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Ecological Consideration for Restoration of the Degraded Urban River

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ABTRACT: Vegetation and riverine structures were compared among urban and several semi-natural rivers by applying direct gradient analysis and ordination method. Urban rivers showed different species composition from the semi-natural ones. Species composition of semi-natural rivers depended on the geographical positions, such as the upstream, midstream, and downstream and on micro-topographies, such as the waterside, flooding bed, and embankment. Semi-natural rivers showed gentle change in micro-topography, whereas urban one did not so. Our restoration plan to improve the ecological quality of the degraded urban river by imitating semi-natural river was prepared based on those data.

Key words: Restoration, Riverine structure, Semi-natural river, Urban river, Vegetation

INTRODUCTION

Riparian landscape including river (or stream) ecosystem, riparian ecosystem, and their surroundings hardly conserves its original form due to excessive exploitation. Waterside landscape has been managed in terms of utilization and disaster protection up to now. But in these days, its significance as a natural environment is reevaluated. Waterside is an ecotone, in which two heterogeneous habitats with quite different properties of terrestrial and aqueous zones confront with each other. Therefore, it provides a habitat with complex and diverse variations to many wildlife organisms. This part is under frequent disturbance due to natural and artificial disturbances, and have many species depended on this disturbance regime. But artificial interference focused on exploitation and disaster protection destroyed such disturbance regime, and consequently made many species faced in a crisis of extinction. In recent years, those who recognized the facts try to restore such ecological capacity of riparian landscape (Petts and Calow 1996).

Ecological restoration is not only the return of a landscape (or ecosystem) to a close approximation of its condition prior to disturbance (National Research Council 1991) but also the re-creation of natural and self-maintaining ecosystems (Berger *et al.* 1993). The goal of this process is to emulate the structure, functioning, diversity, and dynamics of the specified ecosystem (Aronson *et al.* 1993). That is, ecological restoration is the return of an ecosystem to a close approximation of its condition prior to disturbance (National Research Council 1991) and it can be also *recognized as re-creations of naturalistic* and self-maintaining ecosystems (Berger *et al.* 1993).

In order to restore the degraded ecosystem we have to get information base on scientific principles because holistic and synthetic alternatives have to be prepared (Aber 1987). First of all, we have to prepare such alternatives by obtaining diverse ecological information on disturbance factors from the spot (Aber 1987, MacMahon 1987). In particular, we have to get plentiful field information on an area to be restored because restoration efforts have to be practiced in the field (Hough 1984).

This study aims to compares the differences between semi-natural and urban rivers in terms of riverine and vegetation structures, and to discuss a plan to improve the ecological quality of the urban river imitating data from those semi-natural river.

STUDY AREAS

Jungnang river as an urban river is located on the north-eastern Seoul. This river flows through the urbanized area, such as Euijeongbu and Seoul and thereby is under severe artificial interference. Structural frame of this river shows the typical feature of the urban river, which has roads, recreational facilities, etc. on the floodplain and waterside and micro-topography is monotonous and stiff. In addition artificial bank is covered with cement concrete or the introduced plants for landscape architecture.

Semi-natural rivers around Wonju, Goseong, and Yanggu in Kangwon-do province, Jupo, Injeong, and Suip rivers showed some differences from the urban rivers. They have diverse and gentle micro-topography and natural vegetation on the floodplain and in the riverside. Jupo river runs through the agricultural fields composed of upper field and rice paddy terrace. This river corre-

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sponds to the upstream. Injeong river flows through the plain rice fields and corresponds to the downstream. Suip river runs through the natural area relatively conserved well and attributes to the upstream.

METHODS

Riverine structure was investigated by making stand profile including sectional structure in the representative zones of the rivers surveyed.

Vegetation survey was carried out by recording the cover class of plant species appeared in quadrats installed randomly. Cover data were transformed from ordinal scale of Braun-Blanquet (1964), and subjected to direct gradient analysis and Detrended Correspondence Analysis (DCA; Hill 1979).

In addition, we evaluated naturalness of the river based on sectional structure, vegetation structure, surrounding landscape and method for management. We divided the river into 5 degrees according to its naturalness (Table 1).

Restoration plan was prepared by imitating the semi-natural rivers with relatively ecological integrity based on data obtained from there.

RESULTS

Riverine structure

Sectional structure and stand profiles of the semi-natural and the urban rivers were compared in Fig. 1. The river of naturalness 5 indicates the semi-natural river of this study. Rivers of 1 to 4 in naturalness correspond to the urban river(refer to Table 1). The semi-natural river showed gentle and diverse micro-topography, whereas the urban one showed stiff and monotonous structures. Such difference is reflected in the vegetation diversity too. Moreover, most urban rivers are channeled and thereby showed a difference in the longitudinal structure as well from the semi-natural river.

Distribution of major plant species in vegetation zones divided by environmental gradient

Dominant species in small island within the waterway, waterside, floodplain and bank, which appearing in the order of distance from the watercourse of the Jungnang river were *Persicaria hydropiper, P. perfoliata* and *Stellaria aquatica*, *Bromus japonicus* and *Forsythia koreana*, respectively. In addition, *Rorippa islandica* and *S. aquatica*, *P. hydropiper* and *Agropyron tsukushiense* var. *transiens, Trifolium repens* and *Erigeron canadensis*, *E. canadensis* and *A. tsukushiense* var. *transiens* showed high importance value in each zone of the Jungnang river.

Dominant species in small bay and reservoir, and waterside, floodplain and bank, which appearing in the order of distance from the watercourse of the Injeong river were *Aneilema keisak, P. thunbergii, Phragmites japonica, Salix gracilistyla*, and *Alnus japonica*, respectively. In addition, *P. sieboldii* and *P. thunbergiana, Leersia japonica* and *Aneilema keisak, Artemisia capillaris* and *S. gracilistyla, Impatiens textori* and *P. japonica*, and *I. textori* and *Miscanthus sacchariflorus* showed high importance value in each zone of the Injeong river.

Dominant species in grassland, shrubland and woodland zones, which appearing in the order of distance from the water-

Table 1. Degree of naturalness of the riparian ecosystem

Degree	Structural frame	Vegetation structure	Surrounding landscape	Remarks
1	Waterside, floodplain and bank are not only covered with artificial material but also managed artificially.	Herb (usually annual)	Urban	Vegetation covers less than 50% of the land and is usually composed of annuals.
2	Waterside and bank except for floodplain are covered with artificial material but management still depends on artificial one.	Herb (usually perennial)	Urban and rural	Vegetation covers more than 50% of the land and is usually dominated by perennials.
3	Only waterside is covered with artificial material and management partially depends on artificial one.	Herb and shrub	Urban and rural	Vegetation stratification composed of herb and shrub layers appears.
4	All zones of the river are covered with natural material but artificial management is still remained.	Herb, shrub and tree (tree is usually exotic)	Rural and urban	Vegetation stratification composed of herb, shrub, and tree layers appears but trees are exotic or unfamiliar species with the ecological conditions in a given region.
5	All zones of the river are covered with natural material and management is remained in natural state.	Herb, shrub and tree (usually endemic)	Rural and natural	Vegetation stratification composed of herb, shrub, and tree layers appears and trees are not only endemic but also familiar species with the ecological conditions in a given region.

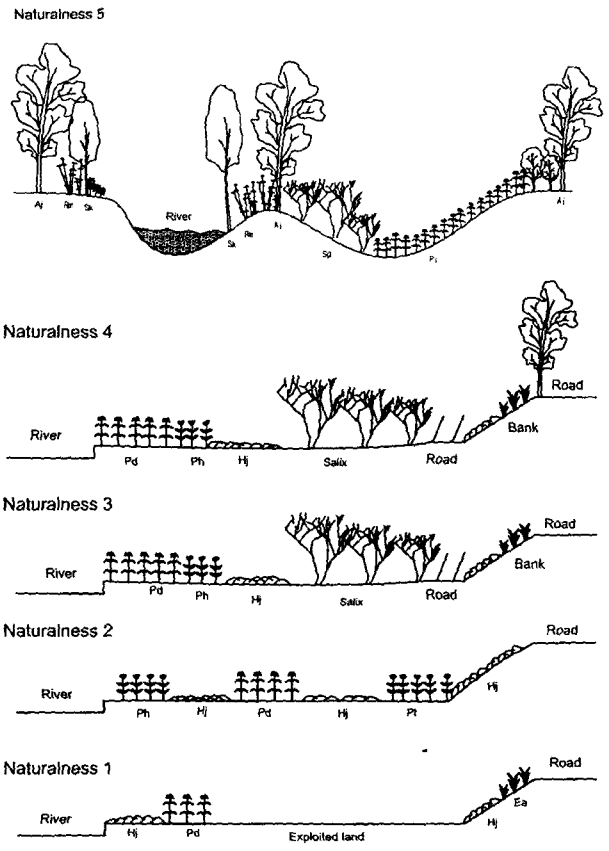

Fig. 1. A comparison of stand profiles of the riparian ecosystems different in naturalness.
Aj: *Alnus japonica*, Rm: *Rosa multiflora*, Sk: *Salix koreensis*, Sg: *S. gracilistyla*, Pj: *Phragmites japonica*, Pd: *Panicum dichotomiflorum*, Ph: *Persicaria hydropiper*, Hj: *Humulus japonicus*, Salix: *Salix* spp. Pt: *Persicaria thunbergii*, Ea: *Equisetum arvense*.

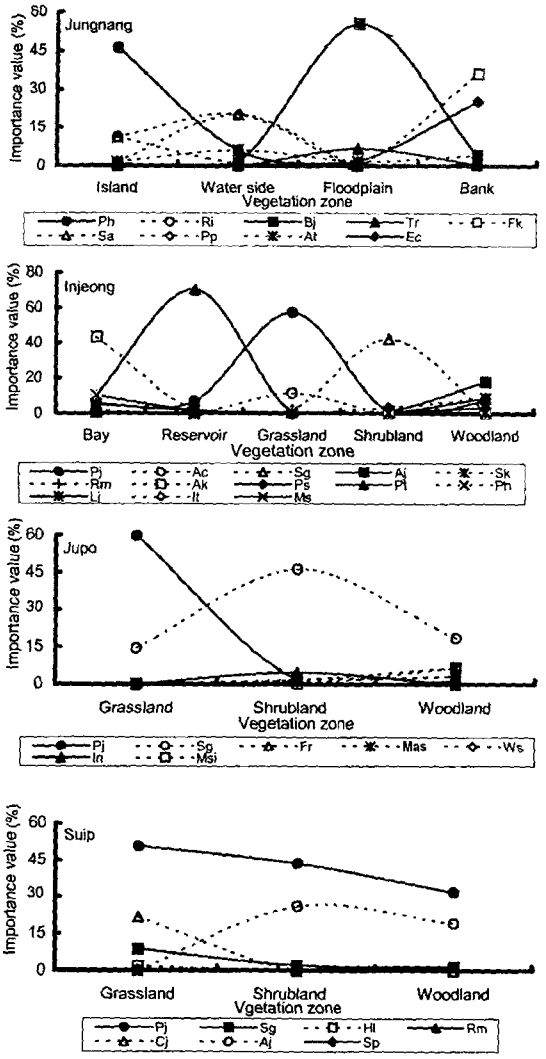

Fig. 2. Changes of the importance value of major species in each vegetation zone of the riparian ecosystem.
Pj: *Phragmites japonica*, Ac: *Artemisia capillaries*, Sg: *S. gracilistyla*, Aj: *Alnus japonica*, Sk: *Salix koreensis*, Rm: *Rosa multiflora*, Ak: *Aneilema keisak*, Ps: *Persicaria sieboldii*, Pt: *Persicaria thunbergii*, Ph: *Persicaria hydropiper*, Lj: *Leersia japonica*, It: *Impatiens textori*, Ms: *Miscanthus* sacchariflorus, Ri: *Rorippa islandica*, Bj: *Bromus japonicus*, Tr: *Trifolium repense*, Fk: *Forsythia koreana*, Sa *Stellaria aquatica*, Pp: *Persicaria perfoliata*, At: *Agropyron tsukushiense* var. *transiens*, Ec: *Erigeron canadensis*, Fr: *Fraxinus rhynchophylla*, Mas: *Magnolia sieboldii*, Ws: *Weigella subsessilis*, In: *Impatiens nolitangere*, Msi: *Malus sieboldii*, Hl: *Hosta longipes*, Cj: *Carex japonica*, Sp: *Spiraea prunifolia* for. *simpliciflora*.

course of the Jupo river were *P. japonica*, *S. gracilistyla*, and *S. gracilistyla*, respectively. In addition, *S. gracilistyla*, *I. nolitangere* and *P japouica*, and *Magnolia sieboldii* and *Malus sieboldii* showed high importance value in each zone of the Jupo river.

Dominant species in all zones of the Suip river was *P. japonica*. In addition, *Carex japonica* and *S. gracilistyla*, *A. japonica* and *S. gracilistyla*, and *A. japonica* and *Spiraea prunifolia* for. simpliciflora showed high importance value in each zone of the Suip river.

Difference between the semi-natural and the urban rivers in vegetation structure

As a result of stand ordination based on species composition, stands of the semi-natural and the urban rivers were divided into the left and right sides, respectively on the Axis I (Fig. 3). Those of the urban rivers were subdivided into two groups of the lower and upper parts on the Axis II. Stands in the lower parts are located on the floodplain or the bank and ones in the upper parts are on the sand bar within the waterway.

Stands investigated in the semi-natural rivers did not show remarkable subdivistion. But arrangement of stands showed

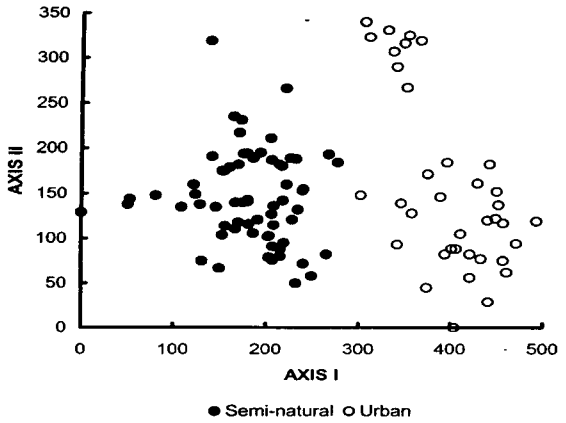

Fig. 3. Stand ordination of the riparian vegetation on the semi-natural river and the urban river. Semi-natural rivers are located on Injeong, Jupo and Suip rivers in Kwangwon-do province and Urban river is Jungyang-river in Seoul.

trends to be classified depending vegetation stratification determined from current velocity (Fig. 4), geographic positions (Fig. 5), and disturbance frequency (Fig. 6). For example, difference among study areas in arrangement of stands (Fig. 5) due to geographic position of each area. On the other hand, stands located bordered on the standing water tended to divide from those around the running water (Fig. 6). That is, the river of Gosung corresponds to downstream and those of Dutayeon and Chiaksan to the upstream.

DISCUSSION

The necessity of restoration of the degraded urban riparian ecosystem

In Korea, most riparian ecosystems have been disappeared and remaining ones are declining. The rapid decline of these valuable ecosystems has made riparian conservation a focal issue in the public eye. Nevertheless, progress toward checking their decline has been marginal. This is due, in part, to the fact that the science of restoring damaged riparian ecosystems is relatively young.

Riparian ecosystems are characterized by high diversity in both plant and wildlife species(Lee *et al.* 2002b). The mesic nature of riparian areas permits the establishment and growth of many plant species not found on adjacent, more xeric uplands.

Riparian ecosystems take on many forms and are characterized by a variety of plant communities(refer to Fig.1). Riparian ecosystems can be narrow, with abrupt transitions between the riparian and upland plant communities, or broad, with the riparian zone extending for hundreds of meters from the stream channel.

Change in elevation (with its concomitant effects on frequency of inundation) appears to be the most significant factor associated with the distribution of riparian plant communities and their species composition (Szaro 1989).

Riparian ecosystems are the vegetation, habitats, and ecosystems associated with water bodies or dependent on the existence of perennial, ephemeral, or intermittent surface or subsurface drainage. The riparian ecosystems are some of the most productive ecosystems. They indirectly affect the stability and

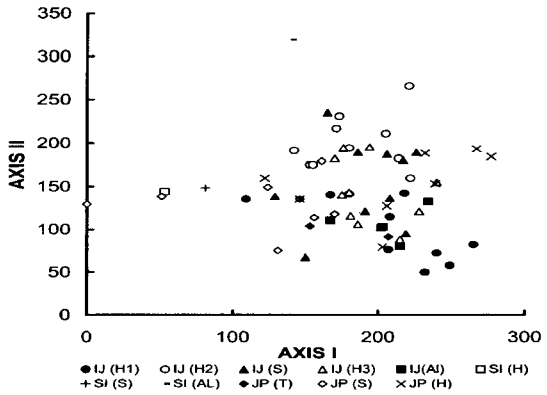

Fig. 4. Stand ordination of the riparian vegetation investigated in the semi-natural river with different conditions. IJ (H1): grassland in Injeong, IJ (H2): grassland around standing water in Injeong, IJ (H3): grassland around small bay in Injeong, IJ (S): shrubland in Injeong, IJ (AI): *Alnus japonica* stand in Injeong, SI (H): grassland in Suip, SI (S): shrubland in Suip, SI (AI): *Alnus japonica* stand in Suip, JP (H): grassland in Jupo, JP (S): shrubland in Jupo, JP (T): subtree or tree stand in Jupo. Injeong, Suip, and Jupo mean name of each river.

Table 2. A list of plant species to be introduced for restoration of the degraded urban river

Herb dominated zone		Shrub dominated zone	Sub-tree or tree dominated zone	
Running water	Standing water		Upstream	Downstream
Phragmites japonica	*Aneilema keisak*	*Salix gracilistyla*	*Fraxinus rhynchophylla*	*Alnus japonica*
Artemisia capillaris	*Persicaria sieboldii*	*Carex japonica*	*Magnolia sieboldii*	*Salix koreensis*
Carex japonica	*Persicaria thunbergii*	*Impatiens textori*	*Malus sieboldii*	*Rosa multiflora*
Impatiens nolitangere	*Leersia japonica*	*P. japonica*	*Spiraea prunifolia* for. *simpliciflora*	*S. prunifolia* for. *simpliciflora*
etc.	etc.	etc.	etc.	etc.

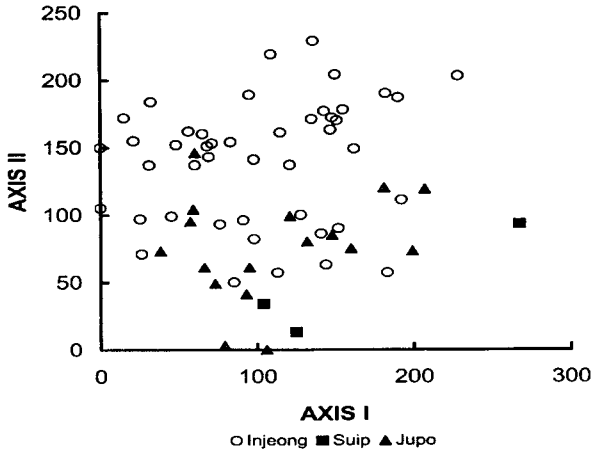

Fig. 5. Stand ordination of the riparian vegetation in the semi-natural rivers, Injeong, Jupo and Suip rivers in Kwangwon province. Injeong river corresponds to downstream and Jupo and Suip rivers to upstream.

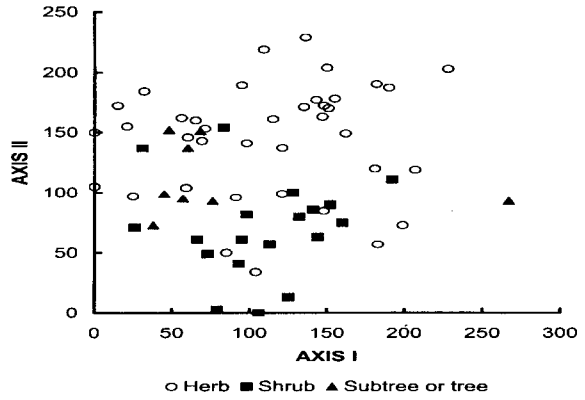

Fig. 6. Stand ordination of the riparian vegetation dominated by herb, shrub, and sub-tree or tree. Flooding was frquent in the order of herb, shrub, and subtree or tree zones

quality of surrounding ecosystems by reducing flood peaks, acting as sediment and nutrient sinks, controlling water temperature, and increasing ground water recharge (Pett and Calow 1996, Schmidt 1987). Therefore, despite their relatively small expanse, riparian areas play a critical role in the life cycles of an inordinate number of wildlife species and provide important recreation opportunities for outdoor enthusiasts. We can find necessity ot restoration of the degraded urban rivers in those viewpoints.

Restoration in terms of riverine structure

The river carries out 3 actions, such as erosion, transport, and deposition. Erosion causes small ponds and the eroded soil particles are transported and deposited toward the downstream. The location that eroded particles are deposited becomes a riffle and the water flow increased here induces another erosion. Those processes create riffles and ponds continuously on the riverbed along the longitudinal section of the river. Flowing water runs meanderingly in the river. Such snake shaped rivers also due to 3 actions of the river.

In the waterway of the meanderingly running river, small islands and ponds appear consecutively. The channeled river also creates such uneven micro-topography on the riverbed through the repeated erosion and deposition without further artificial interference. Uneven topography induces a difference of water depth and variation of water temperature and DO, and consequently lead to diversity of the microhabitats. Furthermore, concavo-convex topography of the riverbed controls speed of water flow and consequently determines species composition in a given area (Lee *et al.*1999, Lee *et al.* 2002a).

That is, when the water flow is remained physical actions of the river create natural state spontaneously. In this viewpoint, we suggest restoring its naturalness by leaving the existing structural frame of the river in the natural condition rather than radical transformation as a starting point to restore the degraded riparian ecosystem.

Restoration in terms of vegetation structure

As was shown in the results of direct gradient analysis and stand ordination (Figs. 2 and 3), the urban river shows different species composition from the semi-natural rivers. Such different species composition is the product of different structural frame and artificial disturbance.

On the other hand, semi-natural rivers showed also different species among them. The difference of species composition among the semi-natural rivers reflected the natural condition of each area. For example, the Injeong river as a downstream showed different species composition from Jupo and Suip rivers of upstream.

Difference of species composition in the semi-natural rivers reflected also variation of the micro-topographies, such as the waterside, flooding bed, and bank. Such difference due to different disturbance regime, life form of vegetation established in each zane reflects such influences.

A plan to restore the degraded vegetation of the urban rivers was prepared by considering such diversity of the semi-natural rivers (Table 2). That is, our restoration plan reflected the differences of disturbance frequency, current velocity, and geographic positions shown in the semi-natural rivers. In order to practice such a restoration plan in the Jungnang river, we can regard Injeong river as a reference of midstream and down stream, and Jupo and Suip rivers as a model of upstream of the river and its tributaries. Furthermore, we would like to recommend extending the spatial range of restoration from that of the present, which is restricted to the waterside to the whole sphere of the river includ-

ing floodplain and bank.

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