FLORA AND SPECIES DIVERSITY INDICES OF WATERSHEDS AT THE JUNGCHON STREAM IN HAPCHEON-GUN, KOREA

Man-Kyu, Huh
Department of Applied Bioengineering,
Dong-eui University
SOUTH KOREA
mkhuh@deu.ac.kr

ABSTRACT

This study of the vegetation of the Jungchon Stream in Korea is examined river naturality and vegetative composition of river riparian zones to identify their most important sources of variation. According to the existing phytosociological data, 21 families, 52 genera, 52 species, 7 varieties have been identified at upper region of this stream. Cover-abundance values of trees and shrubs were 1.67 and 2.63, respectively. The middle region was a total of 64 taxa, including 19 families, 54 genera, 56 species, and eight varieties. Naturalized plants were 20 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 170 and 2,428.6, respectively. Cover-abundance value of shrubs was 3.29. The low region was a total of 48 taxa, including 15 families, 36 genera, 43 species, and five varieties. Riverbed area was dominated by the distribution of genus *Rumex*. The total transformed Braun-Blanquet value and r-NCD at middle area were 138 and 1,971.4, respectively. The spatial heterogeneity of environmental resources results in the variance seen in the spatial distribution of vegetation.

Keywords: Braun-Blanquet, Cover-abundance, Jungchon Stream, riparian vegetation.

INTRODUCTION

Rivers and streams are complex ecosystems (Chiras, 1998). As with lakes, no two streams are alike. In many areas, streams begin in mountains or hilly terrain, collecting water that falls to the Earth as rain or snow. The region drained by a stream is called a watershed. Small streams join to form rivers. Many states define riparian areas to regulate land disturbance activities, to protect water quality, and to comply with the Federal Clean Water Act (Ilhardt et al., 2000). "Streamside management zones," "buffer zone" or "buffer strip" and "riparian management zones," are the terms most frequently used, and minimum widths are usually specified. The riparian management zone excludes the aquatic component and delineates the land and vegetation that buffers the surface water from land disturbance. A riparian has been defined as the area between the stream channels or near shore portion of a lake or pond and the furthest upland extent of the aquatic system's influence (Gregory et al., 1996). Riparian areas are lands that occur along watercourses and water bodies. Typical examples include flood plains and streambanks. They are distinctly different from surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by the presence of water. Because of their variation across the country, riparian areas function in different ways. In spite of their differences, all riparian areas possess some similar ecological characteristics such as energy flow, nutrient cycling, water cycling, hydrologic function, and plant and animal population. These functions give riparian areas unique values relative to the surrounding landscape.

The Jungchon Stream is started at the mountains and two reservoirs and ends at the wide Shinjeon River. Due to their permanent vegetation, buffer strips offer good conditions for effective water infiltration and slowing surface flow; they therefore promote the natural retention of water. The most floodplains of the river have been converted to agricultural or horticultural fields, housing, restricting the river bed to a small channel. Riparian buffers in the Jungchon Stream are treed areas alongside streams and other water bodies. While most commonly associated with set asides following forest harvest, riparian buffers can also be found in urban, agricultural and wetland areas. The purpose of this study is to investigate the flora and species diversity indices on the Jungchon Stream at three regions.

METHODOLOGY

Surveyed Regions

This study was carried out on the Jungchoncheon Stream (upper region: 35°370′436″N/128°166′999″E, low region: 35°381′528″N/128°143′407″E), located at Hapcheon-gun, Gyeongsangnam-do province in Korea (Fig. 1). The stream is located to the eastern region of the city of Hapcheon-gun. The length of the stream is 3.9 km long in length with a varying width of between 2.3 and 20.6 meters. Lowlands are usually no higher than 150 m, while uplands are somewhere around 200 m to 220 m. The stream starts at some high point. The high point can be a mountain, hill, or other elevated. The Jungchon Stream, including three reservoirs, used to be covered with pine trees and other species. The relatively level land can be developed either as agricultural fields (Table 1). 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. Mean annual temperature ranges from -0.5 (January) to 25.4 °C (August) with 13.0°C, and mean annual precipitation ranges from 15.2 (December) to 294.5 mm (August) with 1275.6 mm.

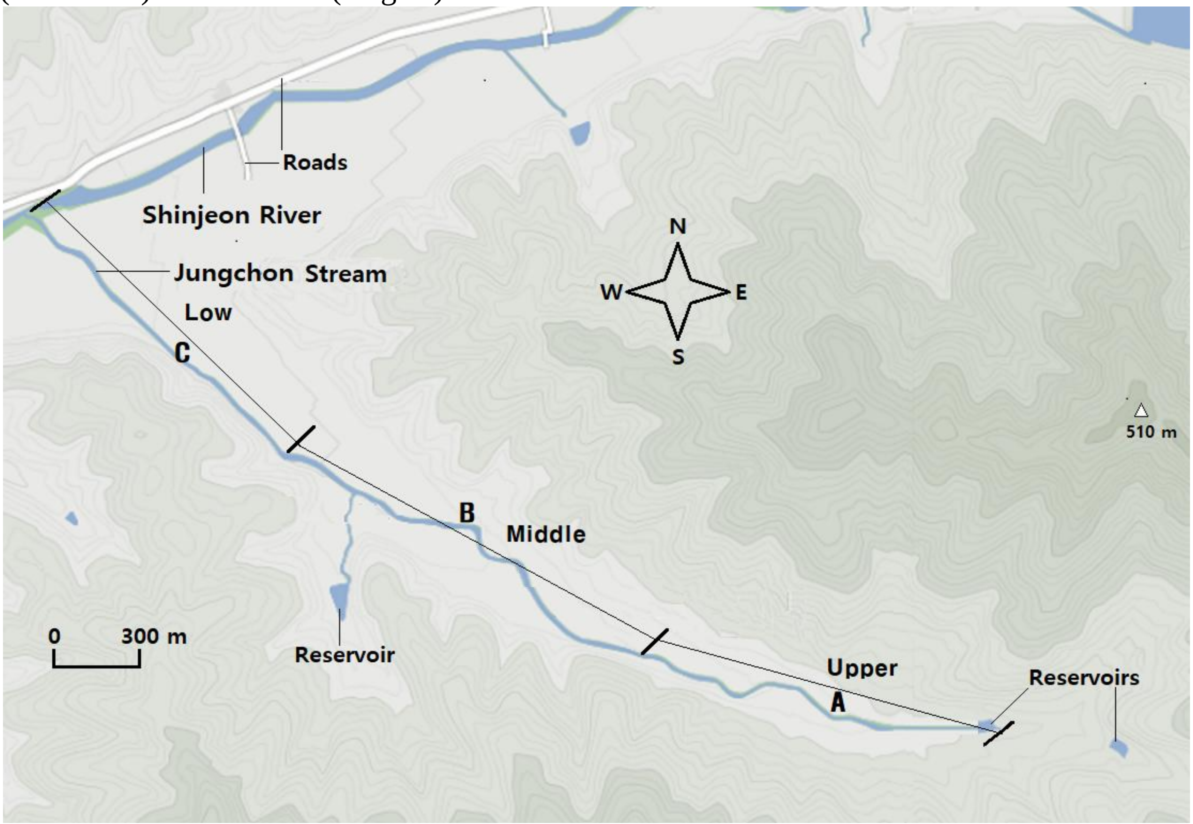

Figure 1: Location of the study area and the three detailed internodes at the Jungchon Stream.

Table 1. Land use in flood plains beyond river levee on the Jungchon Stream

Region	Length (km)	Mean width (m)	Land use
A	1.03	2.3	Forest area, residence, reservoir, farm fields
B	1.35	8.8	Forest area, farm fields, horticulture
C	1.52	20.6	Residence, farm fields

Floristic analysis

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 Jungchon Stream were chosen to study (Fig. 1). 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). Density, cover, frequency, and biomass are the vegetation attributes most commonly monitored. Attributes related to individual plants (e.g., height, number of flowers per plant) are measured. Each species was collected, mounted, labeled, and systematically arranged in a herbarium. The system of plant classification system was followed by Lee (2007). The identifications of 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).

Biotic Indices

Shannon–Weaver index of diversity (Shannon and Weaver, 1963): the formula for calculating the Shannon diversity index (H') is: $H' = -\Sigma\, p_i \ln p_i$

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), $N = e^{H'}$

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 (A)

The mean river width at this region is about 2.3 m. It was found that agricultural activities were dominant on behind left bank of this section and on right bank. The riparian areas of both the river banks were dominated in the form of shrubs, bushes, grasses, and herbs. On outside area of left bank, human interference was recorded than agricultural activities.

Riparian vegetation provides habitat for many wildlife species. 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, 21 families, 52 genera, 52 species, 7 varieties have been identified (Table 2). Naturalized plants were twelve species. Transition zones of this section were distributed pine vegetation. The river width was relative large and the depth of water was swallow and distributions of aquatic plants developed very well in riparian.

The dominant species (according to cover and frequency) that occur in the A region are *Equisetum arvense, Humulus japonicas,* and *Zoysia japonica*. The dominant vegetation of low water's edge was genus *Persicaria.* Dominant species in flood plains was *Zoysia japonica.* The total transformed Braun-Blanquet value and r-NCD at upper area were 137 and 1,957.1, respectively.

The value of cover-abundance was total 9.04 (Table 3). Cover-abundance values of trees and shrubs were 1.67 and 2.63, respectively. Cover-abundance values of grasses and forbs were 2.61 and 2.13, respectively. A Shannon-Weaver indices (H´) of diversity were varied from 1.05 (trees) to 3.31 (forbs). For the community as a whole, richness of trees was very low (1.24). The total richness indices were varied from 1.24 (trees) to 6.97 (forbs). The evenness indices were varied from 0.96 (forbs) to 0.97 (trees). Although evenness indices were different from each other, there were not shown significant differences ($p < 0.05$).

Middle Region (B)

The mean river width at the region was about 8.8 m. Human interference was absent on flood plains beyond stream. During the investigation vegetation like shrubs, bushes, herbs and trees were recorded on the right flood plains beyond the stream. The left flood plains beyond the stream was agriculture fields. The vegetation of low water's edge was natural weeds, shrubs, and mixed. The dominant species of left and right riparian areas was Gramineae vegetation (*Zoysia japonica*) (Table 2). The dominant vegetation of low water's edge was *Boehmeria spicata.* Land use in flood plains beyond river levee was dominated *Pinus densiflora* and *Pinus* ***thunbergii***. Other phyla were occasionally recorded in low densities. The survey region was a total of 64 taxa, including 19 families, 54 genera, 56 species, and eight varieties. Naturalized plants were 20 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 170 and 2,428.6, respectively. Cover-abundance value of shrubs was 3.29 (Table 3). Cover-abundance values of grasses and forbs were3.12 and 2.43, respectively. The value of cover-abundance was total 8.83 (Table 4). A Shannon-Weaver indices (H´) of diversity were varied from 0.0 (trees) to 3.62 (forbs). The total richness indices were varied from 0.0 (trees) to 8.53 (forbs). The evenness indices were varied from 0.97 (shrubs) 0.98 (forbs). Although evenness indices were different from each other, there were not shown significant differences ($p < 0.05$).

Low Region (C)

The mean river width at the region was about 20.6 m. Land use in flood plains beyond river levee was agriculture fields. Flood way vegetation was removed vegetation artificially. The vegetation of low water's edge was blocked by stonework etc. Riverbed area was dominated by the distribution of genus *Rumex*. The survey region was a total of 48 taxa, including 15 families, 36 genera, 43 species, and five varieties (Table 2). Naturalized plants were 22 species. The total transformed Braun-Blanquet value and r-NCD at middle area were 138 and 1,971.4, respectively.
The value of cover-abundance was total 8.56 (Table 3). A Shannon-Weaver index (H´) of diversity was different across growth forms, varying from 0.0 (trees) to 3.41 (forbs). The total richness indices were varied from 0.0 (trees) to 7.71 (forbs). The evenness indices were varied from 0.96 (grasses) to 0.99 (shrubs).

Table 2. List of vascular plants, Braun-Blanquet's score, and r-NCD at three regions of the Jungchon Stream

Family	Species	Region			Invaded plant	r-NCD		
		A	B	C		A	B	C
Equisetaceae	*Equisetum arvense* L.	5	5	3		71.4	71.4	42.9
Pinaceae	*Pinus densiflora* S. et Z.	2	2			28.6	28.6	
	Pinus ***thunbergii*** Parl.	2	3			28.6	42.9	
Ulmaceae	*Zelkova serrata* (Thunb.) Makino	1				14.3		
Salicaceae	*Salix gracilistyla* Miq.	2	2	3		28.6	28.6	42.9
Moraceae	*Morus alba* L.	2				28.6		
Cannabinaceae	*Humulus japonicus* S. et Z.	5	4			71.4	57.1	
Urticaceae	*Boehmeria longispica* Steud.	3	4			42.9	57.1	
	Boehmeria spicata (Thunb.) Thunb.	3	5			42.9	37.5	
Polygonaceae	*Persicaria hydropoper* (L.) Spach.	2				28.6		
	Persicaria longiseta (De Bruyn) Kitagawa	3				42.9		
	Persicaria thunbergii H. Gross	2	2			28.6	28.6	
	Rumex acetocella L.	2	4	5	NAT	28.6	57.1	71.4
	Rumex acetosa L.		3	5			42.9	71.4
	Rumex conglomeratus Murr.			2	NAT			28.6
	Rumex crispus L.		3	4	NAT		42.9	57.1
Chenopodiaceae	*Chenopodium acuminatum* Willd.	2	2	4		28.6	28.6	57.1
	Chenopodium album L.		2	3	NAT		28.6	42.9
	Chenopodium album var. *centrorubrum* Makino	2	3	3		28.6	42.9	42.9
Amaranthaceae	*Achyranthes japonica* (Miq.) Pa.	1	2	3		14.3	28.6	42.9
	Amaranthus lividus L.	2	2		NAT	28.6	28.6	
Phytolaccaceae	*Phytolacca americana* L.		2		NAT		28.6	
Brassicaceae	*Brassica juncea* Czern	2	2	3		28.6	28.6	42.9
	Brassica vampestris var. *nippo-oleifera* Makino	4	2	2		57.1	28.6	28.6

	Capsella bursa-pastoris (L.) Medicus	3	4	5		42.9	57.1	71.4
	Lepidium apetalum Willd.		2	3	NAT		28.6	42.9
	Lepidium bonariense L.			1	NAT			14.3
	Lepidium campestre R.Br.			1	NAT			14.3
	Lepidium virginicum L.			2	NAT			28.6
	Thlaspi arvense L.		1	3	NAT		14.3	42.9
Rosaceae	*Duchesnea chrysantha* (Zoll. Et Morr) Miq.	3	2			42.9	28.6	
	Potentilla fragarioides var. *major* Max.	3	2	1		42.9	28.6	14.3
	Rosa multiflora Thunb.	3	2			42.9	28.6	
Leguminosae	*Amorpha fruticosa* L.		3	2	NAT		42.9	28.6
	Astragalus sinicus L.		2	2	NAT		28.6	28.6
	Kummerowia striata (Thunb.) Schindl.	1	1	2		14.3	14.3	28.6
	Pueraria lobata (Willd.) Ohwi	2	2			28.6	28.6	
	Trifolium pratense L.	2	3	3	NAT	28.6	42.9	42.9
	Trifolium repens L.		3	4	NAT		42.9	57.1
	Vicia tetrasperma (L.) Moench	2			NAT	28.6		
Oxalidaceae	*Oxalis corniculata* L.	1	2	2		14.3	28.6	28.6
	Oxalis stricta L.	1	2	1		14.3	28.6	14.3
Onagraceae	*Oenothera odorata* Jacq.	1	3	2	NAT	14.3	42.9	28.6
Umbelliferae	*Oenanthe javanica* (Bl.) DC.	2				28.6		
Plantaginaceae	*Plantago asiatica* L.	3	3	2		42.9	42.9	28.6
	Plantago laceolata L.		1	2	NAT		14.3	28.6
Caprifoliaceae	*Lonicera japonica* Thunb.	2	3			28.6	42.9	
Compositae	*Ambrosia artemisiifolia* var. *elatior* Descourtils	1	2	2	NAT	14.3	28.6	28.6
	Artemisia princeps Pampan.	4	3	3		57.1	42.9	42.9
	Bidens bipinnata L.	1	2	2		14.3	28.6	28.6
	Cirsium japonicum var. *ussuriense* Kitamura		2				28.6	

	Cosmos bipinnatus Cav.	1			NAT	14.3		
	Conyza canadensis L.	2	3	4	NAT	28.6	42.9	57.1
	Erigeron annuas (L.) Pers.	2	2		NAT	28.6	28.6	
	Galingosa ciliate Blake	4	3	3	NAT	57.1	42.9	42.9
	Petasites japonicus (Sieb. et Zucc.) Maxim.	3	2			42.9	28.6	
	Tagetes minuta L.		1	4	NAT		14.3	57.1
	Taraxacum officinale Weber	1	2	3	NAT	14.3	28.6	42.9
	Xanthium strumarium L.	1	2	2	NAT	14.3	28.6	28.6
Gramineae	*Agropyron tsukusinense* (Honda) Ohwi	3	3	1		42.9	42.9	14.3
	Alopecurus aequalis var. *amurensis* Ohwi.	2	2	2		28.6	28.6	28.6
	Alopecurus pratensis L.	2	2	2		28.6	28.6	28.6
	Avena fatua L.	4	3	4	NAT	57.1	42.9	57.1
	Argostis clavata var. *nukabo* Ohwi.	3	3	2		42.9	42.9	28.6
	Beckmannia syzigachne (Steud.) Fern.	3	3	4		42.9	42.9	57.1
	Bromus japonicus Thunb.	2	2			28.6	28.6	
	Digitaria sanguinalis (L.) Scop.	2	2			28.6	28.6	
	Echinochloa crus-galli (L.) Beauv.	2	3	3		28.6	42.9	42.9
	Miscanthus sacchariflorus Benth.		3	4			42.9	57.1
	Miscanthus sinensis var. *purpurascens* Rendle	2	2			28.6	28.6	
	Phragmites japonica Steud.	1	4			14.3	57.1	
	Poa sphondylodes Trin.	3	2			42.9	28.6	
	Setaria viridis (L.) Beauv.	3	4	3		42.9	57.1	42.9
	Zoysia japonica Steud.	6	7	7		85.7	100.0	100.0
Cyperaceae	*Carex dimorpholepis* Steud.	1	3	3		14.3	42.9	42.9
	Carex neurocarpa Maxim.	2				28.6		
Total						1957.1	2428.6	1971.4

NAT: Naturalized plants.

Table 3. Mean cover-abundance of species and diversity indices at the Jungchon Stream

Growth form	No. species (%)	Mean cover-abundance of species	Diversity (H`)	Diversity (N)	Richness	Evenness
A region						
Trees	3 (5.1)	1.67	1.05	2.87	1.24	0.96
Shrubs	8 (13.6)	2.63	1.99	7.33	2.30	0.96
Grasses	18 (30.5)	2.61	2.78	16.04	4.42	0.96
Forbs	30 (50.8)	2.13	3.31	27.34	6.97	0.97
Total	59 (100.0)	9.04	-	-	-	-
B region						
Trees	0 (0.0)	-	-	-	-	-
Shrubs	7 (10.9)	3.29	1.90	6.66	1.91	0.97
Grasses	17 (26.6)	3.12	2.76	15.80	4.03	0.97
Forbs	40 (62.5)	2.43	3.62	37.46	8.53	0.98
Total	64 (100)	8.83	-	-	-	-
C region						
Trees	0 (0.0)	-	-	-	-	-
Shrubs	3 (6.3)	2.67	1.08	2.95	0.96	0.99
Grasses	12 (25.0)	3.17	2.38	10.86	3.02	0.96
Forbs	33 (68.8)	2.73	3.41	30.24	7.11	0.98
Total	48 (100)	8.56	-	-	-	-

DISCUSSION

Species and population monitoring is the regular observation and recording of changes in status and trend of species or their populations in a certain territory (Hunter and Heywood, 2011). The primary purpose of such monitoring is to collect information that can be used to examine the outcomes of management actions and to guide management decisions. This is frequently carried out for species that have been assessed as monitoring of areas and species so as to determine when existing ones need to be intensified. Quadrats allow researchers to study plant populations spread out over large areas. They are inexpensive, relatively easy to design and adaptable for studying unevenly distributed populations. Quadrat plots are uniform in size and shape and distributed randomly throughout the sample area, which makes the study design straightforward. Despite the relative ease of designing quadrat studies, it is possible to introduce errors into a project. One of the main sources of error in quadrat based sampling occurs when deciding whether an individual is within or outside the quadrat frame. These types are errors are called "boundary decisions" and protocols should be discussed to ensure consistent decisions (Elzinga et al. 1998).

The upstream of the Jungchon Stream is fast and the downstream of the river is slow. For the upper region of the Jungchon Stream, richness indices were varied from 1.24 (trees) to 6.97 (forbs) (Table 3). Species richness is inherently scale-dependent (Olff & Ritchie, 1998; Chesson, 2000). An understanding of the scale dependent variation is needed to be able to generalize about the processes determining species richness between ecosystems and spatial scales (Olofsson et al., 2008). The spatial heterogeneity of environmental resources results in the variance seen in the spatial distribution of vegetation. Spatial heterogeneity and stability are fundamental indices for describing vegetation communities (Song et al., 2005). Heterogeneity of limiting resources is often correlated with species richness (Huston 1980; Chesson 2000; Starr et al. 2005) since heterogeneity controls the spatial extent of competitive hierarchies among species and could thus increase the beta and gamma diversity (Starr et al. 2005). A major goal in ecology is to understand spatial patterns in the distribution of species diversity. A Shannon-Weaver indices (H´) of diversity were varied from 1.05 (trees) to 3.31 (forbs) at upper region of the Jungchon Stream (Table 2). H´ varied from 0.0 (trees) to 3.62 (forbs) at middle region. H´ was different across growth forms, varying from 0.0 (trees) to 3.41 (forbs) at low region. Widespread empirical evidence from many taxonomic and functional groups, geographical and ecological settings and spatial scales supports positive spatial environmental heterogeneity–diversity relationships (MacArthur & MacArthur 1961; Hortal et al., 2009). Separate effects of heterogeneity in land cover, vegetation, climate, soil and topography are significantly positive, with vegetation and topographic heterogeneity showing particularly strong associations with species richness (Stein et al., 2014).

REFERENCES

Braun-Blanquet, J. (1964) *Pflanzensoziologie, Grundzüge der Vegetationskunde* (3rd ed). New York: Springer, Wein.

Chesson, P. (2000) Mechanisms of maintenance of species diversity. *Annual Review of Ecology, Evolution, and Systematics, 31*, 343-366.

Chiras, D.D. (1998) *Environmental Sciences. A Systems Approach to Sustainable Development*. Fifth Ed., Wardsworth Publishing Co, Belmont, CA.

Cox, G. (1990) *Laboratory Manual of General Ecology* (6th ed). Dubuque, Iowa: William C. Brown.

Dietvorst, P., Maarel, V.D., & van der Putten, H. (1982) A new approach to the minimal area of a plant community. *Vegetario, 50,* 77-91.

Elzinga, A.L., Salzer, D.W. & Willoughby, J.W. (1998) *Measuring and Monitoring Plant Populations,* Bureau of Land Management, Denver, CO, USA.

Gregory, S.V., Swanson, F.J., McKee, W.A., & Cummins, K. (1991) An ecosystem perspective of riparian zones. *BioScience, 41*, 540-551.

Hill, M.O. (1973) Diversity and evenness: a unifying notation and its consequences. *Ecology, 54*, 423-432.

Hortal, J. et al. (2013). Species richness can decrease with altitude but not with habitat diversity. *Proceedings of National Academy of Sciences of the United States of America, 110,* E2149-E2150.

Hunter, D., & Heywood, V. (2011). *Crop Wild Relatives. A Manual of in situ Conservation*. Earthsacn, London, UK.

Huston, M. (1980) Soil nutrients and tree species richness in Costa Rican forests. *Journal of Biogeography, 7,* 147-157.

Ilhardt, B.L., Verry, E.S., & Palik, B.J. (2000) Defining Riparian Areas. In Crow, B.L., E.S. Verry, J.W. Hornbeck, C.A. Dolloff (Eds.), *Riparian Management in Forest of the Continental Eastern United States*. CRC Press, Boca Raton, Florida.

Kim, J.W. (1996) Floristic characterization of the temperature oak forests in the Korean Peninsula using high-rank taxa. *Journal of Plant Biology, 39,* 149-159.

Korea National Arboretum. (2012) *Field Guide, Naturalized Plants of Korea.* Korea National Arboretum, Seoul, Korea.

Lee, Y.N. (2007) *New Flora of Korea.* Kyo-Hak Publishing Co., Seoul, Korea.

MacArthur, R., & MacArthur, J.W. (1961). On bird species diversity. *Ecology, 42*, 594-598.

Magurran, A.E. (1988) *Ecological Diversity and its Measurement*. Princeton University Press, Cambridge, USA.

Olff, H., & Ritchie, M.E. (1998) Effects of herbivores on grassland plant diversity. *Trends in Ecology & Evolution, 13*, 261-265.

Olofsson, J., de Mazancourt, C., & Crawley, M.J. (2008) Spatial heterogeneity and plant species richness at different spatial scales under rabbit grazing. *Oecologia*, DOI 10.1007/s00442-008-1038-6.

Pielou, E.C. (1966) The measurement of diversity in different types of biological collection. *Journal of Theoretical Biology*, *13*, 131-144.

Shannon, C.E., & Weaver, W. (1963) *The Measurement Theory of Communication*. Urbana: Univ. of Illinois Press.

Song, Z. et al. 2005. Spatial heterogeneity and variability of a large-scale vegetation community using a power-law model. *Tsinghua Science and Technology*, *10*, 469-477.

Starr, D.A., Hibbs, D.E., & Huston, M.A. (2005) A hierarchical perspective of plant diversity. *The Quarterly Review of Biology*, *80*, 187-212.

Stein, A., Gerstner, K., & Kreft, H. (2014) Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology Letters*, doi:10.1111/ele.12277.

Westfall, R.H. (1992) Objectivity in stratification, sampling and classification of vegetation. Ph.D. thesis. University of Pretoria, Pretoria.