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Control of runner reed (*Phragmites japonicus*) in lentic wetlands

Mun Gi Hong¹, Hyun Jun Park¹, Bo Eun Nam¹ and Jae Geun Kim^{1,2*} 

Abstract

In lotic wetlands, runner reed (*Phragmites japonicus*) plays a role as a pioneer, which helps other plant species to settle by making dense roots trapping floating-sediments. In lentic wetlands, on the other hand, *P. japonicus* could play a role as an invader threatening biodiversity by forming tall and dense stands. To conserve an abandoned paddy terrace in mountainous areas, a habitat of an endangered dragonfly species (*Nannophya pygmaea*), from the monotypic-occupation by *P. japonicus*, we applied three kinds of treatment: (1) hand-clipping in 2009, (2) mechanical excavating in 2012, and (3) planting of alternative vegetational unit in 2012. We have monitored vegetation changes in the wetland in 2008~2012 and 2017. Vegetation cover of *P. japonicus* sharply decreased from 43% in 2011 to 16% in 2012 by the mechanical excavation. After 5 years from applying the treatment, *Schoenoplectiella mucronata* that was utilized in the planting became the predominant species instead of *P. japonicus* and the number of wetland plant species increased from 16 to 25 with the shift in species composition. This study showed the utility of three control methods of *P. japonicus* in a lentic wetland.

Keywords: Abandoned paddy field, Abandoned paddy terrace, Mechanical excavation, Physical control, Stolonization

Background

There are two emergent macrophytes of genus *Phragmites* (Poaceae) in Northeast Asian countries: common reed (*Phragmites australis* (Cav.) Trin. ex Steud.) and runner reed (*Phragmites japonicus* Steud.). It is uneasy to distinguish those species when they are mixed because of their similar appearances (Kim and Kim 2009; Chu et al. 2011; Park et al. 2018). Instead of their outer characteristics, the ecology of those species may be better guides to distinguish them. *P. australis* makes rhizomes and inhabits downstream, estuary, and salt marsh, whereas *P. japonicus* develops stolons and inhabits upstream and adjacent areas (Chun et al. 1999; Hong et al. 2012; Hong and Kim 2014; Park et al. 2018).

In particular, *P. japonicus* with wide-spreading stolons and dense roots system shows high adaptability in oligotrophic environments such as lotic wetlands in upstream and lentic wetlands in mountainous area (Chun et al. 1999; Asaeda et al. 2009; Park et al. 2018). In lotic wetlands, *P. japonicus* plays a role as a pioneer, which helps other plant species to settle by making dense roots

trapping floating-sediments (Choe and Kim 1999; Asaeda et al. 2011). In lentic wetlands, on the other hand, *P. japonicus* could play a role as an invader threatening biodiversity by forming tall and dense stands (Byun et al. 2008; Hong et al. 2012).

In this study, we have focused on an abandoned paddy terrace in which an endangered dragonfly species (*Nannophya pygmaea* Rambur) lives (Yoon et al. 2010, 2011). *P. japonicus* had invaded from a nearby streamlet and spread out rapidly into the wetland. To conserve the habitat of the endangered dragonfly species, we applied three kinds of treatment ((1) hand-clipping in 2009, (2) mechanical excavating in 2012, and (3) planting of alternative vegetational unit in 2012) into the wetland and have monitored vegetational changes as the results of the treatments. This report provides not only effective treatment plans for *P. japonicus* in lentic wetlands but also a 10-year monitoring result on the abandoned paddy field which needs to be conserved for an endangered dragonfly species.

Materials and methods

Study site

Our study site is a unit wetland of an abandoned paddy terrace within mountainous areas (35° 15' 54.13" N, 127°

* Correspondence: jaegkim@snu.ac.kr

¹Department of Biology Education, Seoul National University, Seoul 08826, Korea

²Center for Education Research, Seoul National University, Seoul 08826, Korea



16' 28.11"E) in South Jeolla Province of South Korea. Although the paddy terrace had been abandoned prior to 2001 because of hard accessibility for agriculture (Hong et al. 2012), it became a natural ecological protection area for the inhabitation of scarlet pygmy dragonfly (*N. pygmaea*) which was designated as an endangered species in Korea (Kim et al. 2010; Yoon et al. 2010, 2011). We began to monitor the study site from 2008 because of the occupation by *P. japonicus*. More information on the study site in detail is available in Hong et al. (2012).

Treatment plans

As a preliminary treatment for the control, (1) some of mature stands of *P. japonicus* in the study site were clipped in August 2009. After verifying the effect of the preliminary treatment via the monitoring in September 2011, (2) the rest of mature stands including below-ground parts within shallow areas were mechanically excavated by using an excavator (a heavy machinery of over 10 tons) to the depth of 20~30 cm from the soil surface in March 2012. In our study, mechanical excavation was adopted as a treatment method not only to remove the mature stands which support other juvenile stands but also to form deep water environment, possibly hindering stolonization of *P. japonicus*. (3) We planted *Schoenoplectiella mucronata* (L.) J.Jung & H.K.Choi as an alternative vegetational unit right after the excavation to interfere with re-stolonization of *P. japonicus*. In addition, *Schoenoplectiella* (*Scirpus*) spp. are considered as preferable habitats for scarlet pygmy dragonfly, which is an endangered species in Korea (Yoon et al. 2010, 2011).

Follow-up monitoring

We have surveyed the vegetation cover of the study site at the end of the growing season (early September) from 2008 to 2012 and 2017 to monitor the changes in the vegetation cover. All of wetland plant species of > 1 m² in area were included as vegetation units in the survey. In addition, flora and number of wetland plant species in the study site in 2017 were investigated to compare with those in 2010 as results of the treatment.

Results

Changes in vegetation cover

During the monitoring period, a total of six wetland species were included as vegetational units: *P. japonicus*, *Eleocharis kuroguwai* Ohwi, *Typha orientalis* C. Presl., *S. mucronata*, *Trapa japonica* Flerow, and *Schoenoplectus tabernaemontani* (C.C.Gmel.) Palla (Fig. 1). The sum of vegetation covers (%) had increased continuously from 2008 to 2011. The greater part of the site (97%) was covered by wetland plants, and approximately a half of it was occupied by *P. japonicus* in 2011. The vegetational cover of *P. japonicus* had increased gradually from 2008 to 2010 (from 34 to 46%) despite that the hand-clipped

area of *P. japonicus* had not been restored during the monitoring period (Fig. 1).

After the excavation of *P. japonicus* in September 2012, the sum of vegetation covers decreased from 97 to 80% as the cover of *P. japonicus* declined from 43 to 16%. The vegetation cover of *S. mucronata* increased by two-folds (10 to 20%) as the result of the planting of alternative vegetational unit. On the other hand, *T. orientalis* and *E. kuroguwai* did not show much changes in the vegetation cover by the treatment (Fig. 2).

The vegetation cover of *P. japonicus* had increased slightly from 16 to 21%, whereas the sum of vegetation covers in the study site had increased from 80 to 98% for 5 years (2012~2017). In particular, *S. mucronata* occupied almost a half of the study site (41%) instead of *P. japonicus* in September 2017. The vegetation cover of *T. orientalis* increased from 21 to 29%, whereas that of *E. kuroguwai* sharply decreased from 23 to 7% (Fig. 2).

Flora and number of wetland plant species

Flora of the study site in 2017 differed from that in 2010. Four wetland species disappeared: *Nymphaea tetragona* Georgi, *Ottelia alismoides* (L.) Pers., *Sagittaria aginashii* Makino, and *Salvinia natans* (L.) All. On the other hand, 13 wetland species appeared: *Aeschynomene indica* L., *Ambrosia artemisiifolia* L., *Bidens frondosa* L., *Echinochloa crus-galli* (L.) P.Beauv., *Hypericum japonicum* Thunb., *Isachne globosa* (Thunb.) Kuntze, *Lemna aequinoctialis* Welw., *Polygonum muricatum* Meisn., *Polygonum thunbergii* Siebold & Zucc., *Salix chaenomeoides* Kimura, *S. tabernaemontani*, *T. japonica*, and *Lindernia micrantha* D. Don. The number of wetland plant species of the study site in 2017 increased from 16 to 25 by the shift in species composition when compared with that in 2010 (Table 1).

Discussion

Phragmites japonicus is one of the major vegetational units of wetland ecosystems in Asian countries. In particular, *P. japonicus* plays an important role as a pioneer, which helps other plant species to settle by making dense roots trapping floating-sediments (Choe and Kim 1999; Asaeda et al. 2011). Numerous and wide-spreading stolons with dense roots of *P. japonicus* physically function as stable aggregates under lotic conditions. In addition, high capacity in nutrient uptake of dense roots on many stolons could also contribute to the rapid growth and occupation of *P. japonicus* in lentic conditions (Hong et al. 2012, 2014). *P. japonicus* can grow less than 2 m in height under lotic and oligotrophic conditions, whereas *P. japonicus* can grow higher than 3 m and expand more than 10 m/year in lentic wetlands as shown in our monitoring (Hong et al. 2012).

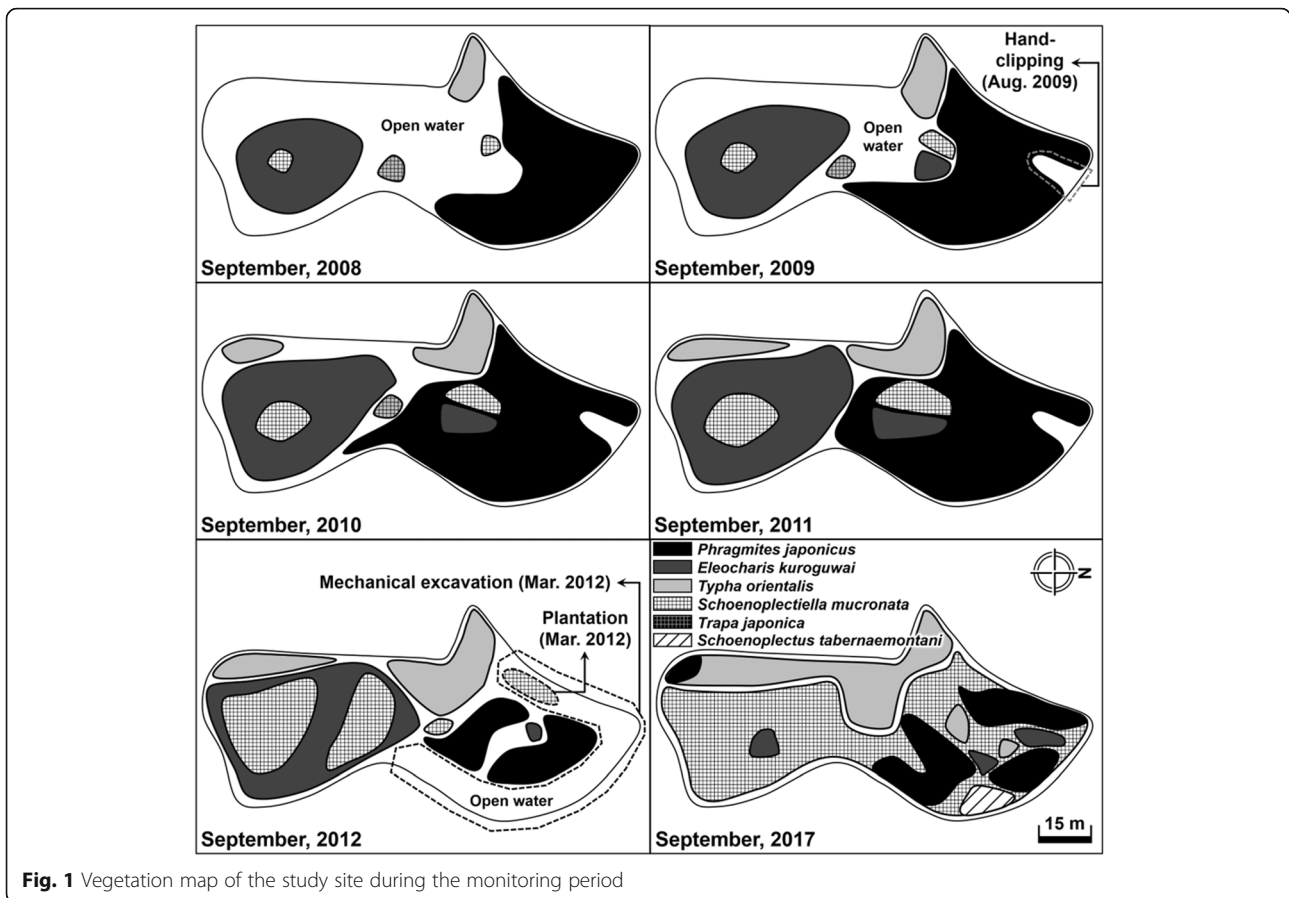


Fig. 1 Vegetation map of the study site during the monitoring period

In lotic wetlands, vigorousness of *P. japonicus* can be used practically such as bed stabilization and water purification (Choe and Kim 1999; Hong et al. 2014). On the other hand, it may affect lentic wetlands as a threat. Monotypic occupation by *P. japonicus* via rapid stolonization in lentic wetlands could decrease biodiversity

diminishing the value of wetland ecosystems (Hong et al. 2012; Yang and Kim 2016, 2018). Decreased plant species diversity means the loss of habitats, and it can be a more severe problem to the endangered. In addition to the habitats, standing litter of *P. japonicus* could also decrease the area of open-water surface which is an essential environmental factor for the dragonfly species to perch (Tsubaki et al. 1994).

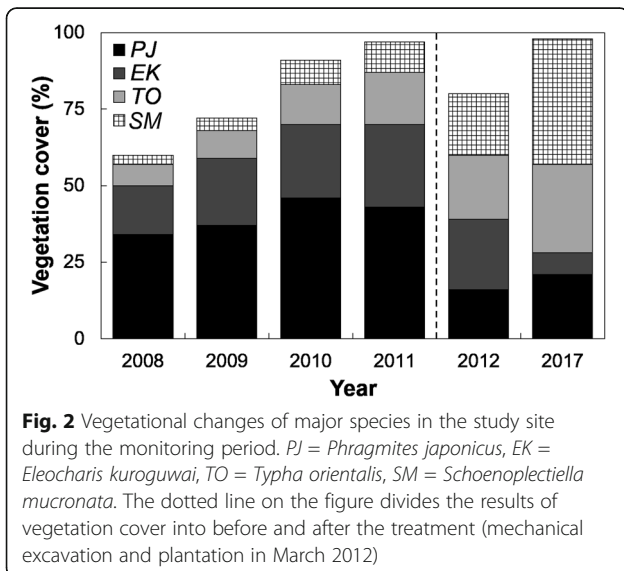


Fig. 2 Vegetational changes of major species in the study site during the monitoring period. PJ = *Phragmites japonicus*, EK = *Eleocharis kuroguwai*, TO = *Typha orientalis*, SM = *Schoenoplectiella mucronata*. The dotted line on the figure divides the results of vegetation cover into before and after the treatment (mechanical excavation and plantation in March 2012)

Not only to control *P. japonicus* in lentic wetlands, but also to conserve the habitat of the endangered dragonfly species, we applied three kinds of treatment (hand-clipping, mechanical excavating, and mechanical excavating and additional planting) to the study site and have monitored vegetational changes as the results of the treatments. Hand-clipping worked well in old dense area of *P. japonicus*. There was no shoot emerging in the clipped area, and this might come from the disability of this plant to make stolon in old dense area (Hong et al. 2012). Although the territory of *P. japonicus* seemed to be widened rapidly by stolonization during the growing season, we found that the stolonization worked well only in shallow and non-vegetated areas based on the territory of *P. japonicus* in the following year. Thus, we expected that deep water (natural or by excavation) and established vegetation would interrupt stolonization

Table 1 Flora and number of wetland plant species in the study site before and after the treatment

Scientific name	Before treatment ^a (2010)	After treatment (2017)
<i>Aeschynomene indica</i> L.		○
<i>Ambrosia artemisiifolia</i> L.		○
<i>Bidens frondosa</i> L.		○
<i>Blyxa aubertii</i> Rich.	○	○
<i>Echinochloa crus-galli</i> (L.) P.Beauv.		○
<i>Eleocharis kuroguwai</i> Ohwi	○	○
<i>Hydrilla verticillata</i> (L.f.) Royle	○	○
<i>Hypericum japonicum</i> Thunb.		○
<i>Isachne globosa</i> (Thunb.) Kuntze		○
<i>Juncus effusus</i> L.	○	○
<i>Lemna aequinoctialis</i> Welw.		○
<i>Lindernia micrantha</i> D. Don		○
<i>Monochoria vaginalis</i> (Burm.f.) C.Presl	○	○
<i>Murdannia keisak</i> (Hassk.) Hand- Mazz.	○	○
<i>Nymphaea tetragona</i> Georgi	○	
<i>Ottelia alismoides</i> (L.) Pers.	○	
<i>Polygonum muricatum</i> Meisn.		○
<i>Polygonum thunbergii</i> Siebold & Zucc.		○
<i>Phragmites japonicus</i> Steud.	○	○
<i>Potamogeton distinctus</i> A.Benn.	○	○
<i>Sagittaria aginashii</i> Makino	○	
<i>Salix chaenomeloides</i> Kimura		○
<i>Salvinia natans</i> (L.) All.	○	
<i>Schoenoplectus tabernaemontani</i> (C.C.Gmel.) Palla		○
<i>Schoenoplectiella mucronata</i> (L.) JJung & H.K.Choi	○	○
<i>Spirodela polyrrhiza</i> (L.) Schleid.	○	○
<i>Trapa japonica</i> Flerow		○
<i>Trapa natans</i> L.	○	○
<i>Typha orientalis</i> C.Presl	○	○
No. of wetland plant species	16	25

^aData from Hong et al. (2012)

process which needs to root in bottom layer of wetland (Byun et al. 2008; Hong et al. 2012). As we expected, deep water and vegetation cover via applying our treatments seemed to effectively disturb the expansion of *P. japonicus* in the study site. In particular, planting of *Schoenoplectiella* spp. as an alternative vegetational unit instead of *P. japonicus* appeared to determine the change of dominant species of the study site from *P. japonicus* to *S. mucronata*.

During the monitoring period of 10 years, seed establishment of *P. japonicus* has not been observed (a new patch of *P. japonicus* within *T. orientalis* in 2017 was also formed by stolonization). It appeared likely that *P. japonicus* widened its territory by expanding stolons only in our site. Unlike *P. australis* which makes underground rhizomes for local territory expansion, *P. japonicus* produces creeping stolons in which aerenchyma tissues develop, making stolons likely to float in water layer (Lenssen et al. 2004; Yang et al. 2011). Thus, hand removal of aerial stolons before rooting in the growing season could also be a cost-effective and non-destructive method in addition to the hand-clipping of aboveground shoots that was verified as an effective treatment method for the control of *P. japonicus* via our monitoring.

Abandoned paddy fields (terraces) in mountainous areas are increasing in number particularly in Asian countries because of their low accessibility and economic value. In these days, they are also gaining recognition as valuable wetlands for wildlife (Kim et al. 2010; Park et al. 2013; Cho et al. 2018). However, those lentic wetlands with relatively monotonous topography and landscape are likely to be occupied by strong competitors such as *P. japonicus* which may result in eventually diminished biodiversity of wetland ecosystems. To conserve abandoned paddy fields as valuable lentic wetlands for wildlife from monotypic occupation by *P. japonicus*, we recommend the methods of treatment as follows: (1) regular removal of aboveground shoots including aerial stolons by hand-clipping at growing season (Tanaka et al. 2017), (2) mechanical excavation of mature stands when the great part of the wetland is already occupied since mature stands do not make stolons, which are essential for *P. japonicus* to expand (Hong et al. 2012), and (3) subsequent planting using alternative vegetational unit such as *S. mucronata*. In our study, the planting after the excavation could interrupt *P. japonicus* to occupy and support the target species such as *N. pygmaea* to thrive particularly in abandoned paddy fields (Kim et al. 2010).

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Availability of data and materials

The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

MGH designed the study and wrote the manuscript draft. HJP and BEN participated in the field works. JGK conceived the study and edited the manuscript. All authors read and approved the final manuscript.

Ethics approval

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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