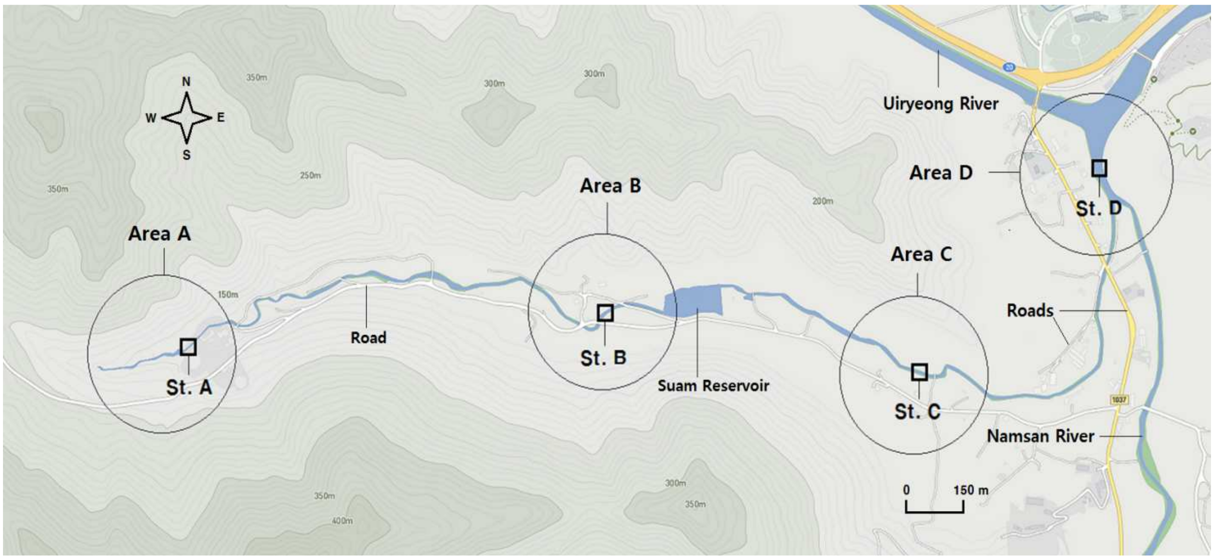
The purpose of this study is to investigate the fauna on the Hari River at four regions during four seasons. The data generated from this study will guide the scenario of material significance for the future appears in the environment to restore or improve the problem may be and will serve as baseline for further research.

MATERIALS AND METHODS

Surveyed regions

This study was carried out on the Hari River (upper region: 35°307′246″N/128°225′384″E, low region: 35°312′744″N/128°256′154″E), located at Uiryeong province, Gyeongsangnam-do, Korea (Fig. 1). Geographical ranges of the Hari River were a total length of 3.85 kilometers from the Mt. Bekha (522 m) to the confluence of the Namsan River. The areas of this river is located at altitude (150~160 m above sea level). The upper regions are surrounded by forests. The dominant species were *Pinus densiflora*, *Pinus thunbergii*, *Quercus acutissima*, *Quercus aliena* and *Quercus variabilis*. The middle and low regions consist of a mosaic of agricultural fields and farming houses. The slopes of river are very low (average < 5°). In this region the mean annual temperature is 13.0℃ with the maximum temperature being 19.8℃ in August and the minimum 7.3℃ in January. The annual average precipitation of this region is approximately 1,276 mm, and sometimes, intensive rainfall such as 100 mm in an hour or 250 to 400 mm in a day can be recorded.

Fig. 1: The four stations (St. A~D) for fish and invertebrates (small quadrangles) and four areas (Area A~D) for mammals, birds, and herpetology (large circles) at the Hari River, Korea



Identification of animals

The water and animal samples were collected from several sampling points of four major River systems of Hari which are given in Fig. 1. The sampling period was divided into four seasons, March, June, September, and December. Animal identification using a means of marking is a process done to identify and track specific animals. A small dredge is also used to collect sediments from the bottom of the river to determine the numbers and kinds of invertebrates present. Identifications of mammals were based on Weon[25]. Identifications of birds were based on Lee et al.[13] and Yoon[26]. Identifications of herpetology were based on Lee et al.[12]. Identifications of fishes were based on Choi[3]. Identifications of invertebrates were based on Kim et al.[11] and Merritt and Cummins[15]. The periods of animal samplings were March, June, September, and December 2014.

Biotic indices

Diversity is defined as the measure of the number of different species in a biotic community[9]. We assume that three aspects of biodiversity are of primary interest: number of species, overall abundance, and species evenness.

Shannon–Weaver index of diversity[21]: the formula for calculating the Shannon diversity index (H') is

$$H' = -\sum p_i \ln p_i$$

p_i is the proportion of important value of the ith species ($p_i = n_i / N$, n_i is the important value index of ith species and N is the important value index of all the species).

$$N1 = e^{H'}$$

$$N2 = 1/\lambda$$

Where λ (Simpson's index) for a sample is defined as

$$\lambda = \sum \frac{n_i(n_i-1)}{N(N-1)}$$

Species richness is a measure of the number of species found in a sample. The species richness of animals was calculated by using the method, Berger-Parker's index (BPI) and Margalef's indices (R1 and R2) of richness[14].

BPI = N_{max}/N where N_{max} is the number of individuals of the most abundant species, and N is the total of individuals of sample.

Evenness indices (E1~E5) was calculated using important value index of species[9,17].

ß-diversity index was calculated using the method of Tuomisto as $ß = \gamma/\alpha$[23]. Here γ is the total species diversity of a landscape, and α is the mean species diversity per habitat.

The homogeneity of variance or mean values to infer whether differences exist among the stations samples or seasons was tested[27]. Except where stated otherwise, statistical analyses were performed using the SPSS software (Release 21.0).

Environmental factors

An ecological distance describes the difference in species composition[10]. The relationship between a distance matrix and a quantitative environmental variable can be analysed with Mantel test. Laboratories and equipment were used to measure a range of water quality parameters including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). DO and pH were measured with YSI field meters (Professional Plus, Geotech, Colorado, USA). The method for BOD was used to a standard method of the American Public Health Association (APHA) and is approved by the U.S. Environmental Protection Agency (USEPA). COD was measured using the 910 colorimeter (YSI Incorporated, Ohio, USA).

RESULTS AND DISCUSSION

The fauna of four surveyed stations was a total of 62 taxa, representing five classes. Invertebrates exhibited the greatest species diversity with 19 taxa identified, followed by birds (Aves) (15 taxa); mammals with 9 taxa, reptiles/amphibians (Sauropsida/Amphibia) with 8 taxa, and fish represented by 11 taxa. Berger-Parker's index (BPI) for mammals was varied from 0.222 to 0.308. Shannon-Weaver indices (H´) for mammals and invertebrates also varied among the stations and seasons. Mammals and reptiles/amphibians were shown with the relative high individual density or abundance in upper region (stations A and B) of river across areas. Birds, Fish, and invertebrate animals were shown with the relative high individual density or abundance in low region (stations C and D). The total numbers of species were 50 taxa within the St. A, 51 taxa within the St. B, 50 taxa within the St. C, and 52 taxa within the St. D (Tables 1 and 2).

In order to assess macro-scale spatial variability of the animal community at the Hari River, we analyzed distributions of species richness, diversity, and evenness of large taxonomic groups as well as four station compositions along geographic distances (Tables 1 and 2). Species richness changes over space and time. BPI values for four kingdoms except bird and fish were low at high region, meaning dominant species were different according to stations or seasons. Upper regions (Areas A and B) were considerable high richness in mammals, birds, and reptiles/amphibians.

Shannon-Weaver indices (H´) of diversity for mammals was varied from 1.565 to 2. 108. H´ for birds, fish, reptiles/amphibians, and invertebrates also varied among the stations and seasons. They were shown high H´ values at low region (Area D) for bird and invertebrates because this station is the place where three rivers join one.

At point of evenness, all ecological communities are variable at a range of spatio-temporal scales[1]. Although evenness indices for five animal kingdoms were different from each other, there were not shown significant differences ($P<0.05$).

The values of ß-diversity for animals were varied from 0.182 for reptiles/amphibians to 0.244 for invertebrates (Fig. 2). For the four community positions as a whole, the values of ß-diversity were the low (from 0.165 for St. D to 0.232 for St. A) (Fig. 3). They indicated that heterogeneity in species compositions among the replicates were high. The parameters paired similarity between season and stations testified. There was high taxonomic heterogeneity of the fauna community in between four seasons. Especially, species compositions of birds for season were different from each other because a lot of migratory birds were included in those regions. The numbers of individuals of reptiles/amphibians were different from each other between seasons because generally begin hibernation in late fall. There were high taxonomic homogeneity of the mammals and fish community in between four seasons and similar trends in seasonal development of animals at riparian and channels of the same river. However, distribution of biological diversity and richness showed a statistically significant upper-low regions different (p <0.05). This decreasing trend was supported mainly by an increase of artificial disturbances such as road or house construction[16]. In addition, we consider that the Suam Reservoir at upper area plays an important role in biodiversity (Fig. 1). This area is a lot of birds and amphibians inhabit.

pH is very important parameter as rise in pH increases the solubility of toxic chemicals which can prove harmful to aquatic fauna. The mean of pH was 7.345 across stations, varying from 7.206 to 7.473 (Table 3). The mean value of DO was 6.273 mg/L. BO value of water sample from the Hari River is found to be within the limit (EPA standard statistical classification of surface freshwater quality for the maintenance of aquatic life)[4]. The average value of BOD and COD were 2.660 mg/L and 3.114 mg/L, respectively. The portion of BOD and COD in the river increased exponentially along the upper-down gradient. BOD increases as micro-organisms accumulate to degrade organic material. Oxygen is essential in aerobic organisms for the electron transport system of mitochondria. Oxygen insufficiency at the mitochondria results in reduction in cellular energy and a subsequent loss of ion balance in cellular and circulatory fluids. Total phosphorus and total nitrogen from the Hari River is found to be within the limit (Current National Recommended Water Quality Criteria)[5]. The Hari River has received increasing levels of nutrients through sewage discharge and fertilizer runoff from agriculture fields. Generally, high Levels of both phosphorus and nitrogen can lead to eutrophication, which increases algae growth and ultimately reduces dissolved oxygen levels in the water. In fact, the variations in the chemical composition of natural waters might play an important role in regulating the abundance, composition, the geographical and temporal distribution on phytoplankton[19]. The excessive growth of algae and macrophytes, the resulting oxygen depletion, and the production of a range of substances toxic to fish, cattle, and humans are now major pollution problems worldwide[8]. It could be affected as one indicator of mortality of fishes[5]. Thus there was decreased the number of species in this river. Many artificial actions reduced the water's natural filtration action and eliminated many species at their habitat in the Hari River.

The Bray-Curtis' distances were calculated from differences in abundance of each species according to geographic distances among four stations at the Hari River (Table 4). Neighboring stations such as St. B and St. C had the similar species composition and the highest remote populations (St. A and St. D) did not share any species.

Human impact on the environment may vary from relatively minor to serve[2]. As a rule minor damage can be offset by homeostatic mechanisms. For example, sewage accidently can dump a stream and people often spill organic chemicals on the water. These substances are food for naturally occurring bacteria. In a health stream, the population of these bacteria is normally small. If organic food supplies increase, however, the bacteria population expands. Because the bacteria consume oxygen as they devour organic waste, the level of dissolved oxygen in the stream plummets. This, in turn, kills off fish and other aquatic organisms that need oxygen to survive.

Problems arise slowly in the Hari River because human activities push ecosystems so far. That is, human activities strain the limits of resilience, gradually altering the biotic and abiotic conditions of the environment, damage can be severe. Many artificial actions reduced the water's natural filtration action and eliminated many species at their habitat in the Hari River.

Table 1: Diversity index for mammals, birds, and reptile/amphibians in the studied areas

Indices	Mammal				Bird				Reptile /Amphibian			
	Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D
No. of species	9	8	6	5	13	13	14	15	7	8	6	6
Richness												
BPI	0.241	0.222	0.250	0.308	0.139	0.150	0.146	0.116	0.294	0.324	0.414	0.316
R1	2.376	2.124	1.803	1.559	3.349	3.252	3.501	3.722	1.747	1.985	1.485	1.375
R2	1.671	1.540	1.500	1.387	2.167	2.055	2.186	2.287	1.257	1.372	1.114	0.973
Diversity												
H'	2.108	1.996	1.754	1.565	2.469	2.474	2.508	2.643	1.747	1.905	1.595	1.649
N1	8.235	7.360	5.778	4.782	11.813	11.863	12.286	14.052	5.995	6.718	4.930	5.202
N2	9.667	8.775	8.000	6.500	15.365	14.717	14.643	18.813	6.039	6.523	4.562	5.207
Evenness												
E1	0.960	0.960	0.979	0.972	0.963	0.964	0.951	0.976	0.920	0.916	0.890	0.920
E2	0.915	0.920	0.963	0.956	0.909	0.913	0.878	0.937	0.886	0.840	0.822	0.867
E3	0.904	0.909	0.956	0.946	0.901	0.905	0.868	0.932	0.832	0.817	0.786	0.840
E4	1.174	1.192	1.384	1.359	1.301	1.241	1.192	1.339	1.007	0.971	0.925	1.001
E5	1.198	1.222	1.465	1.454	1.329	1.263	1.209	1.356	1.009	0.966	0.906	1.001

Table 2: Diversity index for fishes and invertebrates in the studied areas

Indices	Fish				Invertebrates			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
No. of species	8	8	9	11	13	14	15	17
Richness								
BPI	0.303	0.216	0.195	0.208	0.108	0.158	0.163	0.161
R1	2.002	1.939	2.154	2.583	3.323	3.574	3.597	3.975
R2	1.393	1.315	1.406	1.588	2.137	2.271	2.143	2.272
Diversity								
H'	1.927	1.979	2.107	2.271	2.496	2.250	2.617	2.696
N1	6.872	7.234	8.223	9.685	12.135	12.425	13.691	14.816
N2	6.947	7.835	9.111	10.255	15.136	15.622	16.110	16.383
Evenness								
E1	0.927	0.952	0.959	0.947	0.973	0.955	0.966	0.951
E2	0.859	0.904	0.914	0.880	0.933	0.888	0.913	0.872
E3	0.839	0.891	0.903	0.868	0.928	0.879	0.906	0.863
E4	1.011	1.083	1.108	1.059	1.247	1.257	1.177	1.106
E5	1.013	1.096	1.123	1.066	1.270	1.280	1.191	1.113

Table 3: Water quality at four stations in the studied areas

Item	St. A	St. B	St. C	St. D
pH	7.473±0.156	7.456±0.162	7.245±0.165	7.206±0.056
DO (㎎/L)	7.365±0.373	7.220±0.264	6.125±0.470	5.392±0.187
BOD (㎎/L)	1.945±0.277	2.639±0.184	2.928±0.196	3.130±0.290
COD (㎎/L)	3.980±0.331	4.035±0.105	4.325±0.468	4.380±0.302
SS (㎎/L)	15.448±1.421	17.474±1.389	19.528±1.578	20.170±2.295
T-N (㎎/L)	0.018±0.008	0.024±0.009	0.082±0.016	0.016±0.013
T-P (㎎/L)	0.028±0.004	0.045±0.009	0.067±0.033	0.106±0.026

Table 4: Ecological distance (upper diagonal) based on Bray-Curtis' formulae analysis and geographic distances (km) (low diagonal) among four stations at the Hari River

Station	St. A	St. B	St. C	St. D
St. A	-	0.072	0.347	0.518
St. B	1.355	-	0.030	0.350
St. C	2.435	1.080	-	0.016
St. D	3655	2.300	1.220	-

Fig. 2: Occurrence index (β-diversity) for five animal kingdoms at four stations. Bars and vertical lines were mean and standard deviations four seasons and four stations

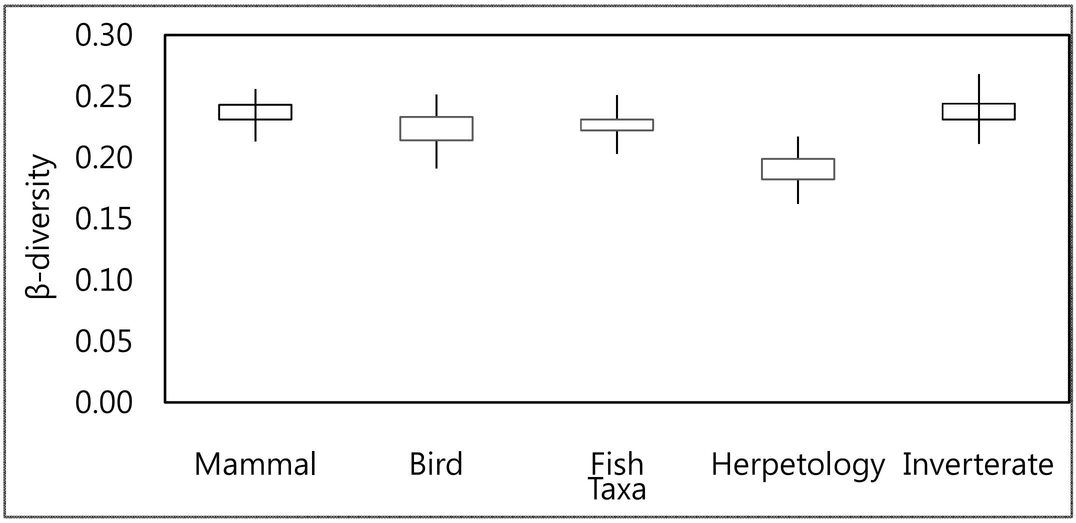
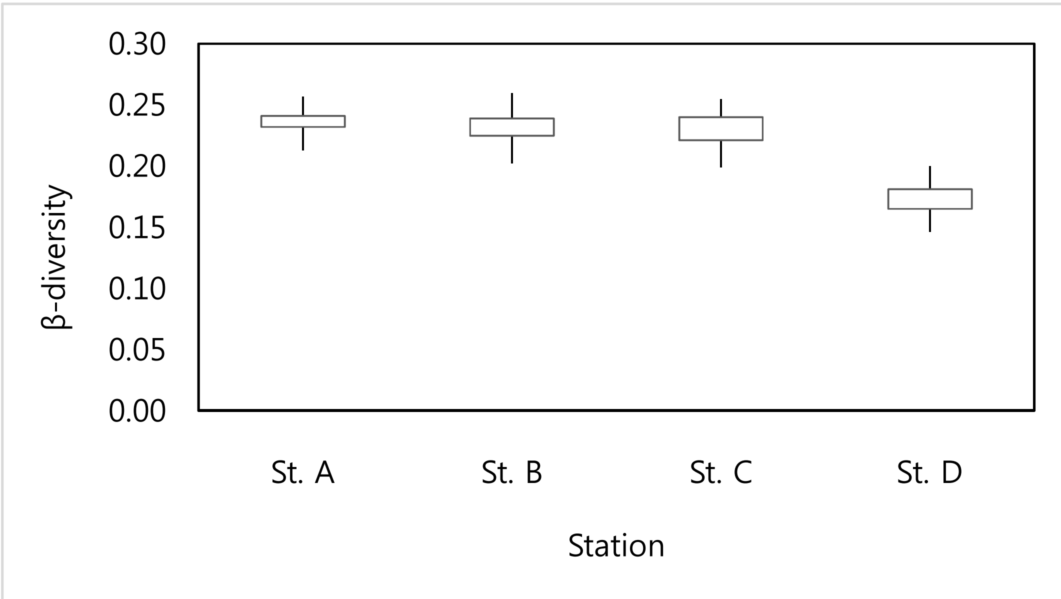


Fig. 3: Occurrence index (β-diversity) of four stations for five animal kingdoms. Bars and vertical lines were same as figure 2



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