FLORA AND SPECIES DIVERSITY OF RIPARIAN SPECIES AT GWINGOK RIVER, HADONG-GUN PROVINCE, KOREA

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ABSTRACT

The objective of this study was to provide flora and species diversity to riparian of Gwingok River, Hadong-gun, Gyeongsangnam-do province in Korea. The stream was divided into 3 compartments for convenience. Sampling with quadrats (plots of a standard size) can be used for most plant communities. At upper area, a total of 81 taxa, including 32 families, 61 genera, 77 species, 3 varieties, and one form have been identified. Naturalized plants were eleven species. Cover-abundance values of trees and shrubs were 1.33 and 2.18, respectively. Cover-abundance values of grasses and forbs were 2.35 and 2.79, respectively. Shannon–Weaver index of diversity (H´) values were varied from 0.69 (trees) to 3.46 (forbs). The middle area was a total of 97 taxa, including 27 families, 67 genera, 90 species, and 6 varieties, and one form. Naturalized plants were 23 species. H´ values were varied from 1.20 (trees) to 3.05 (grasses). The diversity (N) values based on the important value index were varied from 2.62 (trees) to 37.02 (forbs). The low area was a total of 76 taxa, including 21 families, 51 genera, 69 species, and six varieties, and one form (Table 1). Naturalized plants were 22 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 245 and 2,722.2, respectively.

Keywords: Braun-Blanquet, naturalized plants, species diversity, Gwingok River.

INTRODUCTION

River ecosystems encompass ecological, social, and ecosystem functions that interconnect organisms (ecosystem structure), including humans, over some time period (Hauer & Lamberti, 2017). The ecology1of the river refers to the relationships that living organisms have with each other and with their environment – the ecosystems. An ecosystem is the sum of interactions between plants, animals and microorganisms and between them and non-living physical and chemical components in a particular natural environment. In rural settings catchment characterization and land management drive both the river's morphology and biodiversity, and its issues. Rural restoration issues and solutions are therefore more area-based or diffuse, requiring whole farm catchment based approaches. Naturalizing a previously straightened, diverted or realigned river in rural landscapes returns the flow diversity, encouraging creation of natural features, habitats and biodiversity.

Freshwater ecosystems provide vital resources for humans and are the sole habitat for an extraordinarily rich, endemic, and sensitive biota. Human demands on freshwater ecosystems have risen steeply over the past century, leading to large and growing threats to biodiversity around the world (Dudgeon et al. 2006). Rivers are biodiversity hotspots, but are subject to manifold pressures such as abstraction, pollution and impoundment, and have some of the

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highest extinction rates of any ecosystem (Strayer & Dudgeon, 2010). Water resource management, flood protection, inland navigation, hydropower and agriculture, have led to the replacement of naturally occurring and functioning systems with highly modified and human-engineered systems. The bank of a stream or river is called the riparian zone, a place where overhanging foliage provides shade and the tree roots of undercut banks provide shelter (Giller et al., 1999). The deep shade produced by riparian foliage limits photosynthesisand primary production of organic nutrients. Much or most of the organic matter that nourishes the stream habitat originates as foliage that falls into the water, ranging from leaves, twigs, and seeds to fallen trees. Aquatic food chains in first-order streams thus begin with coarse particulate organic matter.

For an organism to survive it must have access to appropriate habitats. Habitat is a combination of physical and biological characteristics of an area (or areas) essential for meeting the food and other metabolic needs, shelter, breeding, and over-wintering requirements of a particular species. For some species habitat can be as small as individual rocks or pebbles in the streambed. Riparian habitats are ecologically diverse and may occur in a range of general habitat types, including damp grasslands, wetlands, marshes, and forests. Riparian land, posed at the transition zone between land and water, supports a number of ecosystem services (Dosskey et al., 2012; NRC, 2002; Stutter et al., 2012). In contributing wood and litter materials, these areas offer important wildlife habitat and support food webs (Vigiak et al., 2016).

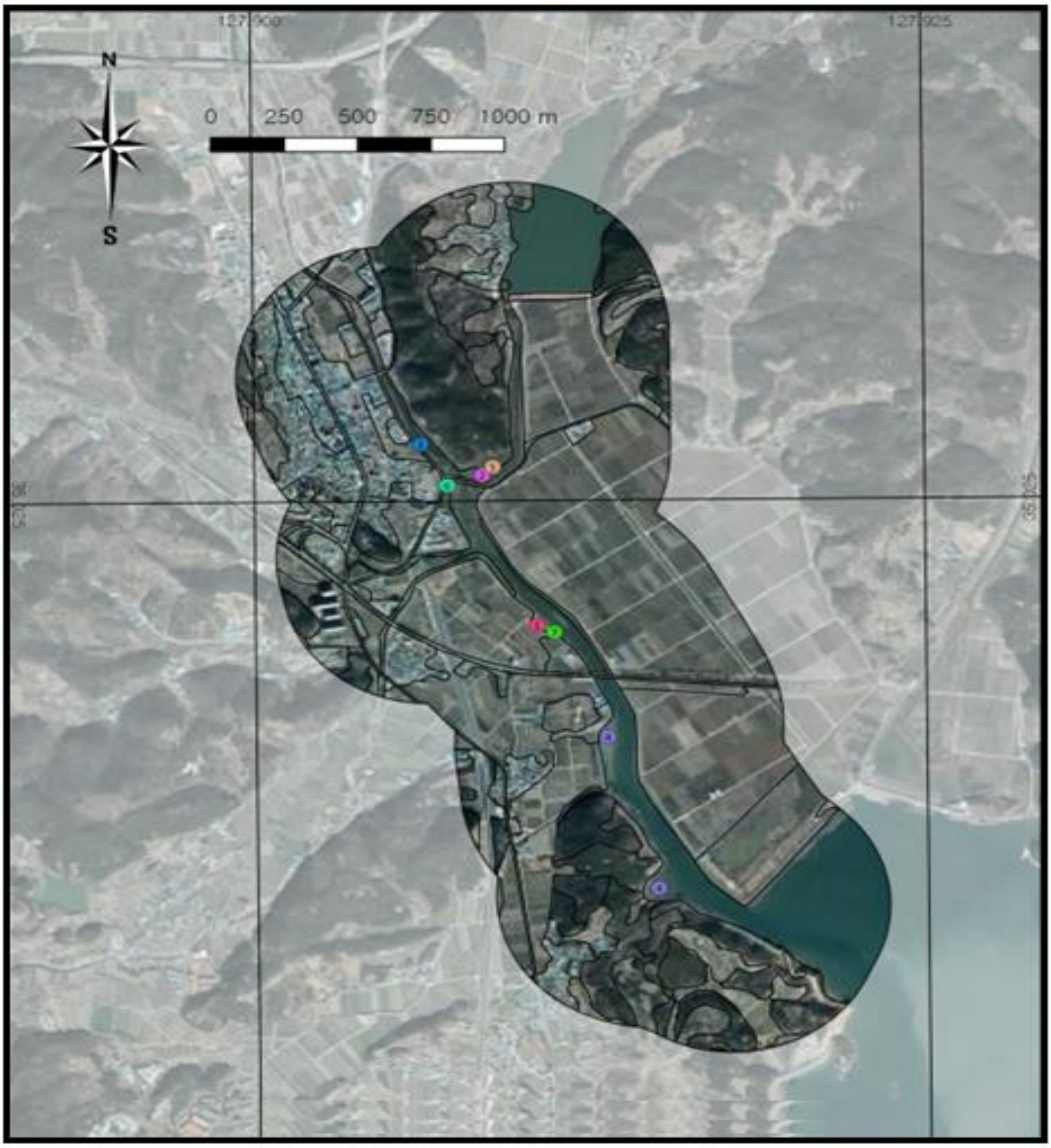
A variety of aquatic plants live in the freshwater portion of the middle and low areas of Gwingok River. The river is started at the mountains and flows into the Pacific Ocean. There is increasing interest in the importance of rivers from hydrological, geomorphological, ecological as well as environmental points of view, and the number of scientific symposia, publications and books on the subject is rapidly expanding (Burns, 2002).

The objective of this study was to provide flora and species diversity to riparian of Gwingok River, Hadong-gun, Gyeongsangnam-do province in Korea, from surveys of three areas. We intended to increase plant communities, encourage growth of desirable plant species, and improve plant species composition. The results can be used to guide management and improvement of the riverine environment in the river.

METHODOLOGY

Surveyed Areas

This study was carried out on Gwingok River upper area: 35°055′127″N/127°882′882″E, low area: 35°010′206″N/127°917′935″E), located at Jingyo-myeon, Hadong-gun, Gyeongsangnam-do in Korea. The river is approximately 33.6 kilometers in length. We excluded the top upstream narrow valleys where riparian was not developed. However, the upper areas of developed aquatic plants in the middle or both sides of the river were included in this study. The river was divided into 3 compartments for convenience. These included (1) upland, forest; (2) middle land riparian; and (3) lowland, riparian/riverbank communities. The upper surveyed area of Gwingok River consisted of a mosaic of agricultural fields, two schools (primary and middle schools) and farming houses. The middle area included government offices, city areas, and flood plains of this area are usually very fertile agricultural areas. The low area was consisted of a mosaic of agricultural fields and farming houses.



1: *Forsythia koreana* community, 2: *Plantago camtschatica*, 3: *Acer palmatum*, 4: halophytic community, 5: *Salix chaenomeloides*, 6: *Ulmus parvifolia*, 7: *Salix* koriyanagi.

Figure 1: Location of the study area at the Gwingok River and representative species.

Floristic Analysis

Sampling with quadrats (plots of a standard size) can be used for most plant communities (Cox, 1990). A quadrat delimits an area in which vegetation cover can be estimated, plants counted, or species listed. 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). Each species was collected, mounted, labeled, and systematically arranged in an herbarium. The identification of naturalized plants was 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). 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).

Biotic Indices

Unlike species diversity indices *community* diversity indices are based on total numbers of species and their relative abundances. This provides a better numerical measure of community structure. Jaccard's Index of Similarity (ISj) was used to assess differences/similarities among the three sites (Hastings & Rothenberger, 2013). For comparison, it was useful to apply another similarity test, The Sørensen index, also known as Sørensen's similarity coefficient (ISs), is a statistic used for comparing the similarity of two samples. Shannon–Weaver index of diversity (Shannon & Weaver, 1963) is that the diversity of a community is similar to the amount of *information* in a code or message. The species richness of animals was calculated by using the method, Margalef's index (R) of richness (Magurran, 1988). Evenness index was calculated using important value index of species (Hill, 1973; Pielou, 1966). The percent of naturalized plant species, PN) and urbanization index (UI) were calculated the methods of Numata (1975) and Yim & Jeon (1980), respectively.

RESULTS

Upper area

The mean stream width at this area is about 8.8 m. The riparian area was formed on both sides (flood plains) of the river. The application of the Braun-Blanquet approach for plant classification in this area is presented (Table 1). According to the existing phytosociological data, a total of 81 taxa, including 32 families, 61 genera, 77 species, 3 varieties, and one form have been identified. Naturalized plants were eleven species. The dominant species (according to cover and frequency) that occur in the upper area are *Persicaria hydropoper* and *Artemisia princeps* which are the ordinal transform scale 9 for the application of the Braun-Blanquet approach. The second highest score (8) was *Persicaria longiseta*. *Persicaria thunbergii* also had a high score of 6. The total transformed Braun-Blanquet value and r-NCD at upper area were 202 and 2,244.4, respectively. The value of cover-abundance was total 8.65 (Table 2). Cover-abundance values of trees and shrubs were 1.33 and 2.18, respectively. Cover-abundance values of grasses and forbs were 2.35 and 2.79, respectively. H´ values were varied from 0.69 (trees) to 3.46 (forbs). For the community as a whole, diversity (N) values based on the important value index were varied from 2.00 (trees) to 31.83 (forbs). The total richness indices were varied from 1.44 (trees) to 7.93 (forbs). The evenness indices were varied from 0.631 (trees) to 0.985 (grasses). Although evenness indices were different from each other, there were not shown significant differences ($p < 0.05$). Naturalized Index(NI) and Urbanization Index(UI) were 13.6% and 3.4%, respectively (Table 3). When Jaccard's Index of Similarity (ISj) were applied to Gwingok River, the most similar areas were middle and low (ISj = 73.0%) (Table 3). ISj value of the two riparian areas (upper and low) which was only 40.2%. Sorensen's Index of Similarity was also used because it gives greater weight than Jaccard's to the species that recur in the two test areas than to those that are unique to either area. The ISs indices were varied from 36.4% (upper and low) to 45.8% (middle and low).

B area

The mean river width at the area is about 24.0 m. The dominant species (according to cover and frequency) that occur in the upper area are *Trifolium repens, Artemisia princeps*, and *Phragmites communis* which are the ordinal transform scale 9 for the application of the Braun-Blanquet approach. The survey area was a total of 97 taxa, including 27 families, 67 genera, 90 species, and 6 varieties, and one form. Naturalized plants were 23 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 266 and 2,935.5, respectively. The value of cover-abundance was total 9.37 (Table 2). H´ values were varied from 1.20 (trees) to 3.05 (grasses). The diversity (N) values based on the important value index were varied from 2.62 (trees) to 37.02 (forbs). The total richness indices were varied from 2.23 (trees) to 10.99 (forbs). The evenness indices were varied from 0.599 (trees) 0.893 (forbs). Although evenness indices were different from each other, there were not shown significant differences ($p < 0.05$). NI and UI were 24.7% and 7.4%, respectively (Table 4).

C area

The mean river width at the area was about 43.5 m. The dominant species (according to cover and frequency) that occur in the upper area are *Trifolium repens*, *Artemisia princeps*, *Miscanthus sinensis* for. *purpurascens*, and *Phragmites communis* which are the ordinal transform scale 9 for the application of the Braun-Blanquet approach. *Suaeda glauca* had a high score of 7. *Phragmites communis* formed communities in large areas over 100 m x 300 m. The survey area was a total of 76 taxa, including 21 families, 51 genera, 69 species, and six varieties, and one form (Table 1). Naturalized plants were 22 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 245 and 2,722.2, respectively.

The value of cover-abundance was total 10.45 (Table 2). H´ value was different across growth forms, varying from 1.01 (shrubs) to 3.84 (forbs). The diversity (N) values based on the important value index were varied from 2.76 (shrubs) to 46.73 (forbs). The total richness indices were varied from 1.12 (shrubs) to 9.98 (forbs). The evenness indices were varied from 0.921 (shrub) 0.973. (forbs). NI and UI were 30.3% and 7.1%, respectively (Table 4).

Table 1: List of vascular plants, Braun-Blanquet's score, and r-NCD at three areas of Gwingok River

Family	Species	Area			Invaded plant	r-NCD		
		Upper	Middle	Low		Upper	Middle	Low
Salicaceae	*Salix chaenomeloides* Kimura		1				11.1	
	Salix gracilistyla Miquel	2				22.2		
	Salix koreensis Andersson		1	1			11.1	11.1
	Salix koriyanagi Kimura	2	2			22.2	22.2	
	Salix subfragilis Anderson	2	3			22.2	33.3	
Moraceae	*Humulus japonicus* S. et Z.	3	3			33.3	33.3	
	Morus alba L.	3	2			33.3	22.2	
	Morus bombycis Koidz.	2	1			22.2	11.1	
Urticaceae	*Boehmeria longispica* Steud.	2	2			22.2	22.2	
	Boehmeria spicata (Thunb.) Thunb.	2				22.2		
Polygonaceae	*Persicaria hydropoper* (L.) Spach.	9	6	4		100.0	66.7	44.4
	Persicaria longiseta (De Bruyn) Kitagawa	8	5	4		88.9	55.6	44.4
	Persicaria orientalis Spach	3	3			33.3	33.3	
	Persicaria perfoliata (L.) H. Gross	2	3	2		22.2	33.3	22.2
	Persicaria sieboldii (Meisn.) Ohki	3	3	4		33.3	33.3	44.4
	Persicaria thunbergii H. Gross	6	4	3		66.7	44.4	33.3
	Reynoutria japonica Houtt.	2				22.2		
	Rumex acetosa L.		3	4			33.3	44.4
	Rumex acetoscella L.		3	5			33.3	55.6
	Rumex conglomeratus Murr.	2	3	3		22.2	33.3	33.3
	Rumex crispus L.	2	3	5		22.2	33.3	55.6
	Rumex nipponicus Fr. et Sav.		3	3			33.3	33.3
Chenopodiaceae	*Chenopodium album* L.		4	3			44.4	33.3
	Chenopodium album var. *centrorubrum* Makino	2	4	3		22.2	44.4	33.3
	Suaeda glauca (Bunge) Bunge			7				77.8
Amaranthaceae	*Achyranthes japonica* (Miquel) Nakai	2	3	2		22.2	33.3	22.2

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Caryophyllaceae	*Arenaria serpyllifolia* L.	1	1	1		11.1	11.1	11.1
	Stellaria aquatica (L.) Scop.		2	3			22.2	33.3
Ranunculaceae	*Ranunculus sceleratus* L.		2	2			22.2	22.2
	Ranunculus tachiroei Fr. et Sav.		1	2			11.1	22.2
Papaveraceae	*Chelidonium majus* var. *asiaticum* Ohwi		2	2			22.2	22.2
	Corydalis speciosa Maxim.	2				22.2		
Brassicaceae	*Brassica juncea* Czern		2	2			22.2	22.2
	Brassica vampestris var. *nippo-oleifera* Makino	2	2	3		22.2	22.2	33.3
	Capsella bursa-pastoris (L.) Medicus	2	3	3		22.2	33.3	33.3
	Cardamine flexuosa With.		2	3			22.2	33.3
	Thlaspi arvense L.		3	2			33.3	22.2
Rosaceae	*Prunus jamasakura* Sieb.	2	2	2		22.2	22.2	22.2
	Rosa multiflora Thunb.	2	3	2		22.2	33.3	22.2
	Rubus crataegifolius Bunge	2	2			22.2	22.2	
Leguminosae	*Albizzia julibrissin* Durazz.	1	1	1		11.1	11.1	11.1
	Amorpha fruticosa L.	2	2	3		22.2	22.2	33.3
	Astragalus sinicus L.		4	5			44.4	55.6
	Glycine soja S. et Z.	2	3	3		22.2	33.3	33.3
	Pueraria lobata (Willd.) Ohwi	4	4			44.4	44.4	
	Robinia pseudo-acacia L.	1	1	1		11.1	11.1	11.1
	Trifolium pratense L.		2	3			222	33.3
	Trifolium repens L.	5	9	9		55.6	100.0	100.0
	Vicia amoena Fischer		2				22.2	
	Vicia tetrasperma (L.) Moench	3	3	2		33.3	33.3	22.2
	Vicia villosa Roth		2	3			22.2	33.3
Geraniaceae	*Geranium thunbergii* Sieb.et Zucc.	2	2	2		22.2	22.2	22.2
Oxalidaceae	*Oxalis corniculata* L.	2	2	2		22.2	22.2	22.2
	Oxalis stricta L.		2	2			22.2	22.2
Anacardiaceae	*Rhus javanica* L.	2				22.2		
	Rhus tricocarpa Miquel	2				22.2		

Aceraceae	*Acer palmatum* Thunb.	1	1	1		11.1	11.1	11.1
	Acer pseudo-sieboldianum (Pax) Komar.	1	1			11.1	11.1	
Violaceae	*Viola patrinii* DC.	2				22.2		
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	2				22.2		
Cucurbitaceae	*Cucurbita moschata* (Duchesne) Poiret	2	2			22.2	22.2	
Onagraceae	*Oenothera odorata* Jacq.	2	2	3		22.2	22.2	33.3
Araliaceae	*Aralia elata* (Miquel) Seemann	2				22.2		
Umbelliferae	*Oenanthe javanica* (Bl.) DC.	2	3	3		22.2	33.3	33.3
Ericaceae	*Rhododendron mucronulatum* Turcz.	3				33.3		
	Rhododendron schlippenbachii Maxim.	2	3			22.2	33.3	
Oleaceae	*Forsythia koreana* (Rehder) Nakai	3	3			33.3	33.3	
Convolvulaceae	*Ipomoea hederacea* Jacq.		2	2			22.2	22.2
	Ipomoea triloba L.		2	2			22.2	22.2
Scrophulariaceae	*Veronica anagallis-aquatica* L.	2	2	2		22.2	22.2	22.2
	Veronica persica Poir		2	3			22.2	33.3
Plantaginaceae	*Plantago* asiatica L.	3	3	4		33.3	33.3	44.4
	Plantago camtschatica Chamisso			3				33.3
	Plantago lanceolata L.		2	2			22.2	22.2
Caprifoliaceae	*Lonicera japonica* Thunb.	2	2			22.2	22.2	
Compositae	*Artemisia princeps* Pamp.	9	9	9		100.0	100.0	100.0
	Cirsium japonicum var. *ussuriense* Kitamura		2	2			22.2	22.2
	Cosmos bipinnatus Cav.	2	3	3		22.2	33.3	33.3
	Erigeron annuus (L.) Pers.	2	3	4		22.2	33.3	44.4
	Erigeron canadensis L.	2	4	5		22.2	44.4	55.6
	Hemistepta lyrata Bunge		2	2			22.2	22.2
	Kalimeris yomena Kitamura		3	2			33.3	22.2
	Lactuca indica L. var. *laciniata* Hara		2	2			22.2	22.2
	Petasites japonicus (Sieb. et Zucc.) Maxim.	2	3			22.2	33.3	
	Sonchus asper (L.) Hill		2				22.2	
	Taraxacum officinale Weber	2	4	5		22.2	44.4	55.6

	Taraxacum platycarpum Dahlst.	2	2	3		22.2	22.2	33.3
	Xanthium strumarium L.		2	2			22.2	22.2
Typhaceae	*Typha angustifolia* L.	3				33.3		
Gramineae	Agropyron *tsukusinense* var. *transiens* Ohwi	2	3	4		22.2	33.3	44.4
	Alopecurus pratensis L.	2	3	3		22.2	33.3	33.3
	Arthraxon hispidus (Thunb.) Makino	2				22.2		
	Beckmannia syzigachne (Steud.) Fernald	2	3	3		22.2	33.3	33.3
	Bromus japonicus Thunb.	2	2	2		22.2	22.2	22.2
	Dactylis glomerata L.	3	2	3		33.3	22.2	33.3
	Digitaria ciliaris (Retz.) Koel.	3	3			33.3	33.3	
	Echinochloa crus-galli (L.) Beauv.	3	3			33.3	33.3	
	Eragrostis curvula Nees	2	2	2		22.2	22.2	22.2
	Eragrostis ferruginea (Thunb.) Beauv.	2	3	3		22.2	33.3	33.3
	Festuca arundinacea Schreb.	3	2			33.3	22.2	
	Lolium perenne L.	2	2			22.2	22.2	
	Miscanthus sacchariflorus (Maxim.) Bentham	3	4	1		33.3	44.4	11.1
	Miscanthus sinensis for. *purpurascens* Nakai	2	3	9		22.2	33.3	100.0
	Phalaris arundinacea L.		2	5			22.2	55.6
	Phragmites communis Trinius	1	9	9		11.1	100.0	100.0
	Phragmites japonica Steud.	3	2			33.3	22.2	
	Setaria viridis (L.) Beauv.	2	2	3		22.2	22.2	33.3
	Zizania latifolia Turcz.	1	2	2		11.1	22.2	22.2
	Zoysia japonica Steud.	4	6	3		44.4	66.7	33.3
	Zoysia sinica Hance		4	9			44.4	100.0
Cyperaceae	*Carex dimorpholepis* Steud.	3				33.3		
	Carex scabrifolia Steud.			4				44.4
Commelinaceae	*Commelina communis* L.	2	2			22.2	22.2	
Dioscoreaceae	*Dioscorea japonica* Thunb.	2				22.2		
Total		81	97	76		2244.4	2935.5	2722.2

NAT: Naturalized plants.

Table 2: Mean cover-abundance of species and diversity indices at Gwingok River

Growth form	No. species (%)	Mean cover-abundance of species	Diversity (H`)	Diversity (N)	Richness	Evenness
A area						
Trees	3 (3.7)	1.33	0.69	2.00	1.44	0.631
Shrubs	17 (21.0)	2.18	2.78	16.15	4.43	0.982
Grasses	23 (28.1)	2.35	3.09	21.98	5.52	0.985
Forbs	38 (46.3)	2.79	3.46	31.83	7.93	0.951
Total	81 (100.0)	8.65	-	-	-	-
B area						
Trees	5 (5.2)	1.20	0.96	2.62	2.23	0.599
Shrubs	13 (13.4)	2.31	2.14	8.45	3.53	0.834
Grasses	21 (21.6)	3.05	2.57	13.09	4.81	0.845
Forbs	58 (59.8)	2.81	3.61	37.02	10.99	0.893
Total	97 (100)	9.37	-	-	-	-
C area						
Trees	5 (6.8)	1.20	1.56	4.76	2.23	0.970
Shrubs	3 (3.9)	2.00	1.01	2.75	1.12	0.921
Grasses	16 (21.1)	4.06	2.60	13.45	3.59	0.937
Forbs	52 (68.4)	3.19	3.84	46.73	9.98	0.973
Total	76 (100)	10.45	-	-	-	-

Table 3: Index of similarity values comparing the three areas

Area	Jaccard's (ISj)	Sorensen's (ISs)
A and B	60.4	43.0
A and C	40.2	36.4
B and C	73.0	45.8

A, B, and C are the same as Table 2.

Table 4: Naturalized index (NI) and urbanization index (UI) in the three areas

Index	Area			Total
	Upper	Middle	Low	
NI(%)	13.6	24.7	30.3	21.9
Ul(%)	3.4	7.4	7.1	7.7

DISCUSSION

A riparian buffer zone is a vegetated strip of land along the margins of a water channel. Riparian vegetation provides a barrier (buffer) between the water (river, streams, and estuaries) and the land. Due to the presence of water and nutrients, riparian land often supports significant plant communities that are generally denser, faster growing and have a greater number of layers or strata, than adjacent plant communities. When surface water (runoff) from the surrounding catchment runs through the riparian zone, contaminants (sediments, nutrients) contained in the runoff are trapped in the roots of any riparian vegetation, allowing the silty or contaminated water to infiltrate the soils.

Although riparian zones are an interface between terrestrial and aquatic ecosystems and also play a critical role in supporting biota and therefore biodiversity, a study of 16 streams in eastern North America shows that riparian deforestation causes channel narrowing, which reduces the total amount of stream habitat and ecosystem per unit channel length and compromises in-stream processing of pollutants (Sweeney et al., 2004).

The beneficial role of riparian vegetation in terms of sediment retention has been extensively described in the scientific literature (Daniels & Gilliam, 1996, Dosskey et al., 2010, McKergow et al., 2003, Yuan et al., 2009). Riparian land contributes to reducing sediment fluxes in freshwater bodies. For thousands of years, sand and gravel have been used in the construction of roads and buildings. Today, demand for sand and gravel continues to increase. Mining operators, in conjunction with cognizant resource agencies, must work to ensure that sand mining is conducted in a responsible manner. The accumulated sand at Gwingok River is being collected in a useful way as a building material. Excessive sand extraction can threaten the survival of vegetation in terms of travel, such as damaging plant roots. Excessive instream sand-and-gravel mining causes the degradation of rivers. Instream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. Planting of sand dune vegetation alone does not entirely restore or protect sand dunes from human impacts. For example, seedlings need to be protected from human trampling, which is done mainly by fencing off newly planted areas. Fencing also acts as another way of trapping and accumulating sand among the dunes and can also act as protection against strong winds (Gadgil & Ede, 1998).

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