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VEGETATION BEHAVIOR AND ITS HABITAT REGION AGAINST FLOOD FLOW IN URBAN STREAMS

JIN-HONG KIM[1,*], IL-KI CHOI[2]

[1]Department of Civil, Environmental and Plant Engineering,
Chung-Ang University, Seoul, Korea
[2]Institute for Nature and Environment, Eco-Top Corporation, Seoul, Korea
*Corresponding Author: jinhkim@cau.ac.kr

Abstract

Hydraulic effects on the vegetation behavior and on its habitat region against flood flow in the urban streams were analysed in this paper. Vegetation behavior was classified into stable, recovered, damaged and swept away stages. Criteria between recovered and damaged status were determined by the bending angle of the aquatic plants. Aquatic plants whose bending angle is lower than 30~50 degree is recovered, but they were damaged and cannot be recovered when the bending angle is higher than 30~50 degree. *Phragmites japonica* was inhabited in the hydraulic condition of high Froude number which shows that it was inhabited in the upstream reaches. *Phragmites communis* was inhabited in the relatively low Froude number compared with *Phragmites japonica*. This shows that it was inhabited in the downstream reaches. *Persicaria blumei* was found in the relatively wide range of flow velocity and flow depth, which shows that it was inhabited in the middle and downstream reaches. Criterion on the vegetation behavior of *Persicaria thunbergii* was not clear, which implies that it may be affected by the flow turbulence rather than flow velocity and flow depth.

Keywords: Vegetation behavior, Habitat, Flood flow, Stable, Recovered, Damaged, Swept away.

1. Introduction

Floods represent a major disturbance that influences vegetation communities whether submerged, emergent or riparian [1, 2]. Flood itself, however, enables the colonization of vegetation on sand bars with accumulated organic matter and trapped silt [3].

Vegetation in the river is affected by the flow structure, but inversely affects the flow structure [4]. It is collapsed and destroyed by the high flow velocity, and cannot be recovered well. Meanwhile, it reduces the flow conveyance, increases the flow resistances and raises the water level. Thus, the vegetation and the flow structure have mutually reciprocal relationships. Seasonal changes of the vegetation area in the urban streams follow the repeated cycle of the contraction and the expansion, which is originated by destruction by flood flow and by the restoration of vegetative behavior, respectively [5]. Transport of bed sediments during flood resulted in the deposition of the vegetated area [6].

During the flood seasons, the vegetation may be destroyed by the high tractive force of flood flow, and be buried and damaged by the transportation of the riverbed sediments [7]. Thus, the vegetation behavior is strongly affected by the hydraulic parameters such as the flow velocity, the turbulence and the flow depth of flood flow.

The role of vegetation is very important for the control of water quality and for the ecological habitat, thus, the environmental design of vegetation in the urban streams are recently performed in Korea [8]. But vegetation planted were frequently collapsed and washed out by the high tractive force of the flood flow since the vegetation impacts by the flood flow are not studied well. Thus, the vegetation behavior and its habitat region against the flood flow are very important especially in the urban streams.

Although many researches are focused on the physiological and morphological attributes of the aquatic plants by the stream flow [9-11], hydraulic effects on the vegetation behavior and on its habitat region against the flood flow by the plant species are not studied well.

This paper presents the hydraulic effects on the vegetation behavior and on its habitat region against the flood flow by the plant species in the urban streams. Typical four aquatic plants in the urban streams such as *Phragmites japonica*, *Phragmites communis, Persicaria thunbergii* and *Persicaria blumei* were chosen. Flow measurements during flood seasons were performed and vegetation impacts by the flood flow were investigated.

2. Flow Measurements and Vegetation Impacts by Flood Flow

For the hydraulic analyses of the vegetation behavior, measurements of flow velocity and its depth during the flood times must be performed. But their measurements are very difficult and dangerous. Thus, the flow velocity is usually measured at the bridge using the floats [12, 13]. In this study, the flow velocity and the flow depth were measured using the current meter and the staff at the vegetated area during normal times, but they were measured at the bridge near the vegetated area in case their values are so high as shown in Fig. 1. Flow velocity was measured using the floats, and flow depth was measured by the traces of the water levels during the flood times [8].

Vegetation impacts by the flood flow were investigated in the urban streams. For this purpose, urban streams such as Suweon-cheon and Tan-cheon were chosen and the vegetation impacts were investigated. Flow parameters such as flow velocity and flow depth were measured.

(a) Measurement of Flow Velocity (b) Measurement of Flow Depth
Fig. 1. Measurements of Flow Velocity and Flow Depth at the Vegetated Area.

Vegetation status at Suweon-cheon after flood is shown in Fig. 2. Large flood occurred at Suweon-cheon in July 6th, 2012 and almost of the aquatic plants except for *Salix gracilistyla* and *Phragmites japonica* were collapsed and destroyed by the high tractive force of the flood flow. This phenomenon was also shown at Tan-cheon. Large flood occurred in August 13th, 2012 and most of the aquatic plants were also destroyed.

We have had severe rainfall recently and have experienced vegetation damage especially in the urban streams due to the high density of urbanization, but the vegetation impacts by the flood flow are not still studied well. Thus, the vegetation behavior and its habitat region against the flood flow must be presented.

(a) Wash away of *Phragmites japonica* (b) Collapse of *Phragmites japonica*

Fig. 2. Vegetation Impacts by Flood Flow.

3. Vegetation Behavior by Flood Flow

Vegetation behavior by flood flow is usually divided into four stages such as stable, recovered, damaged and swept away stage shown in Fig. 3 [7]. In this figure, 'stable' means the vegetation is not affected against the flood flow. 'Recovered' means the vegetation is affected by the tractive force of the flood flow, but it can recover its features after flood. 'Damaged' means the vegetation is affected seriously by the tractive force of the flood flow and cannot recover its features even if the flood is finished. 'Swept away' means some or all the parts of the vegetated area are swept away to downstream part by the high flood flow.

Aquatic plants at stable or recovered stage will not be impacted by the flood flow, but aquatic plants at damaged or swept away stage will be impacted by the flood flow. Thus, the criterion between recovered and damaged stage of the vegetation is important. Examples of the four stages of the vegetation behavior are shown in Fig. 4.

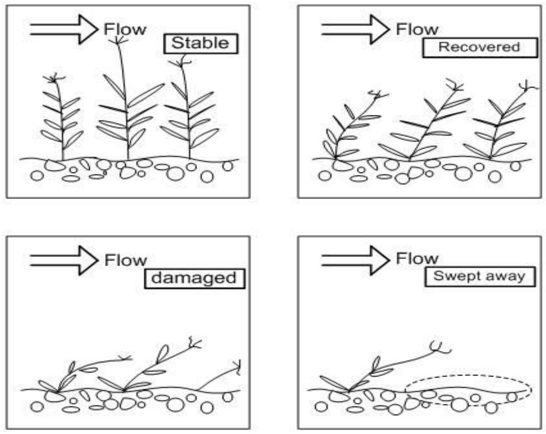


Fig. 3. Four Stages of Vegetation Behavior by Flood Flow [7].

(a) Stable

(b) Recovered

(c) Damaged

(d) Swept away

Fig. 4. Examples of Four Stages of Vegetation Behavior by Flood Flow.

Typical four aquatic plants in the urban streams such as *Phragmites japonica*, *Phragmites communis, Persicaria thunbergii* and *Persicaria blumei* were chosen. They are well inhabited in Korea and have important roles for water control and ecological habitat.

Field study showed that the division criterion between recovered and damaged stage of the vegetation was about 30~50 degree of the bending angle of the aquatic plants. Vegetation whose bending angle is lower than 30~50 degree was recovered, but the vegetation whose bending angle is higher than 30~50 degree was damaged and could not recover.

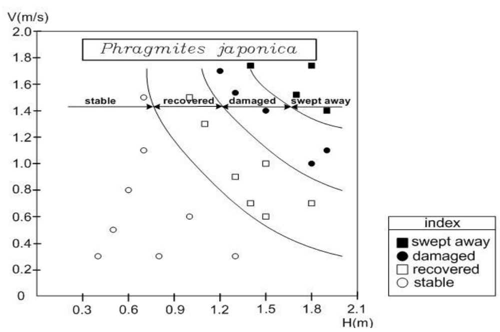
This criterion may be a little different by the species of the aquatic plants. Bending angle of *Phragmites japonica* will be larger than that of *Phragmites communis, Persicaria thunbergii* and *Persicaria blumei.* They must be further verified through more data of the field study.

According to the above criterion, vegetation behaviors of the aquatic plants in the urban streams were analysed as follow.

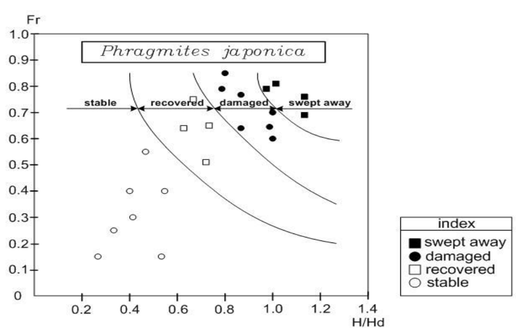
3.1. Vegetation behavior of *Phragmites japonica*

Vegetation behavior of *Phragmites japonica* against flow velocity and flow depth is shown in Fig. 5. Here, V (m/s) is flow velocity and H (m) is flow depth. Fr is the Froude number which is represented by,

$$Fr=\frac{V}{\sqrt{gH}} \tag{1}$$



(a) Flow Depth and Flow Velocity



(b) Froude Number and Vegetation Growth

Fig. 5. Vegetation Behavior of *Phragmites japonica*.

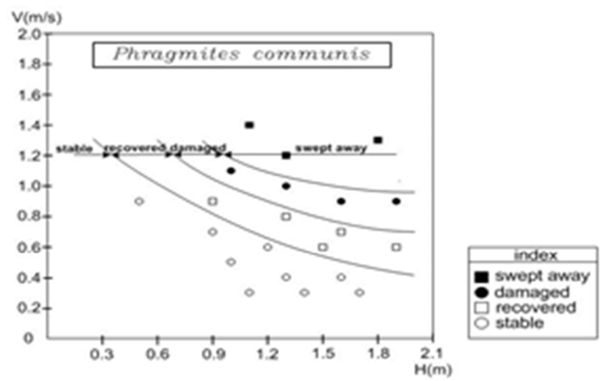
Meanwhile, growth of the aquatic plants has effects on vegetation behavior [14]. If they grow well, they can cope with the flow velocity. Thus, in Fig. 5, growth of the aquatic plants, H_d, was also considered in the vegetation behavior.

	V (m/s)	H (m)	Fr	H/H_d
Stable stage	$V < 1.4$	$H < 1.3$	Fr < 0.6	$H/H_d < 0.6$
Recovered stage	$0.6 < V < 1.6$	$1.0 < H < 1.8$	0.5 < Fr < 0.7	$0.6 < H/H_d < 0.8$
Damaged stage	$1.0 < V < 1.8$	$1.2 < H < 2.0$	0.6 < Fr < 0.9	$0.8 < H/H_d < 1.0$
Swept away stage	$V > 1.4$	$H > 1.4$	Fr > 0.7	$1.0 < H/H_d$

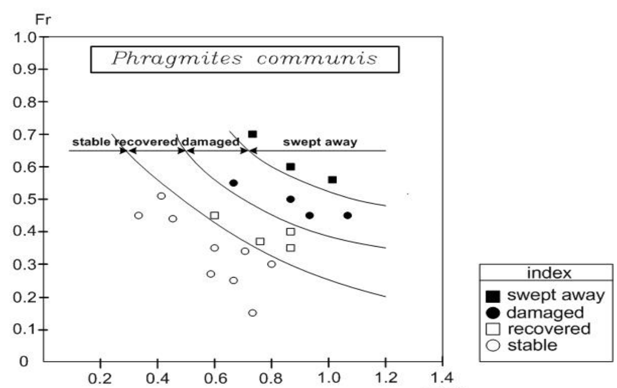
Phragmites japonica was inhabited in the hydraulic condition of high velocity and low flow depth, thus in the relatively high Froude number. This shows that it was inhabited in the upstream reaches of the stream which was surveyed by Cho [14].

3.2. Vegetation behavior of *Phragmites communis*

Vegetation behavior of *Phragmites communis* against flow velocity and flow depth is shown in Fig. 6.



(a) Flow Depth and Flow Velocity



(b) Froude Number and Vegetation Growth

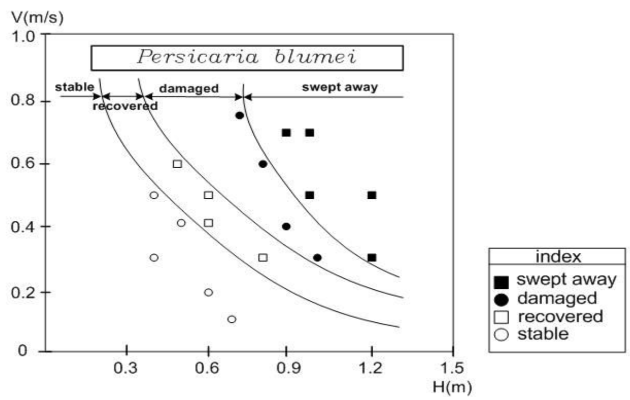
Fig. 6. Vegetation Behavior of *Phragmites communis.*

	V (m/s)	H (m)	Fr	H/H_d
Stable stage	$V < 0.9$	$H < 1.7$	Fr < 0.5	$H/H_d < 0.8$
Recovered stage	$0.6 < V < 0.9$	$0.9 < H < 1.9$	0.35 < Fr < 0.45	$0.6 < H/H_d < 0.85$
Damaged stage	$1.0 < V < 1.1$	$1.0 < H < 2.0$	0.45 < Fr < 0.55	$0.62 < H/H_d < 1.1$
Swept away stage	$V > 1.2$	$H > 1.1$	Fr > 0.6	$0.75 < H/H_d$

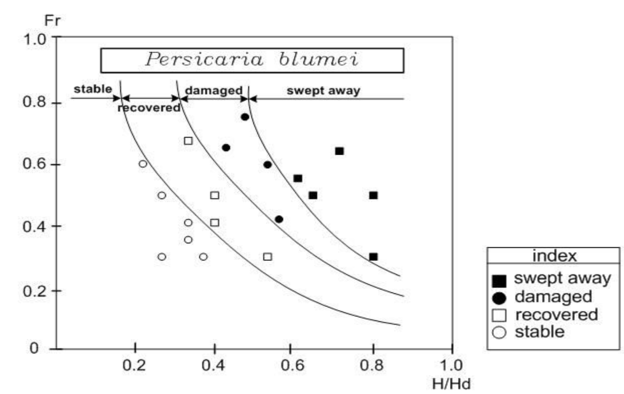
Phragmites communis was *inhabited* in the hydraulic condition of low velocity and high flow depth, thus in the relatively low Froude number compared with *Phragmites japonica*. This shows that it was inhabited in the downstream reaches of the stream [14].

3.3. Vegetation behavior of *Persicaria blumei*

Vegetation behavior of *Persicaria blumei* against the flow velocity and the flow depth is shown in Fig. 7.



(a) Flow Depth and Flow Velocity



(b) Froude Number and Vegetation Growth

Fig. 7. Vegetation Behavior of *Persicaria blumei*.

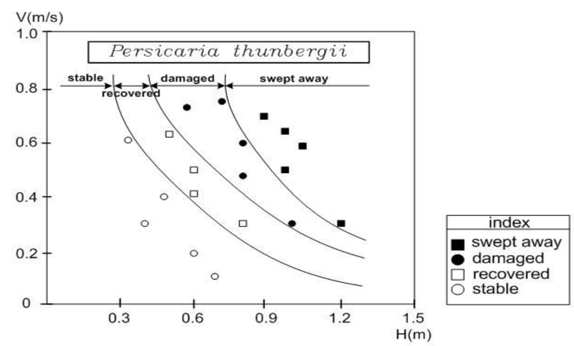
	V (m/s)	H (m)	Fr	H/H_d
Stable stage	$V < 0.5$	$H < 0.7$	Fr < 0.6	$H/H_d < 0.4$
Recovered stage	$0.3 < V < 0.6$	$0.4 < H < 0.8$	0.3 < Fr < 0.47	$0.35 < H/H_d < 0.55$
Damaged stage	$0.3 < V < 0.8$	$0.7 < H < 1.0$	0.4 < Fr < 0.75	$0.45 < H/H_d < 0.55$
Swept away stage	$V > 0.3$	$H > 0.9$	Fr > 0.3	$0.65 < H/H_d$

Persicaria blumei was found in the relatively wide range of flow velocity and flow depth, which shows that it was inhabited in the middle and downstream reaches of the streams.

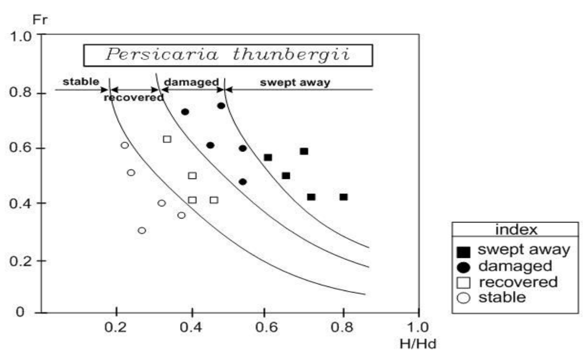
3.4. Vegetation behavior of *Persicaria thunbergii*

Vegetation behavior of *Persicaria thunbergii* against flow velocity and flow depth is shown in Fig. 8.

Criterion on the vegetation behavior of *Persicaria thunbergii* was not clear, which implies that it may be affected by the flow turbulence rather than the flow velocity and the flow depth. This must be further studied after collecting more data through the field study.



(a) Flow Depth and Flow Velocity



(b) Froude Number and Vegetation Growth

Fig. 8. Vegetation Behavior of *Persicaria thunbergii*.

	V (m/s)	H (m)	Fr	H/H_d
Stable stage	$V < 0.6$	$H<0.7$	Fr < 0.6	$H/H_d< 0.4$
Recovered stage	$0.3 < V < 0.6$	$0.5 < H < 0.8$	0.40< Fr < 0.65	$0.35 < H/H_d< 0.45$
Damaged stage	$0.3 < V < 0.7$	$0.6 < H < 1.0$	0.45 < Fr < 0.75	$0.45 < H/H_d < 0.55$
Swept away stage	$V>0.5$	$H >0.9$	Fr > 0.4	$0.6 < H/H_d$

4. Conclusions

Vegetation behavior and its habitat region in the urban streams were analysed. For the hydraulic analyses of the vegetation behavior, measurements of flow velocity and its depth during the flood times was performed. Since their measurements are very difficult and dangerous, they were measured using the current meter and the staff in case their values are not so high, but were measured using the floats, and by the traces of the water levels.

Vegetation behavior was classified into stable, recovered, damaged and swept away stage. Criteria between recovered and damaged stage were determined by the bending angle of the aquatic plants. Aquatic plants the bending angle of which is lower than 30~50 degree can recover, but they were damaged and cannot recover when the bending angle is higher than 30~50 degree.

Phragmites japonica was inhabited in the hydraulic condition of high Froude number. This shows that it was inhabited in the upstream reaches. *Phragmites communis* was inhabited in the relatively low Froude number compared with *Phragmites japonica*. This shows that it was inhabited in the downstream reaches. *Persicaria blumei* was found in the relatively wide range of flow velocity and flow depth, which shows that it was inhabited in the middle and downstream reaches. Criterion on the vegetation behavior of *Persicaria thunbergii* was not clear, which implies that it may be affected by the flow turbulence rather than flow velocity and flow depth.

Criterion of the vegetation behavior suggested in this study may be a little different by the species of the aquatic plants. Bending angle of *Phragmites japonica* will be larger than that of *Phragmites communis, Persicaria thunbergii* and *Persicaria blumei.* They must be further verified through more data of the field study.

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References

1. Giller, P.S.; and Malmqvisit, B. (1998). *The Biology of streams and rivers*. Oxford University, Oxford.
2. Nilsson, C. (1987). Distribution of stream-edge vegetation along a gradient of current. *Journal of Ecology*, 75(2), 513-522.
3. Wilson, S.D.; and Keddy, P.A. (1988). Species richness, survivorship, and biomass accumulation along an environmental gradient. *Oikos*, 53, 375-380.

4. Nagata, A.; Yanani, S.; and Nagasaka, Y. (2006). Differences in up and downstream inhabitant opinions responding to the alteration of watershed environment. *Ecology and Civil Engineering*, 9(1), 73-84.
5. Park, Y.-S.; Chon, T.-S.; Kwak, I.-S.; and Lek, S. (2004). Hierarchical community classification and assessment of aquatic ecosystems using artificial neural networks. *Science of the Total Environment*, 327(1-3), 105-122.
6. Yalin, M.S. (1972). *Mechanics of sediment transport*. Pergamon Press. Oxford.
7. Kim, J.H. (2009). Analysis on vegetation behavior by flood flow and its habitat region. *Proceedings 6th Annual Meeting AOGS*, Singapore, 108-109.
8. Ministry of Construction (2012), *Field investigation of vegetation behavior by flood flow* (in Korean). Suweon, 16-20.
9. Naiman, R.J.; Decamps, H.; and Pollock, M. (1993). The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications*, 3(2), 209-212.
10. Lenssen, J.P.M.; ten Dolle, G.E.; and Blom, C.W.P.M. (1998). The effect of flooding on the recruitment of reed marsh and tall forb plant species. *Plant Ecology*, 139(1), 13-23.
11. Capon, S.J. (2005). Flood variability and spatial variation in plant community composition and structure on large arid flood plain. *Journal of Arid Environment*, 60(2), 283-302.
12. Ministry of Environment (2007). *Survey and evaluation of aquatic ecosystem health in the Nakdong River*. National Institute of Environmental Research, Seoul.
13. National Rivers Authority (1992). *River corridors survey-methods and procedures*. London.
14. Cho, Y.H. (1997), A study on evaluation method of stream naturalness for ecological restoration of stream corridors. *Journal of Korea Institute Landscape*, 25(2), 73-81.