SPATIAL AND TEMPORAL ANALYSIS FOR BIOLOGICAL DIVERSITY OF KINGDOM ANIMALIA AT THE IMGI RIVER, BUSAN-CI PROVINCE IN KOREA

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ABSTRACT

Biodiversity or biological diversity is the sum of the species on Earth, including all their interactions and variations with their biotic and abiotic environment in space and in time. Spatial and temporal analyses were performed to study the spatial pattern of the temporal dynamics of the animal species for four stations at the Imgi River in Korea. The fauna community at the Imgi River on 2016 was identified with 69 taxa, representing five classes. Birds (Aves) exhibited the greatest species diversity with 19 taxa identified, followed by invertebrates (18 taxa); mammals with 10 taxa, reptiles/amphibians (Sauropsida/Amphibia) with 11 taxa, and fish represented by 11 taxa. Shannon-Weaver indices (H´) of diversity for mammals was varied from 1.735 to 2.223. H´ for birds was varied from 2.059 to 2.515. Reptiles/amphibians, fish, and invertebrates also varied among the stations and seasons. The values of ß-diversity for animals were varied from 0.211 for reptiles/amphibians to 0.303 for birds. Middle region (C) was considerable high richness in birds and reptiles/amphibians. Upper region (D) was considerable high richness in mammals. Although evenness indices for five animal kingdoms were different from each other, there were not shown significant differences ($p < 0.05$).

Keywords: Animal kingdoms, biodiversity, Imgi River, richness indices, Shannon-Weaver indices.

INTRODUCTION

The term “biodiversity” was coined from the expression “biological diversity”, though it transcended its original meaning. Biodiversity is the sum of the species on Earth, including all their interactions and variations with their biotic and abiotic environment in space and in time (Erwin, 1991). It was expanded to encompass, besides genetic diversity and species diversity, ecological diversity as well. It encompasses all of the variation among individuals of a population, as well as among spatially distinct populations of the same species. The diversity of ecosystems is more ambiguous than the other two categories in the Convention of Biological Diversity (CBD). Ecosystems are essentially functional systems, characterized by their dynamic. Biodiversity is changing over time (Yoccoz et al., 2001). By that, we mean that the number of species present on Earth changes over time, and the composition of species changes as well. However, using the dynamic as a basis for evaluating, inventorying, or monitoring the diversity of ecosystems is quite impractical, though not impossible. By any means, in practical terms, the diversity of ecosystems has been treated as being correlated with the diversity of the physiognomy of vegetation, of landscape, or of biomass, but this does not completely resolve the question.

This distance decay of similarity is an almost universal phenomenon in biogeography

(Nekola and White, 1999; Soininen and Hillebrand, 2007). It results from three non-exclusive types of processes: species-sorting along environmental gradients, dispersal constraints imposed by topography, and intrinsic species differences in dispersal abilities (Soininen and Hillebrand, 2007). The limited dispersal abilities of most organisms can certainly contribute to distance decay in community similarity, but so can the influence of environmental gradients across biogeographic space (Nekola and White, 1999).

Rivers have always had a powerful hold over humankind. Rivers have been a focus of human activity throughout ancient and modern times. During ancient times, human settlements were usually located near a river, with utilization of water for both agricultural purposes and raising livestock (Zhang et al., 2015). All land-uses (agriculture, forestry, peat production etc.) have some environmental impact on a river's ecosystem, be it through the loading of suspended solids, nutrients, metals and acidifying substances. Rivers are one of the most important types of earth ecosystem, home to many species and habitats. Many rivers of the world are currently facing moderate to severe water crises due to population growth, industrialization, improved living standards and poor water management strategies.

The Imgi River is composed of two small tributaries within Busan in Korea, and its adjacent waters and wetlands do provide important habitats for birds, and are also used by certain mammals, reptiles and amphibians. In this paper several biodiversity indices at the Imgi River were measured different spaces and seasons if it is to be used to quantify change over time.

METHODOLOGY

Surveyed regions

This study was carried out on the Imgi River (upper region: 35°323′787″N/129°1348′794″E, low region: 35°319′942″N/129°114′306″E), located at Imgi-ri, Busan-ci province in Korea (Fig. 1). Lowlands are usually no higher than 120 m (394 ft.), while uplands are somewhere around 250 m (820 ft.) to 350 m (1148 ft.). Throughout the course of a river, the total volume of water transported downstream composed of the visible free water flow together with a substantial contribution flowing through rocks and sediments that underlie the river and its floodplain called the hyporheic zone. The relatively level land can be developed either as agricultural fields or sites for habitation or business. It is estimated that 80-90% of the Imgi-River water has be used for irrigation. Flood plains of this river are usually very fertile agricultural areas and out sides of this river consist of a mosaic of agricultural fields and farming houses.

It has a temperate climate with a little hot and long summer. In this region the mean annual temperature is 14.7℃ with the maximum temperature being 29.4℃ in August and the minimum -0.6℃ in January. Mean annual precipitation is about 1519.1 mm with most rain falling period between June and August.

In the field, each region was further divided by the four major geographic sites. The plots were randomly located within each sampling site for a total of 12 sampling transects.

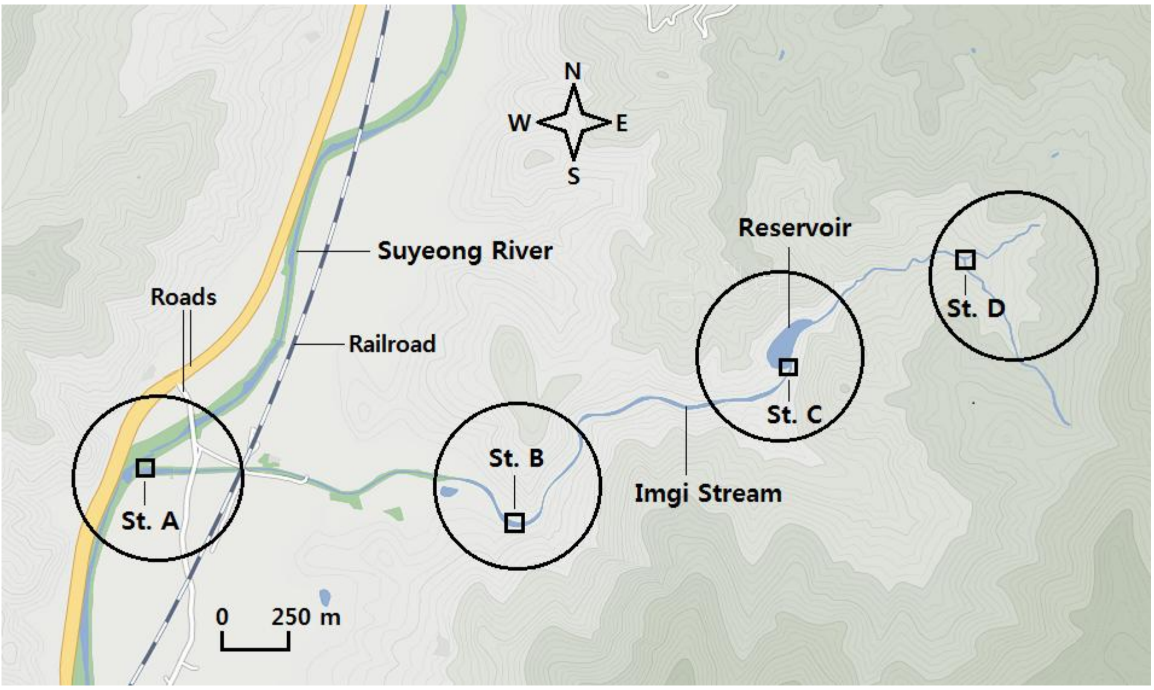

Figure 1. The four stations (St. A~D) for fish and invertebrates (small quadrangles) and four areas (large circles) for mammals, birds, and herpetology at the Imgi Stream in Korea.

Identification of animals

To understand how different physical or biological factors influence the distribution or abundance of species, it usually need to measure changes in population abundances over space or time. At one extreme is a complete census of individually identifiable organisms. 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 and herpetology were based on Weon (1967). The identification of birds followed Lee et al. (2005). Identifications of herpetology were based on Lee et al. (2012), respectively. Identifications of fishes were based on Choi (2001). Identifications of invertebrates were based on Kim et al. (2013) and Merritt and Cummins (1996). The periods of animal samplings were January, April, July, and October 2016.

Biotic indices

Shannon–Weaver index of diversity (Shannon and Weaver, 1963): the formula for calculating the Shannon diversity index (H') is

$H' = -\Sigma\, pi \ln pi$

*p*i is the proportion of important value of the *i*th species (*p*i = *n*i / N, *n*i is the important value index of *i*th 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

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

Species richness is the number of species of a particular taxon that characterizes a particular biological community, habitat or ecosystem type (Colwell, 2011). Species richness was also calculated for all derived emergent groups separately. 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 (Magurran, 1988).
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.
Species evenness is a measure of biodiversity which quantifies how equal the community is numerically. Evenness indices (E1~E5) was calculated using important value index of species (Pielou, 1966; Hill, 1973).
ß-diversity, defined as the differences in species composition among plots as a region, is calculated using the method of Tuomisto (2010) as $ß = \gamma/\alpha$. 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 (Zar, 1984). Except where stated otherwise, statistical analyses were performed using the SPSS software (Release 21.0).

Cluster analyses

The current study examines the performance of cluster analysis with dichotomous data using distance measures based on response pattern similarity.

RESULTS AND DISCUSSION

Spatial and temporal analyses were performed to study the spatial pattern of the temporal dynamics of the animal species for four stations at the Imgi River in Korea during four seasons. Spatially consistent variations were detected in abundance, season-to-season fluctuation as well as in periodicity. Although this area was not wide, the fauna community at the Imgi River on 2016 was identified with 69 taxa, representing five classes. Birds (Aves) exhibited the greatest species diversity with 19 taxa identified, followed by invertebrates (18 taxa); mammals with 10 taxa, reptiles/amphibians (Sauropsida/Amphibia) with 11 taxa, and fish represented by 11 taxa. Fish and invertebrate animals were shown with the relative high individual density or abundance in low region (station A). Mammals and birds were shown with the relative high individual density or abundance in upper region (station D) of river across areas. The total numbers of species were 48 taxa within the St. A, 41 taxa within the St. B, 51 taxa within the St. C, and 42 taxa within the St. D (Tables 1 and 2).

In order to assess macro-scale spatial variability of the animal community at the Imgi River, I 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). Shannon-Weaver indices (H´) of diversity for mammals was varied from 1.735 to 2.223. H´ for birds was varied from 2.059 to 2.515. Reptiles/amphibians, fish, and invertebrates also varied among the stations and seasons. They were shown high H´ values at the B region of river for fish and reptiles/amphibians. Whereas, the high H´ values were shown at low region (A) of river for invertebrates. Low region (A) was considerable high richness in fish and invertebrates. Middle region (C) was considerable high richness in birds and reptiles/amphibians. Upper region (D) was considerable high richness in mammals. Although evenness indices for five animal kingdoms were different from each other, there were not shown significant differences ($p < 0.05$). BPI values for four kingdoms except fish and invertebrates were low at high region, meaning dominant species were different according to stations or seasons. The 'average spatial patterns' indicated relatively high differences in abundance from one location to another (Fig. 2). The values of ß-diversity for animals were varied from 0.211 for reptiles/amphibians to 0.303 for birds (Fig. 2). For the four community positions as a whole, the values of ß-diversity were the low (from 0.218 for St. D to 0.297 for St. B) (Fig. 3). They indicated that heterogeneity in species compositions among the replicates were high. When the parameters paired similarity between season and stations testified, there was high taxonomic heterogeneity of the fauna community in between four seasons. The Bray-Curtis' distances were calculated from differences in abundance of each species according to geographic distances among four stations at the Imgi River (Table 3).

Each day, birds must find food, water, shelter, and places offering refuge from predators. This becomes even more important during migration as birds are often moving through unfamiliar terrain with unknown risks. The Imgi River valley--along with its rich diversity of habitats--provides birds with those important resources. The floodplains and wetlands of the Imgi River provide some of the most important habitat for around 19 species of birds. Distributions and habitat-use patterns of wildlife are not static in time or space (Block and Morrison, 1991). Especially, species compositions of birds for season were different from each other because a lot of migratory birds were included in those regions (Huh, 2015). The climate of Siberia varies dramatically, but all of it basically has short summers and long and extremely cold winters. This region in Busan is not so cold in the winter and the river hardly freezes even in a winter. Thus, migratory birds fly south to warmer regions. Instead, new migratory birds have often visited these regions from winter areas such as the Siberian. The number of individuals of reptiles/amphibians were different from each other between seasons because generally begin hibernation in late fall.

Cluster analysis of the four sites identified and the sites differed in species composition and abundance (Fig. 4). Neighboring stations such as St. A and St. B, St. B and St. C or St. C and St. D had the similar species composition. Though the highest remote populations (St. A and St. D) share with only some species, their species compositions were very different in number (abundance or richness) of each species. Similarity in animal community composition often decreases with both increasing geographic distance and environmental dissimilarity between localities (Fig. 5).

Table 1. Diversity index for mammals, birds, and reptile/amphibians in four studied areas at the Imgi River

Indices	Mammal				Bird				Reptile /Amphibian			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
No. of species	6	6	9	10	9	10	14	13	8	7	9	6
Richness												
BPI	0.250	0.217	0.156	0.179	0.258	0.146	0.160	0.130	0.229	0.355	0.279	0.316
R1	1.699	1.595	2.308	2.457	2.330	2.424	3.323	3.134	1.969	1.747	2.127	1.375
R2	1.342	1.251	1.591	1.601	1.616	1.562	1.980	1.917	1.352	1.257	1.372	0.973
Diversity												
H'	1.735	1.750	2.132	2.223	2.059	2.251	2.515	2.402	1.998	1.762	2.007	1.649
N1	5.671	5.754	8.430	9.238	7.835	9.499	12.363	11.045	7.375	5.823	7.444	5.502
N2	7.037	7.028	10.333	10.739	8.611	11.389	13.920	15.221	8.264	5.602	7.167	5.207
Evenness												
E1	0.969	0.977	0.970	0.966	0.937	0.978	0.953	0.936	0.961	0.905	0.914	0.920
E2	0.945	0.959	0.937	0924	0.871	0.950	0.883	0.850	0.922	0.832	0.827	0.867
E3	0.934	0.951	0.929	0.915	0.854	0.944	0.874	0.837	0.911	0.704	0.806	0.840
E4	1.241	1.221	1.226	1.163	1.099	1.199	1.126	1.378	1.120	0.962	0.963	1.001
E5	1.292	1.268	1.256	1.182	1.113	1.222	1.137	1.416	1.139	0.954	0.957	1.011

Table 2. Diversity index for fishes and invertebrates in four studied areas at the Imgi River

Indices	Fish				Invertebrates			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
No. of species	11	5	8	5	14	12	11	9
Richness								
BPI	0.241	0.296	0.211	0.294	0.235	0.159	0.216	0.185
R1	2.507	1.517	1.924	1.412	3.306	2.907	2.769	2.427
R2	1.497	1.155	1.298	1.213	1.960	1.809	1.808	1.732
Diversity								
H'	2.188	1.688	1.991	1.564	2.457	2.389	2.288	2.137
N1	8.916	5.409	7.321	4.780	11.667	10.906	9.853	8.478
N2	8.418	5.850	8.080	5.913	11.087	12.784	11.101	10.969
Evenness								
E1	0.912	0.942	0.957	0.972	0.931	0.962	0.954	0.973
E2	0.811	0.901	0.915	0.956	0.833	0.909	0.896	0.942
E3	0.792	0.882	0.903	0.945	0.821	0.901	0.885	0.935
E4	0.944	1.082	1.104	1.237	0.950	1.172	1.127	1.294
E5	0.937	1.100	1.120	1.301	0.946	1.190	1.141	1.333

Table 3. Ecological distance (upper diagonal) based on Bray-Curtis' formulae analysis and geographic distances (km) (low diagonal) among four stations at the Imgi River

Station	St. A	St. B	St. C	St. D
St. A	-	0.059	0.067	0.346
St. B	1.575		0.069	0.262
St. C	2.997	1.422	-	0.048
St. D	3.733	2.158	0.736	

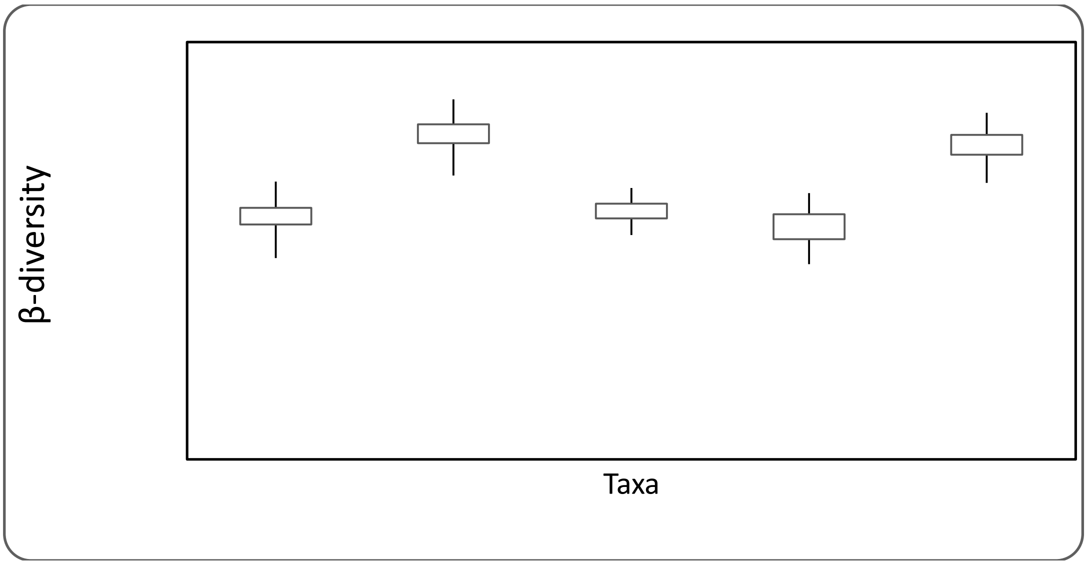

Figure 2. Occurrence index (β-diversity) for five animal kingdoms at four stations.

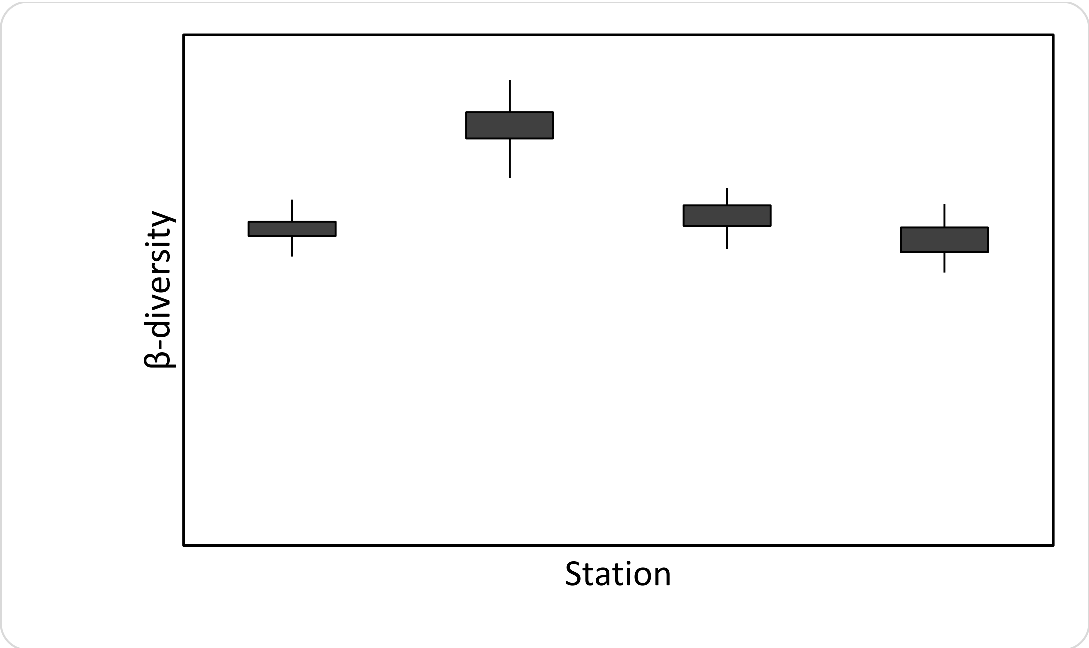

Figure 3. Occurrence index (β-diversity) of four stations for five animal kingdoms.

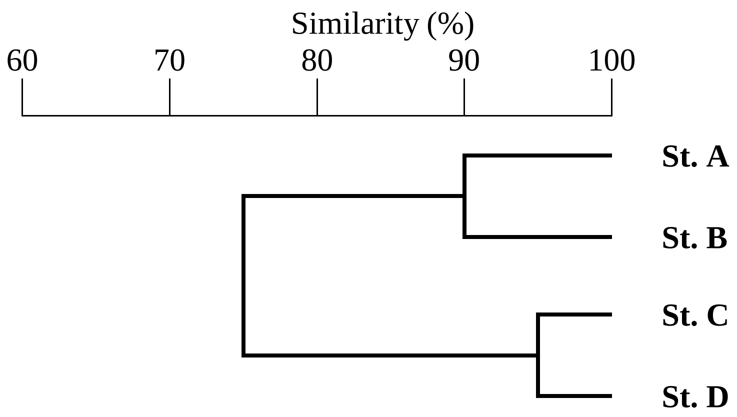

Figure 4. A phenogram showing the animal distribution relationships among four stations at the Imgi River.

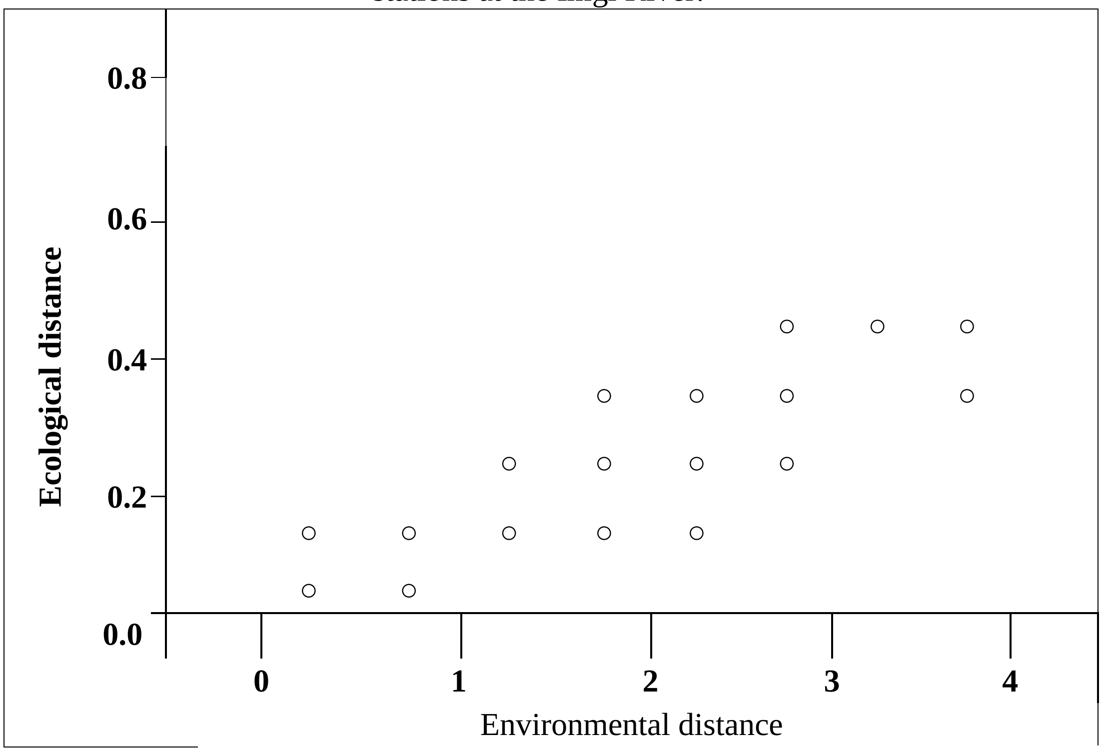

Figure 5. The plot of Bray-Curtis distance in relationship with ecological and environmental distances in Mantel test for five animal kingdoms at the Imgi River, Korea.

CONCLUSIONS

Distributions, abundances, and patterns of resource use of mammals, birds, amphibians, reptiles, fish, and small invertebrates varied spatially and temporally at the Imgi River in Busan. Knowledge of spatial and temporal variations in microhabitats is needed to elucidate variations in populations, habitat associations, and community structure and to provide a basis for predicting effects of environmental perturbations on individual species and entire assemblages of species.

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