Gyeongju (Kim *et al*., 2013), and Hwasan Wetland of Gunwi (Kim *et a*l., 2017). Studies on royal tombs of the Joseon Dynasty have been conducted in Donggureong (Lee & Chin, 2002), Seooreung (Yee & Bae, 2006), Heonilleung (Kim *et al*., 2010), Sareung (Lee *et al*., 2011a), Jangreung (Lee *et al*., 2011b), Yunggeolleung (Lee *et al*., 2011c), Samreung (Kwak *et al*., 2012), Hongyureung (Lee *et al*., 2013), Taereung (Kim *et al*., 2015), and Gwangreung (Oh *et al*., 2019). These studies were mostly focused on vegetation, while studies on flora were only performed in a sporadic manner. Although studies on vegetation of the entire Heonilleung area have already been conducted, a detailed study on the flora of East Asian alder forest wetland of Heonilleung has not been reported yet.

Thus, the objective of the present paper was to investigate vascular plant flora of the East Asian alder forest wetland of Heonilleung. Results of this study could be used as fundamental data to demonstrate botanical diversity of the study area. The outcome of this study may help us plan future conservation strategies for the wetland.

Materials and Methods

Study area

Heonilleung East Asian alder Forest Wetland is located at San 13-1, Naegokdong, Seochogu, with GPS coordinates of 37° 46' N and 127° 08' E, covering an area of 30,592.2 ㎡. The wetland covers the majority of space of Heonilleung area. It is at the entrance of the royal tomb (Fig. 1). The wetland lies at a lowland with altitudes of 31-60 m. It has a mixture of flatland and gentle-slope land with a gradient less than 15°. The wetland is an alluvium region. Its soil comprises silty clay loam, sandy loam, and loam, rendering the area fertile and moist. The underground water level of the area is 65.2-75 cm in average with consistency (Dongguk University Industry-Academic Cooperation Foundation, 2017). Regarding the climatic condition of the wetland, it has an average annual temperature of 13.9°C, a mean maximum temperature of 19.0°C, a mean minimum temperature of 9.2°C, an average annual precipitation of 988.0 mm, and an average wind velocity of 1.5 m/s.

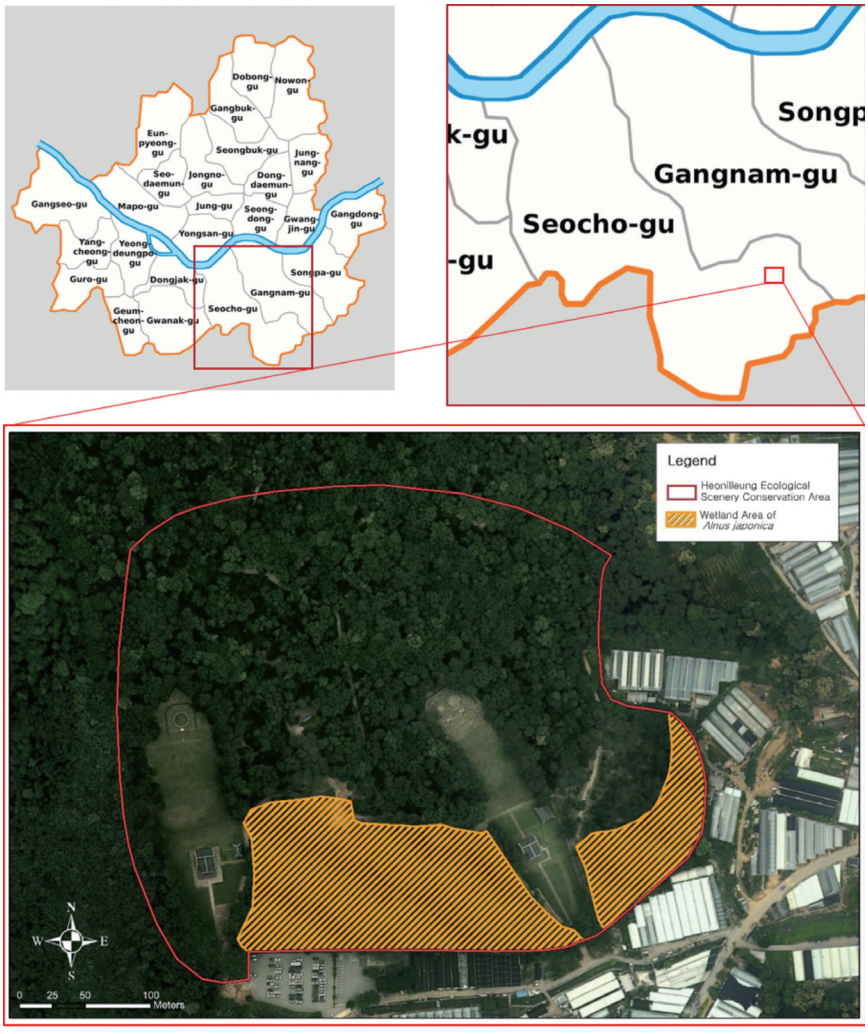

Fig. 1. Study area boundary (red) shown around the range of East Asian alder forest wetland of Heonilleung.

Study methods

A field study was performed three times (in spring, summer, and autumn) from May to September of 2020. Plants occurring inside the wetland and its edge were investigated. Most of these plants were identified during the investigation. However, some plants could not be determined. They were photographed and identified by referring to databases of Kim and Kim (2011), Cho *et al*. (2016), and Kim *et al*. (2018). Arranging the order of plants and recording their scientific names were performed according to the Korean Plant Names Index (Korea National Arboretum, 2017) and the Engler system (Melchior, 1964). Based on results of investigation, all occurring plant species were categorized according to Raunkiaer's life form system (Mueller-Dombois & Ellenberg, 1974). List of rare plants (Korea National Arboretum, 2008), invasive alien plants (Kim *et al*., 2018), and floristic regional indicator plants (Korea National Arboretum, 2019) of the wetland were sorted out afterwards.

Results and Discussion

Vascular plant species compositions

A total of 166 vascular plant species were identified, including 159 species, three subspecies, three varieties, and one cultivar. They represented 132 genera and 59 families (Table 1, Supplementary Table 1), accounting for 8.3% of 1,996 vascular plant species inhabiting Seoul. Among them, five (3%) species, five genera, and four families represented pteridophytes. One (0.6%) species, one genus, and one family represented gymnosperms. One hundred and twenty -two (73.5%) species, 98 genera, and 48 families represented dicotyledons. Thirty-eight (22.9%) species, 28 genera, and six families represented monocotyledons. In terms of species diversity, *Poaceae* had the highest diversity with 20 (12%) species, followed by *Asteraceae* with 16 (9.6%) species, *Rosaceae* with nine (5.4%) species, *Cyperaceae* with eight (4.8%) species, and *Fabaceae* and *Lamiaceae* with seven species each. Plants such as *Equisetum arvense, Persicaria thunbergii, Corydalis ternata, Oenanthe javanica, Mentha canadensis, Phryma leptostachya* var. *asiatica, Lobelia chinensis, Juncus effusus, Murdannia keisak, Poa acroleuca, Leersia oryzoides, Pinellia ternata, Carex dispalata,* and *Scirus juncoides* that could tolerate moist to wet soil were major herbaceous species inhabiting the wetland. Canopy tree species such as *Salix koreensis* and *Alnus japonica*, understory tree species such as *Quercus aliena, Prunus padus, Acer ginnala, Euonymus hamiltonianus, Styrax japonicus,* and *Fraxinus rhynchophylla,* and shrub species such as *Akebia quinata, Ampelopsis glandulosa* var. *heterophylla, Rosa multiflora, Zanthoxylum piperitum, Ampelopsis brevipedunculata, Eleutherococcus senticosus, Clerodendrum trichotomum,* and *Viburnum erosum* were major woody plant species in the wetland. In addition, saplings or shrubs of plant species including *Ginkgo biloba, Zelkova serrata, Magnolia denudata, Cercis chinensis, Robinia pseudoacacia, Acer palmatum, Euonymus alatus, Cornus officinalis, Callicarpa dichotoma, Sambucus canadensis, Viburnum opulus* were found. They were introduced from planted trees in the neighborhood of Heonilleung Royal Tomb.

Life-forms of Plants

All 166 plant species of Heonilleung Wetland according to Raunkiaer's life-form system were ranked in decreasing order of species richness as follows: Therophytes (Th), 52 (31.3%) species; Hemicryptophytes (H), 24 (14.5%) species; Nanophanerophytes (N), 19 (11.4%) species; Hydrophytes (HH), 18 (10.8%) species; Geophytes (G), 17 (10.2%) species; Megaphanerophytes (MM), 16 (9.6%) species; Microphanerophytes (M), 14 (8.4%) species; and Chamaephytes (Ch), six (3.6%) species (Table 2).

Rare Plants

There was one rare plant species found in the wetland. It was *Melothria japonica* with a Least Concern (LC) status (Table 3). A small number of *Melothria japonica* were found inside the wetland. Their natural habitats need protection as a small number of them are occasionally seen growing near reservoirs and mountains in Korea (Lee *et al*., 2016).

Table 1. Categorization of plant species in Heonilleung Wetland by taxon

Taxon	Family	Genus	Species	Subspecies	Variety	Cultivar	subtotal
Pteridophyta	4	5	5	-	-	-	5
Gymnospermae	1	1	1	-	-	-	1
Dicotyledonae	48	98	117	3	1	1	122
Monocotyledonae	6	28	36	-	2	-	38
Total	59	132	159	3	3	1	166

Table 2. Categorization of plant species in Heonilleung Wetland by life-form

Life-form*	Th	G	H	Ch	N	M	MM	HH
Number of Species (%)	52 (31.3)	17 (10.2)	24 (14.5)	6 (3.6)	19 (11.4)	14 (8.4)	16 (9.6)	18 (10.8)

* Life-form: Th (Therophytes), G (Geophyte), H (Hemicryptophytes), Ch (Chamaephytes), N (Nanophanerophytes), M (Microphanerophytes), MM (Megaphanerophytes), HH (Hydatophytes).

Table 3. Categorization of rare plant species in Heonilleung Wetland

Scientific name	Grade*
Melothria japonica (Thunb.) Maxim. ex Cogn.	LC

*Grade: LC (Least Concerned).

Floristic regional indicator plants

There were a total of 15 floristic regional indicator plant species. One of them, *Carex accrescens*, belonged to floristic grade IV. Two of them, *Acer palmatum* and *Callicarpa dichotoma*, belonged to grade III. Four of them, *Alnus japonica, Spiraea salicifolia, Scutellaria dependens,* and *Glyceria leptolepis,* belonged to grade IV. Eight of them, *Onoclea interrupta, Pyrus calleryana, Impatiens noli-tangere, Melothria japonica, Eleutherococcus sessiliflorus, Viburnum opulus, Cirsium pendulum,* and *Carex dispalata,* belonged to grade I. Three of them belonged to floristic grades III and IV. Thus, their habitats are discontinuous and isolated to some degree (Table 4). *Carex accrescens,* a species with a small range, was inhabiting the interior of the wetland in small numbers. On the other hand, the presence of *Acer palmatum* and *Callicarpa dichotoma,* both of which belonged to floristic grade III, showed no particular ecological significance as those individuals were introduced from the outside.

Invasive alien plants

A total of 19 invasive alien plant species were identified, including *Phytolacca americana, Chenopodium album, Robinia pseudoacacia, Trifolium repens, Ipomoea nil, Erigeron annuus, Taraxacum officinale,* and *Panicum dichotomiflorum.* Twelve (63.2%) of them were of North American origin and three (15.8%) of them were of Euro-African origin. One (5.3%) species was of temperate European origin. One (5.3%) species was of temperate Eurasian origin. One

Table 4. Categorization of floristic regional indicator plant species in Heonilleung Wetland

Scientific name	Grade
Carex accerescens Ohwi	IV
Acer palmatum Thunb. *Callicarpa dichotoma* (Lour.) Raeusch. ex K.Koch	III
Alnus japonica (Thunb.) Steud. *Spiraea salicifolia* L. *Scutellaria dependens* Maxim. *Glyceria leptolepis* Ohwi	II
Onoclea interrupta (Maxim.) Ching & P.C.Chiu *Pyrus calleryana* Decne. var. *fauriei* (C.K.Schneid.) Rehder *Impatiens noli-tangere* L. *Melothria japonica* (Thunb.) Maxim. ex Cogn. *Eleutherococcus sessiliflorus* (Rupr. & Maxim.) S.Y.Hu *Viburnum opulus* L. var. *calvescens* (Rehder) H.Hara *Cirsium pendulum* Fisch. ex DC. *Carex dispalata* Boott	I

Table 5. Categorization of invasive alien plant species in Heonilleung Wetland

Scientific name	Origin*	Introduction time**	Spread rate***
Phytolacca americana L.	AM	3	5
Stellaria media (L.) Vill.	TEM, EA, AM	1	5
Cerastium glomeratum Thuill.	EU, AF	3	2
Chenopodium album L.	TEM, EU	2	3
Robinia pseudoacacia L.	AM	1	5
Trifolium repens L.	EU, AF	1	5
Oxalis dillenii Jacq.	AM	3	1
Veronica peregrina L.	AM	1	1
Lindernia dubia (L.) Pennell	AM	3	1
Veronica arvensis L.	EU, AF	2	5
Erigeron annuus (L.) Pers.	AM	1	5
Conyza canadensis (L.) Cronquist	AM	1	5
Bidens frondosa L.	AM	3	5
Erechtites hieraciifolius (L.) Raf. ex DC.	AM	2	5
Ageratina altissima (L.) R.M.King & H.Rob.	AM	3	1
Taraxacum officinale F.H.Wigg.	EU	2	5
Galinsoga ciliata (Raf.) S.F.Blake	AM	3	5
Panicum dichotomiflorum Michx.	AM	3	4
Poa pratensis L.	TEM	2	4

*Origin: AF (Africa), AM (America), EA (Eurasia), EU (Europe), TEM (Temperate).

**Introduced time: 1 (1500-1931), 2 (1932-1961), 3 (1962-present).

***Spread rate: 1 (Potential Spread), 2 (Minor Spread), 3 (Concemed Spread), 4 (Serious Spread), 5 (Wide Spread).

(5.3%) species was of temperate American origin and one (5.3%) species was of European origin. Eleven (57.9%) species were of spread rate V (widespread, WS). Four (21.1%) were of spread rate I (potential spread, PS). Two (10.5%) were of spread rate IV (serious spread, SS). One (5.3%) was of spread rate II (minor spread, MS) and one (5.3%) was of spread rate III (concerned spread, CS) (Table 5). The species with spread rate V including *Stellaria media, Trifolium repens, Erigeron annuus, Conyza canadensis, Taraxacum officinale, Galinsoga ciliata* were evenly distributed in and around the wetland in numbers. As for non-invasive alien species, there were a few individuals of *Ginkgo biloba, Magnolia denudata, Cercis chinensis, Ailanthus altissima, Perilla frutescens, Solanum nigrum,* and *Sambucus canadensis* inside the wetland.

Conclusion

This study obtained fundamental data about the biodiversity of vegetation in East Asian alder forest wetland of Heonilleung Royal Tombs. These data could be used to develop a future plan for the conservation of the wetland. Results of this study indicated that constant invasive plant species control and restoration of the water regime of the wetland are needed to conserve the wetland. Study results are summarized as follows:

1) A total of 166 vascular plant species were found, accounting for 8.3% of 1,996 vascular plant species inhabiting Seoul.
2) Therophyte was the most common plant life-form in Heonilleung Wetland. Arrangement of life-forms of plants in Heonilleung Wetland according to Raunkiaer's life-form system ranked in decreasing order of species richness is as follows: Hemicryptophytes > Nanophanerophytes > Hydrophytes > Geophytes > Megaphanerophytes > Microphanerophytes > Chamaephytes.
3) Only one rare plant species was found in the wetland. However, 15 floristic regional indicator plant species were found in the wetland, including one belonging

to floristic grade IV, two belonging to grade III, four belonging to grade IV, eight belonging to grade I, and three belonging to floristic grades III and IV, indicating that their habitats were isolated to some degree.

4) There were 19 invasive alien plant species found in the wetland. Most of them were introduced from North America after the year 1964 with a spread rate of V. As for non-invasive alien species, *Ginkgo biloba, Magnolia denudata, Cercis chinensis, Ailanthus altissima, Perilla frutescens, Solanum nigrum, Sambucus canadensis* were identified which were introduced from the outside.
5) The surrounding ground of Heonilleung East Asian alder forest wetland has a deep layer of soil and a stable groundwater table, which provides habitats for a number of plants tolerant of moist soil, all of which are rarely seen in Seoul. However, most of them were found to grow in small quantity. Their populations are expected to either rapidly diminish or get wiped out from the wetland if their habitat becomes desiccated or if ruderal species, invasive alien species, and cultivated plant species are kept being introduced from other areas. Therefore, detailed monitoring accompanying time series analysis and ecological management on ruderal species, alien species (including invasive alien species), and cultivated plant species should be conducted.

Conflict of Interest

The authors declare that they have no competing interests.

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Supplementary Table 1. List of vascular plant species in Heonilleung Wetland

Scientific Name	Scientific Name
Equisetaceae	*Asarum sieboldii* Miq.
Equisetum arvense L.	**Papaveraceae**
Thelypteridaceae	*Chelidonium majus* L. subsp. *asiaticum* H.Hara
Thelypteris palustris (A.Gray) Schott	*Corydalis ternata* (Nakai) Nakai
Onocleaceae	**Brassicaceae**
Onoclea interrupta (Maxim.) Ching & P.C.Chiu	*Rorippa indica* (L.) Hiern
Athyriaceae	*Draba nemorosa* L.
Athyrium yokoscense (Franch. & Sav.) Christ	*Capsella bursa-pastoris* (L.) Medik.
Deparia conilii (Franch. & Sav.) M.Kato	*Cardamine fallax* (O.E.Schulz) Nakai
Ginkgoaceae	*Cardamine flexuosa* With.
Ginkgo biloba L.	**Rosaceae**
Salicaceae	*Stephanandra incisa* (Thunb.) Zabel
Salix pierotii Miq.	*Prunus padus* L.
Betulaceae	*Spiraea salicifolia* L.
Alnus japonica (Thunb.) Steud.	*Duchesnea indica* (Andrews) Focke
Fagaceae	*Prunus serrulata* Lindl. *f. spontanea* (E.H.Wilson)
Quercus aliena Blume	Chin S.Chang
Quercus acutissima Carruth.	*Potentilla fragarioides* L.
Quercus serrata Murray	*Rubus pungens* Cambess.
Ulmaceae	*Rosa multiflora* Thunb.
Zelkova serrata (Thunb.) Makino	*Pyrus calleryana* Decne. var. *fauriei (C.K.Schneid.)* Rehder
Cannabaceae	**Fabaceae**
Humulus scandens (Lour.) Merr.	*Maackia amurensis* Rupr.
Urticaceae	*Cercis chinensis* Bunge
Pilea pumila (L.) A.Gray	*Amphicarpaea bracteata* (L.) Fernald subsp.
Boehmeria japonica (L.f.) Miq.	*edgeworthii* (Benth.) H.Ohashi
Polygonaceae	*Robinia pseudoacacia* L.
Persicaria longiseta (Bruijn) Kitag.	*Albizia julibrissin* Durazz.
Persicaria thunbergii (Siebold & Zucc.) H.Gross	*Pueraria lobata* (Willd.) Ohwi
Persicaria pubescens (Blume) H.Hara	*Trifolium repens* L.
Phytolaccaceae	**Oxalidaceae**
Phytolacca americana L.	*Oxalis dillenii* Jacq.
Caryophyllaceae	**Rutaceae**
Sagina japonica (Sw.) Ohwi	*Zanthoxylum schinifolium* Siebold & Zucc.
Stellaria uliginosa Murray	**Simaroubaceae**
Stellaria media (L.) Vill.	*Ailanthus altissima* (Mill.) *Swingle*
Stellaria aquatica (L.) Scop.	**Aceraceae**
Cerastium glomeratum Thuill.	*Acer palmatum* Thunb.
Cerastium holosteoides Fr. var. hallaisanense (Nakai) Mizush.	*Acer pseudosieboldianum* (Pax) Kom.
	Acer tataricum L. subsp. *ginnala* (Maxim.) Wesm.
Chenopodiaceae	**Balsaminaceae**
Chenopodium album L.	*Impatiens noli-tangere* L.

Scientific Name	Scientific Name
Magnoliaceae	*Impatiens textorii* Miq.
Magnolia denudata Desr.	**Celastraceae**
Ranunculaceae	*Celastrus orbiculatus* Thunb.
Ranunculus sceleratus L.	*Euonymus hamiltonianus* Wall.
Clematis apiifolia DC.	*Celastrus flagellaris* Rupr.
Lardizabalaceae	*Euonymus alatus* (Thunb.) Siebold
Akebia quinata (Houtt.) Decne.	*Euonymus alatus* (Thunb.) Siebold f. *ciliato-dentatus*
Menispermaceae	(Franch. & Sav.) Hiyama
Menispermum dauricum DC.	**Vitaceae**
Aristolochiaceae	*Ampelopsis heterophylla* (Thunb.) Siebold & Zucc.
Elaeagnus umbellata Thunb.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.
Violaceae	**Elaeagnaceae**
Viola arcuata Blume	**Plantaginaceae**
Cucurbitaceae	*Plantago asiatica* L.
Melothria japonica (Thunb.) Maxim. ex Cogn.	**Caprifoliaceae**
Alangiaceae	*Viburnum erosum* Thunb.
Alangium platanifolium (Siebold & Zucc.) Harms var.	*Sambucus canadensis* L.
trilobum (Miq.) Ohwi	*Viburnum opulus* L. var. *calvescens* (Rehder) H.Hara
Cornaceae	**Campanulaceae**
Cornus officinalis Siebold & Zucc.	*Lobelia chinensis* Lour.
Araliaceae	**Asteraceae**
Eleutherococcus sessiliflorus (Rupr. & Maxim.) S.Y.Hu	*Erigeron annuus* (L.) Pers.
Apiaceae	*Ixeris chinensis* (Thunb.) Nakai
Oenanthe javanica (Blume) DC.	*Conyza canadensis* (L.) Cronquist
Angelica decursiva (Miq.) Franch. & Sav.	*Bidens frondosa* L.
Primulaceae	*Ixeris polycephala* Cass.
Lysimachia japonica Thunb.	*Erechtites hieraciifolius* (L.) Raf. ex DC.
Ebenaceae	*Youngia japonica* (L.) DC.
Diospyros lotus L.	*Ageratina altissima* (L.) R.M.King & H.Rob.
Styracaceae	*Taraxacum officinale* F.H.Wigg.
Styrax japonicus Siebold & Zucc.	*Artemisia indica* Willd.
Styrax obassis Siebold & Zucc.	*Lactuca indica* L.
Oleaceae	*Centipeda minima* (L.) A.Braun & Asch.
Fraxinus rhynchophylla Hance	*Hemistepta lyrata* (Bunge) Bunge
Ligustrum obtusifolium Siebold & Zucc.	*Sigesbeckia glabrescens* (Makino) Makino
Rubiaceae	*Cirsium pendulum* Fisch. ex DC.
Rubia cordifolia L.	*Galinsoga ciliata* (Raf.) S.F.Blake
Galium spurium L.	**Liliaceae**
Rubia argyi (H.Lév. & Vaniot) H.Hara ex Lauener	*Smilax riparia* A.DC.
Boraginaceae	*Hosta longipes* (Franch. & Sav.) Matsum.
Trigonotis peduncularis (Trevis.) Benth. ex Baker & S.Moore	*Allium macrostemon* Bunge
Bothriospermum tenellum (Hornem.) Fisch. & C.A.Mey.	*Disporum smilacinum* A.Gray
Verbenaceae	*Smilax sieboldii* Miq.

Scientific Name	Scientific Name
Clerodendrum trichotomum Thunb.	**Juncaceae**
Callicarpa japonica Thunb.	*Juncus decipiens* (Buchenau) Nakai
Callicarpa dichotoma (Lour.) Raeusch. ex K.Koch	*Juncus tenuis* Willd.
Lamiaceae	*Juncus diastrophanthus* Buchenau
Perilla frutescens var. *japonica* (Hassk.) Hara	**Commelinaceae**
Mosla scabra (Thunb.) C.Y.Wu & H.W.Li	*Commelina communis* L.
Mentha arvensis L. var. *piperascens* Malinv. ex Holmes	*Aneilema keisak* Hassk.
Lycopus lucidus Turcz. ex Benth.	**Poaceae**
Scutellaria dependens Maxim.	*Phalaris arundinacea* L.
Mosla dianthera (Buch.-Ham. ex Roxb.) Maxim.	*Setaria viridis* (L.) P.Beauv.
Elsholtzia ciliata (Thunb.) Hyl.	*Panicum bisulcatum* Thunb.
Solanaceae	*Festuca parvigluma* Steud.
Solanum nigrum L. var. *nigrum*	*Microstegium vimineum* (Trin.) A.Camus
Scrophulariaceae	*Echinochloa crus-galli* (L.) P.Beauv.
Veronica peregrina L.	*Alopecurus aequalis* Sobol
Lindernia dubia (L.) Pennell	*Panicum dichotomiflorum* Michx.
Lindernia procumbens (Krock.) Philcox	*Digitaria violascens* Link
Veronica arvensis L.	*Poa annua* L.
Mazus pumilus (Burm.f.) Steenis	*Poa acroleuca* Steud.
Phrymaceae	*Glyceria leptolepis* Ohwi
Phryma leptostachya L. var. *oblongifolia* (Koidz.) Honda	*Eleusine indica* (L.) Gaertn.
Leersia oryzoides (L.) Sw.	*Poa pratensis* L.
Oplismenus undulatifolius (Ard.) P.Beauv.	*Carex accerescens* Ohwi
Molinia japonica Hack.	*Carex aphanolepis* Franch. & Sav.
Paspalum thunbergii Kunth ex Steud.	*Pycreus sanguinolentus* (Vahl) Nees
Melica grandiflora Koidz.	*Scirpus wichurae* Boeck.
Microstegium vimineum (Trin.) A.Camus var. *polystachyum* (Franch. & Sav.) Ohwi	*Carex dispalata* Boott
Araceae	*Eleocharis acicularis* (L.) Roem. & Schult. var. longiseta Svenson
Pinellia ternata (Thunb.) Makino	*Schoenoplectus juncoides* (Roxb.) Palla
Cyperaceae	*Kyllinga brevifolia* Rottb. var. *leiolepis* (Franch. & Sav.) H.Hara