ECOSYSTEM AND FLORISTIC BIODIVERSITY OF RIPARIAN ZONES AT THE IMGI RIVER, BUSAN-CI, KOREA

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ABSTRACT

The present study was conducted in three different riparian areas distributed throughout the Imgi River in Busan, Korea to investigate diversity and distributional patterns of riparian communities along a lowland stream size gradient (first to third order). Vegetation analyses were performed in transects placed perpendicular to the stream channel. According to the existing phytosociological data, 17 families, 27 genera, 30 species, 2 varieties, 14 associations, and 7 communities have been identified at the upper stream. The numbers of naturalized plants were five species. The total transformed Braun-Blanquet value and r-NCD at upper area were 73 and 1217, respectively. The middle survey region was a total of 41 taxa, including 16 families, 35 genera, 36 species, and 5 varieties. The numbers of naturalized plants were 13 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 98 and 1633, respectively. The low stream region was a total of 46 taxa, including 16 families, 37 genera, 41 species, and 5 varieties. The numbers of naturalized plants were 19 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 109 and 1817, respectively. This represents that the rate of alien species in Imgi River was high. It is the result of artificial interference and environmental condition.

Keywords: Braun-Blanquet, Imgi River, naturalized plants, riparian.

INTRODUCTION

A plant community is an association of plant species in a given place. Community structure is inclusive of all plants that occur in the tree, sapling and shrub, and ground cover (vine/liana and herbs) vegetative layers. The composition and percent areal cover of plants, as well as their general condition with respect to both native and non-native species, describes riparian plant communities. The richness of plant communities in riparian areas is in large part because plants respond to differences in the physical environment, such as hydraulic forces, river structure, slope of the channel, water availability, topography or disturbances, and soil textures or chemistry. The ability of plants to establish, survive and grow is affected by the physical environment, which results in an uneven distribution of plant species according to spatial distance. A plant community is an identifiable assemblage of plant species shaped by the interactions of individual plants with the environment and each other. Different plant communities are dominated by different tree, shrub or herbaceous species. Plant communities can be recognized as distinct from neighboring plant assemblages by the species composition (patchy ecosystems). Worldwide, the ecological condition of streams and rivers has been impaired by agricultural practices such as broad scale modification of catchments, high nutrient and sediment inputs, loss of riparian vegetation, and altered hydrology (Lester and Boulton, 2008).

Riparian ecosystems have been identified as important zones of management because of their values as wildlife habitat (Ames, 1977; Patton 1977; Thomas, 1979). Riparian ecosystems are biophysically complex, highly biodiverse and provide a broad array of essential ecosystem services to both humans and surrounding landscapes (Lawson, 2016). The riparian plant community is a complex association of river structure and understory trees, shrubs, vines, and herbs. Each layer plays a dynamic role in providing shelter and food for hundreds of species of insects and other invertebrates, birds, fish, amphibians, reptiles, and mammals (Southern Sonoma Country Resource conservation District Petaluma River Watershed Enhancement Plan, 1988). As the development and awareness of the importance of riparian zones increase they are becoming very valuable and, in some cases, protected by law (Korol, 1996).

The Imgi River is composed of two small tributaries within Gijang-gun, Busan in Korea, and its adjacent waters and wetlands do provide important habitats for birds, and the river are also home to many mammals, reptiles and amphibians (Huh, 2017). This paper uses desert riparian vegetation data collected in the total reaches of The Imgi River to explore ecology community as a means of gaining spatial distributing knowledge to support remote sensing applications. The floristic biodiversity of riparian zones featured here were collected in 2016. The spatial analysis was designed to identify and quantify the spatial characteristics of plants within sampled communities.

METHODOLOGY

Surveyed Regions

This study was carried out on the Imgi River (upper region: 35°323′787″N/129°134′794″E, low region: 35°319′942″N/129°114′306″E), located at Imgi-ri, Gijang-gun, Busan-ci in Korea (Fig. 1). The river is located to the north-eastern region of Busan-ci. The river is approximately 3.8 kilometers in length with a varying width of between 2.7 and 22.0 meters. Lowlands are usually no higher than 120 m (394 ft.), while uplands are somewhere around 250 m (820 ft.) to 350 m (1148 ft.). The upstream of the river is divided into two small streams. There is one reservoir between the upper stream and the middle stream. Land use in flood plains beyond river levee can be developed either as agricultural fields or sites for habitation or business (Table 1). Mean annual temperature ranges from -0.6 (January) to 29.4 °C (August) with 14.7°C, and mean annual precipitation is about 1519.1 mm with most rain falling period between June and August.

Table 1. Land use in flood plains beyond river levee

Region	Length (km)	Land use
A	1.25	Cropping, horticulture with N and P fertilizers
B	1.80	Residence, cropping with or without N and P fertilizers
C	0.75	Forest, without N and P fertilizers

Floristic analysis

The field data collection was performed from January to December 2016. Sampling with quadrats (plots of a standard size) can be used for most plant communities (Cox, 1990). Three sectors of the riparian vegetation on the Imgi River were chosen to study. The following floristic parameters were recorded within each of the quadrats: all plant taxa, identifiable at the time of sampling, rooted in the stand, a growth form (tree, shrub, grass and forb) was assigned to each species recorded following Westfall (1992). A quadrat delimits an area in which vegetation cover can be estimated, plants counted, or species listed. Quadrats were established randomly, regularly, or subjectively within a study site since plants often grow in clumps, long, narrow plots often include more species than square or round plots of equal area (Moon and Huh, 2016). Each species was collected, mounted, labeled, and systematically arranged in a herbarium. The system of plant classification system was followed by Lee (2007). Naturalized plants were followed by Korea National Arboretum (2012). Abundance and cover degree are usually estimated together in a single combined estimation or cover-abundance scale from Braun-Blanquet (1964). Two scales are used. One consists of a plus sign and a series of numbers from 1 to 5 denoting both the numbers of species and the proportion of the area covered by that species, ranging from + (sparse and covering a small area) to 5 (covering more than 75% of the area). The second scale indicates how the species are grouped and ranges from Soc. 1 (growing singly) to Soc. 5 (growing in pure populations). In order to relate the model to the field situation in which usually Braun-Blanquet figures are recorded, the % occupancy figures were transformed in to the ordinal transform scale from 1 (one or few individuals) to 9 (75~100% cover of total plot area, irrespective of number of individuals) (Dietvorst et al., 1982). The relative net contribution degree (r-NCD) was obtained by summing up the NCD values for those species belonging to particular taxa under consideration (Kim, 1996).

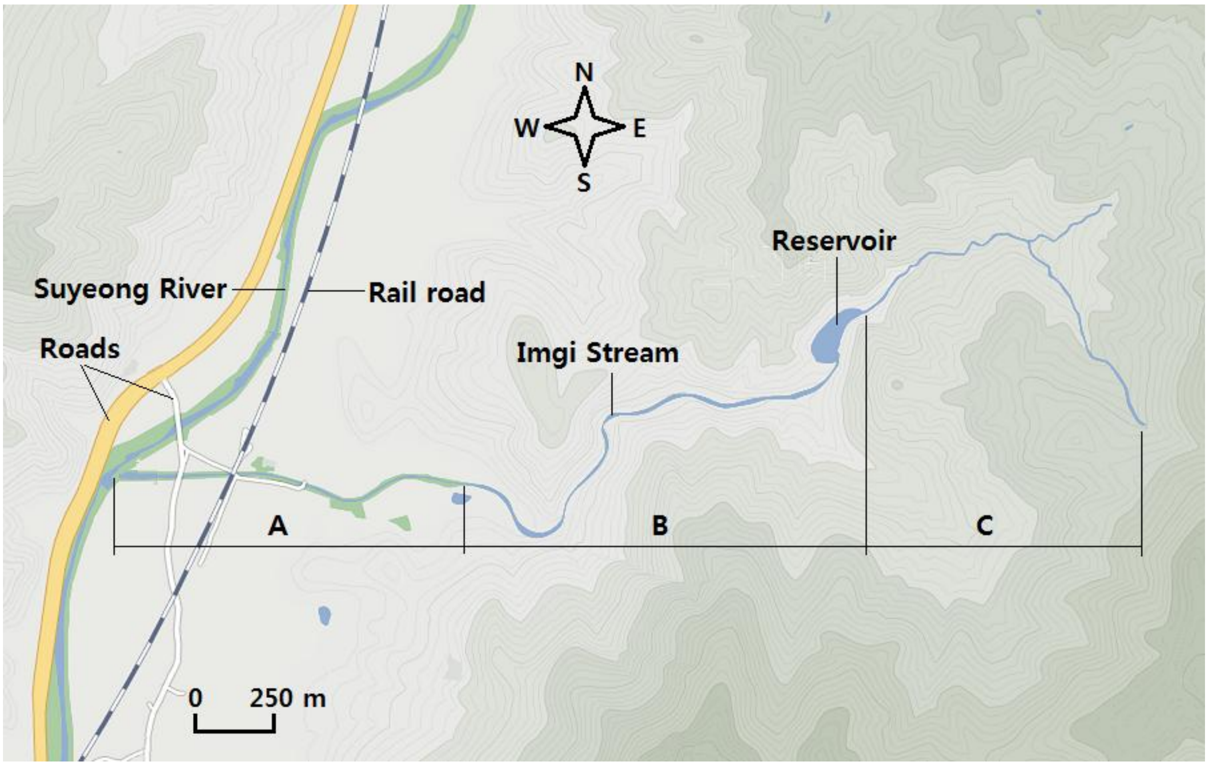

Figure 1. Location of the study area and the three detailed internodes at the Imgi Stream.

Biotic Indices

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

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

*p*i is the proportion of important value of the *i*th species ($pi = ni / N$, *n*i is the important value index of *i*th species and N is the important value index of all the species). $N = e^{H'}$

The species richness of animals was calculated by using the method, Margalef's index (R) of richness (Magurran, 1988). $R = (S-1)/ \ln(n)$

S is the total number of species in a community and *n* is the total number of individuals observed.

Evenness index was calculated using important value index of species (Hill, 1973; Pielou, 1966). E = H' / ln(S)

RESULTS

Upper Region (upstream)

The river width at this region is about 2.7 m. The low water's edge vegetation and flood way vegetation were naturally formed a variety of vegetation communities. Near riparian vegetation provides habitat for many wildlife species (Table 1). Right riparian areas at upper region were distributed Pinaceae vegetation (*Larix leptolepis*, *Pinus densiflora*, and *Pinus rigida*). Left riparian areas at upper region were distributed Fegaceae vegetation (*Castanea crenata*, *Quercus acutissima*, *Quercus dentata*, and *Quercus variabilis*). Riverbed area was dominated by *Pueraria thunbergiana* community. Dominant species in flood plains was *Equisetum arvense*. At total area, the application of the Braun-Blanquet approach for plant classification in this area is presented in the article. According to the existing phytosociological data, 17 families, 27 genera, 30 species, 2 varieties, 14 associations, and 7 communities have been identified (Table 2). The numbers of naturalized plants were five species. In some cases the quantitative and qualitative levels illustrated considerably. The total transformed Braun-Blanquet value and r-NCD at upper area were 73 and 1217, respectively.

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 3). Shannon-Weaver indices (H´) of diversity for upper region was varied from 1.061 (shrubs) to 2.728 (forbs). Diversity parameter, N was varied from 2.889 to 15.299. It showed a statistically significant difference ($p < 0.05$). Upper region (C) was considerable low richness in shrubs and grasses. Although evenness indices for four growth forms were different from each other, there were not shown significant differences ($p < 0.05$). There are varied from 0.934 (trees) to 0.985 (grasses).

Middle Region (middle-stream)

The river width at the region is about 8.8 m. The low water's edge vegetation was naturally formed weeds, shrubs, and mixed with various vegetation communities. The flood way vegetation was artificial vegetation with lawns, and so on. Land uses in riparian zones river levee were arable land, urban, residential mixed. Land use in flood plains beyond river levee was arable land or artificial vegetation. Left and right riparian areas were distributed Cruciferae vegetation (*Trifolium repens*, *Capsella bursa-pastoris*, *Capsella flexuosa*, *Lepidium apetalum*, and Cruciferae) (Table 2). Riverbed area was dominated by *Persicaria blumei* community. The survey region was a total of 41 taxa, including 16 families, 35 genera, 36 species, and 5 varieties. The numbers of naturalized plants were 13 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 98 and 1633, respectively.

H´ of diversity for middle region was varied from 1.257 (trees) to 3.645 (forbs). Diversity parameter, N was varied from 3.514 to 38.369. It showed a statistically significant difference ($p < 0.05$). Middle region (B) was considerable low richness in trees (1.019) and shrubs (2.216). Although evenness indices for four growth forms were different from each other, there were not shown significant differences ($p < 0.05$). There are varied from 0.856 (shrubs) to 0.976 (forbs).

Low Region (downstream)

The river width at the region was about 22.0 m. The low water's edge vegetation was natural weeds and mixed (Table 1). The flood way was removed from naturally formed vegetation. Land uses in riparian zones within river levee were arable land, flower gardens, residential mixed. There were occurred in *Ginko biloba* and *Salix koriyanagi* (Table 2). Left and right riparian areas were distributed Polygonaceae vegetation (*Persicaria blumei*, *Salix koriyanagi*, *Persicaria sieboldi*, *Persicaria thunbergii*, *Rumex acetocella*, and *Rumex crispus*). Flood plains were distributed Gramineae vegetation (*Avena fatua*, *Imperata cylindrica* var. *koenigii*, and *Miscanthus sacchariflorus*). The survey region was a total of 46 taxa, including 16 families, 37 genera, 41 species, and 5 varieties. The numbers of naturalized plants were 19 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 109 and 1817, respectively.

H´ of diversity for middle region was varied from 1.373 (trees) to 3.619 (forbs). Diversity parameter, N was varied from 3.947 to 37.285. It showed a statistically significant difference ($p < 0.05$). Low region (A) was considerable high richness in grasses (4.472) and forbs (8.104). Although evenness indices for four growth forms were different from each other, there were not shown significant differences ($p < 0.05$). There are varied from 0.990 (trees) to 0.981 (forbs).

Table 2. List of vascular plants, Braun-Blanquet's score, naturalized plant and r-NCD at the Imgi River

Family	Species	Region			Natural-ized plant	r-NCD		
		Upper	Middle	Low		Upper	Middle	Low
Equisetaceae	*Equisetum arvense* L.	3	3			50.0	50.0	
Ginkoaceae	*Ginko biloba* L.	1	1	1		16.7	16.7	16.7
Pinaceae	*Larix leptolepis* (S. et Z.) Gordon	6				100.0		
	Pinus densiflora S. et Z.	5				83.3		
	Pinus rigida Mill.	3				50.0		
Salicaceae	*Salix gracilistyla* Miq.	3	2			50.0	33.3	
	Salix koriyanagi Kimura			1				16.7
Fegaceae	*Castanea crenata* Sieb. Et Zucc	3				50.0		
	Quercus acutissima Carruth.	2				33.3		
	Quercus dentata Thunb. ex Murray	2				33.3		
	Quercus variabilis Blume	2				33.3		
Moraceae	*Morus alba* L.		1				16.7	
Cannabinaceae	*Humulus japonicus* S. et Z.	2				33.3		
Polygonaceae	*Persicaria blumei* Gross		4	3			66.7	50.0
	Persicaria hydropoper (L.) Spach.			2				33.3
	Persicaria sieboldi Ohki			3				50.0
	Persicaria thunbergii H. Gross		3	4			50.0	66.7
	Polygonum aviculare L.		2			33.3	33.3	
	Rumex acetocella L.		2	3	NAT		33.3	50.0
	Rumex acetosa L.			2				33.3
	Rumex conglomeratus Murr.		2	3	NAT		33.3	50.0
	Rumex crispus L.		3	3	NAT		50.0	50.0
Chenopodiaceae	*Chenopodium album* var. *centrorubrum* Makino		2	3			33.3	50.0

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	Chenopodium ficifolium Smith			2	NAT			33.3
Phytolaccaceae	*Phytolacca americana* L.			1	NAT			16.7
Ranunculaceae	*Ranunculus chinensis* Bunge		1	3			16.7	50.0
	Ranunculus japonicus Thunb.		3	2			50.0	33.3
Araliaceae	*Aralia elata* (Miq.) Seem.			2				33.3
Cruciferae	*Capsella bursa-pastoris* (L.) Medicus		2				33.3	
	Capsella flexuosa With.		2				33.3	
	Lepidium apetalum Willd.		3		NAT		50.0	
	Lepidium virginicum L.			2	NAT			33.3
	Rorippa indica (L.) Hiern	2				33.3		
	Thlaspi arvense L.		1	2	NAT		16.7	33.3
Rosaceae	*Agrimonia pilosa* Ledeb.	2				33.3		
	Potentilla fragarioides var. *major* Max.	2				33.3		
	Prunus serrulata var. *spontanea* (Max.) Wils.			1				16.7
	Rosa multiflora Thunb.	3		2		50.0		33.3
Leguminosae	*Amorpha fruticosa* L.	2	3		NAT	33.3		
	Amphicarpaea edgeworthii var. *trisperma* Ohwi		2	2			33.3	33.3
	Kummerowia striata (Thunb.) Schindl.		4	4			66.7	66.7
	Pueraria thunbergiana Benth.	4				66.7		
	Robinia pseudo-acacia L.	1			NAT	16.7		
	Trifolium pratense L.		2	2	NAT		33.3	33.3
	Trifolium repens L.	2	3	4	NAT	33.3	50.0	66.7
Aceraceae	*Acer pseudo-sibolianum* (Paxton) Kom.	1				16.7		
Oxalidaceae	*Oxalis corniculata* L.		2	2			33.3	33.3
Violaceae	*Viola mandshurica* W. Becker	1				16.7		
Onagraceae	*Oenothera odorata* Jacq.	2	4	3	NAT	33.3	66.7	50.0
Umbelliferae	*Oenanthe javanica* (Bl.) DC.	2	4			33.3	66.7	
Oleaceae	*Forsythia koreana* Nakai		2				33.3	

Plantaginaceae	*Plantago asiatica* L.	2	3	4		33.3	50.0	66.7
	Plantago laceolata L.			2	NAT			33.3
Caprifoliaceae	*Lonicera japonica* Thunb.	2				33.3		
Compositae	*Ambrosia artemisiifolia* var. *elatior* Descourtils			2	NAT			33.3
	Artemisia princeps Pampan.	2	2	3		33.3	33.3	50.0
	Aster ciliosus Kitamura		1				16.7	
	Cirsium japonicum var. *ussuriense* Kitamura		2				33.3	
	Cosmos bipinnatus Cav.		3	2	NAT		50.0	33.3
	Conyza canadensis L.		1		NAT		16.7	
	Erechtites hieracifolia Raf.			2	NAT			33.3
	Erigeron annuas (L.) Pers.		2	1	NAT		33.3	16.7
	Galingosa ciliate Blake	1			NAT	16.7		
	Taraxacum officinale Weber			3	NAT			50.0
	Xanthium strumarium L.	2		1	NAT	33.3		16.7
Gramineae	*Avena fatua* L.		1	2	NAT		16.7	33.3
	Argostis clavata var. *nukabo* Ohwi.		1				16.7	
	Digitaria sanguinalis (L.) Scop.	1	2	2		16.7	33.3	33.3
	Echinochloa crus-galli (L.) Beauv.		3	1			50.0	16.7
	Eleusine indica (L.) Gaertner		2	2			33.3	33.3
	Imperata cylindrica var. *koenigii* Durand et Schinz			2				33.3
	Miscanthus sacchariflorus Benth.	2		3		33.3		50.0
	Miscanthus sinensis var. *purpurascens* Rendle	2	3			33.3	50.0	
	Phragmites japonica Steud.		3	5			50.0	83.3
	Poa sphondylodes Trin.		3	3			50.0	50.0
	Setaria viridis (L.) Beauv.			2				33.3
	Zoysia japonica Steud.	3		4		50.0		66.7

NAT: Naturalized plants.

Table 3. Mean cover-abundance of species and diversity indices at the Imgi River

Growth form	No. species (%)	Mean cover-abundance of species	Diversity (H`)	Diversity (N)	Richness	Evenness
A region						
Trees	31.3	2.71	2.150	8.586	2.731	0.934
Shrubs	9.4	3.01	1.061	2.889	0.910	0.966
Grasses	9.4	2.67	1.082	2.951	0.962	0.985
Forbs	50.0	1.81	2.728	15.299	4.455	0.984
Total	100.0	10.18	3.363	28.888	7.225	0.970
B region						
Trees	4.8	1.49	1.257	3.514	1.019	0.906
Shrubs	7.3	1.67	1.665	5.286	2.216	0.856
Grasses	12.2	2.81	2.601	13.475	3.964	0.938
Forbs	75.6	2.32	3.645	38.369	8.962	0.976
Total	100.0	8.29	3.609	36.955	8.625	0.978
C region						
Trees	4.4	1.00	1.373	3.947	1.251	0.990
Shrubs	6.5	1.33	2.112	8.262	2.670	0.961
Grasses	13.0	6.17	2.871	17.646	4.472	0.975
Forbs	76.1	2.43	3.619	37.285	8.104	0.981
Total	100.0	7.93	3.745	42.365	9.574	0.979

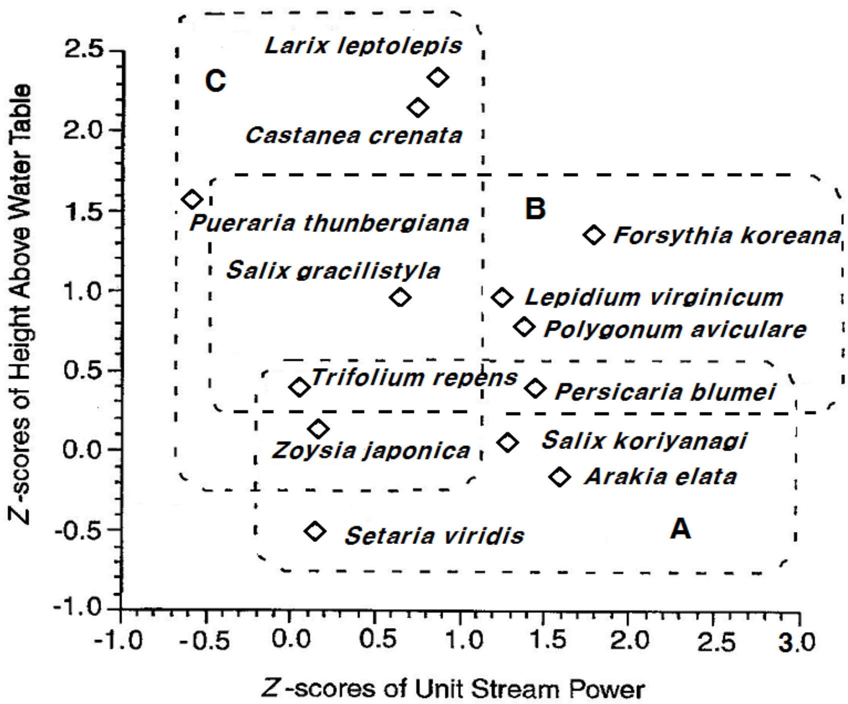

Figure 2. Relationship of 13 common riparian species to unit stream power and height above water table. A, B, and C are regions of the Imgi River. Modified from Benix and Hupp (2000).

DISCUSSION

A major goal in ecology is to understand spatial patterns in the distribution of species diversity. Among the most important factors governing diversity gradients are contemporary factors such as ambient energy, water availability and productivity, area, biotic interactions and environmental heterogeneity, and factors related to historical processes such as phylogenetic niche conservatism and geological or climatic history (Stein et al., 2014). The spatial heterogeneity of environmental resources results in the variance seen in the spatial distribution of vegetation (Fig. 2). The upstream of the Imgi River is fast and the downstream of the river is slow. In addition, the speed of water of the river is fast at surface and that of water is slow at the bottom of the river. Common species were sorted along a power, but those species that occurred on surface with low/stream power were differentiated along a gradient of height above water table. The species found in locales with high stream power are either quite flexible, such as *Salix gracilistyla* or grow so large that mature individuals are resistance to flood damage, such as *Populus* (Benix & Hupp, 2000). The occurrence of patches of mosaics of vegetation is a common feature in worldwide regions including arid and desert (He & Zhao, 2006). A large number of hypotheses have been suggested regarding the origins of this vegetation pattern. Jeltsch et al. (1997) related vegetation patterns to the interplay of factors such as competition, colonization, and changes in the vegetation caused by fire and grazing. However, riparian plant communities depend upon several key environmental factors which affect the environment and consequently the distribution of individual riparian plant species (He and Zhao, 2006). One key environmental factor is the groundwater necessary to support riparian plant communities dependent upon water flow in the river. In recent years, the water flows that reach the middle and low regions of the Imgi River are getting smaller and smaller by artificial action such as road construction. Competition is one of the most important factors controlling species distribution, and it is generally assumed that competitive ability varies along natural environment gradients of fertility (Grime, 1977; Tilman, 1985; Austin, 1986)

Of the 79 species analyzed, 23 (29.1%) are invasive, 56 (70.9%) naturalized. Invasive species at upper region, middle region, and low region were 5 (15.6%), 13 (31.7%), and 19 (41.3%), respectively (Table 2). The number of plant species in South Korea was 8271 and naturalized plants was 321 species. Thus naturalized plant rate is only 3.9% in South Korea. This represents that the rate of alien species in Imgi River was high. It is the result of artificial interference and environmental condition. In particular, Busan is a port city and the introduction center for naturalized plants.

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