

Vegetation structure of wetlands in Eastern Himalayan Highlands of Gasa, Bhutan

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Received 19 Mar 2020

Accepted 2 Nov 2020

ABSTRACT: The study was conducted on the unexplored wetland vegetation of the eastern Himalayan highlands of Gasa District, Northern Bhutan. A random quadrat sampling of $1 \times 1 \text{ m}^2$ method was used to assess the presence-absence of species, including shrubs, trees, mosses, ferns, and climbers, that were occurring adjacent to plots. Altogether, 201 taxa from 81 families, distributed in 149 genera, were recorded. Among the total species, 6 bryophytes, 20 monilophytes, 2 gymnosperms, and 173 angiosperms species were found. The most abundant life forms represented were herbaceous (62%) and shrub (29%), followed by tree (7%) and climber (2%). The four unique vegetation structure (represented in schematic profile diagrams) of habitats: *fresh water meadow*, *seasonally flooded basin of flat*, *shallow fresh marsh*, and *poor fen*, were found. The study suggests protecting ecotone (a transition zone between the wetland and surrounding uplands) as part of the measures to protect wetlands and their vegetation in the Himalayas.

KEYWORDS: wetland, vegetation structure, schematic profile diagram, ecotone

INTRODUCTION

Wetlands are biologically diverse ecosystems that provide critical habitat to a wide range of plants and animals in the world. The ability of plants to inhabit wet places and represent a various grouping of species with different ecological tolerances, adaptations, and life history strategies that allows their existence in flooded or saturated soils are termed as wetland plants [1]. Further, wetland plants are defined by their ability to grow on a substrate or in water that is periodically lacking in oxygen due to excessive water content [2].

Wetland plants are interesting as they have unique evolutionary tactics for coping with life in a flooded environment and help us to identify the boundaries of a wetland [1]. These wetland plants occur mostly in heath forests, forest fragments and bottomlands surrounded by upland forests. These small wetland habitats provide unique combination of upland forest species and wetland specialist species with high plant diversity [3]. Further, Kent and Coker [4] claimed that these marginal species from the adjacent areas around the habitat or community type can greatly increase species diversity. Also, Van der Maarel [5], emphasized that transactional or ecotone areas are of great interest ecologically and deserve more attention in research.

The Himalayan Region is known as one of the worldwide significant biodiversity hotspots due to rich repository of native and endemic biodiversity [6]. As part of Eastern Himalaya, Flora of Bhutan documented 5603 species of vascular plants out of which approximately 94 percent are native species [7]. Eastern Himalaya, including Bhutan, is also a remarkable repository for fauna and flora [8,9]. Further, National Biodiversity Centre [10] recorded 144 species as currently endemic to Bhutan Himalaya, which is a remarkable diversity of endemism considering the size of the country. Of the total species recorded (144), about 49% (71) are incredibly recorded in Jigme Dorji National Park (JDNP). Hence, in order to ensure their conservation and management, study of the plants in such environments should be considered of key importance. Moreover, several natural habitats are at risk and the species within them experience potential extinction [11]. There is also massive habitat loss in the buffer zone that results in species destructions [12] and positioning numerous wetland species on threatened and endangered species lists. The lack of International Union for Conservation of Nature (IUCN) assessment further makes it challenging to understand the status of native species of national concern [7]. There was also no comprehensive study on the vegetation structure of

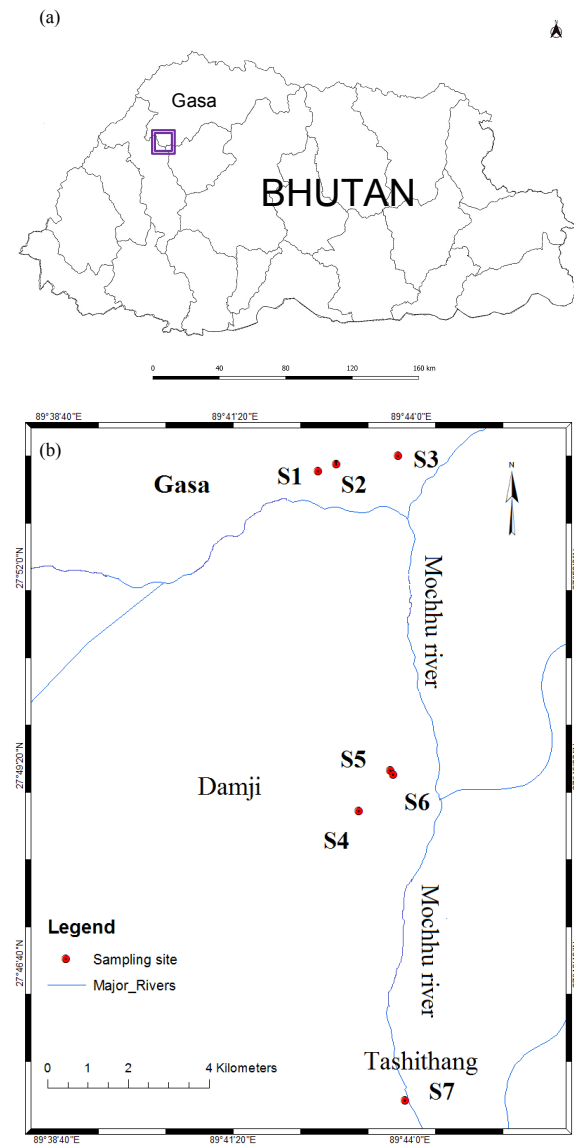


Fig. 1 Gasa, the location for this study is indicated in Bhutan map diagram (a); whereas, S1, Gasa1; S2, Gasa2; S3, Gasa3; S4, Damji1; S5, Damji2; S6, Damji3; S7, Tashithang (black circle dots) (b) were represented for sampling sites.

wetlands in Gasa, a part of JDNP, and therefore, objectives of the study were to: (1) provide a checklist of the freshwater wetland plants and (2) describe the structure of habitats in highland wetlands of Gasa, Bhutan.

MATERIALS AND METHODS

Study area

The study was conducted in Gasa, a part of JDNP, along the 28 km road stretch on the left side of Mochu River, that lies between $27^{\circ}43'05''$ – $28^{\circ}09'35''$ N (latitudes) and $89^{\circ}45'33''$ – $89^{\circ}38'44''$ E (longitude) (Fig. 1). The elevation ranges from 1597 to 2538 m above sea level. The vegetation type in the region is warm temperate forest [13]. The area experiences short summer and long winter with the mean annual rainfall over a decade (2008–2017) ranged from 498 to 1824 mm and heavy rainfall in the month of July to August. Similarly, air temperature of the region ranges from 5 – 16 °C [14]. The study areas were mostly occurred in the bottomlands, slopes, and forest fragments surrounded by natural vegetation.

Data collections

Floristic inventory was done almost every month (February to November 2018) to assess the status and flowering seasons for detailed identification of plants. All collected plant materials were prepared according to the guidelines of herbarium handbook [15]. A random quadrat sampling of 1×1 m² method was used to assess the presence-absence of species. The number of quadrat samples taken from each site varied due to occurrence of different sizes in wetlands. The vegetation of each quadrat sample was identified in the field and recorded all species in that plot, including the ones (shrubs, trees, mosses, ferns, and climbers) occurring adjacent to the plots, in order to acquire the comprehensive list of plants within the wetlands. The life form group was followed with slight modifications [16]. The classification of wetland habitats according to Smith [17] was followed and later identified habitats [18] were represented in the form of schematic profile diagram to represent the vegetation structure in the region. Vegetation profile of representative sites (X and Y-axes) were drawn accounting the measurement of plant height [19] and length of site (measured using 100 m measuring tape). A graded bamboo stick was used to measure the depth of water in each site. All collected specimens were taken to the National Biodiversity Center, Thimphu, Bhutan for confirmation; and unknown species were identified in consultation with specialized literature and specialists in different taxonomic groups. Floras of Bhutan (including a record of plants from Sikkim [20–23], a record of plants from Sikkim and Darjeeling [24–26], the grasses of Bhutan [27], the orchids of Bhutan [28],

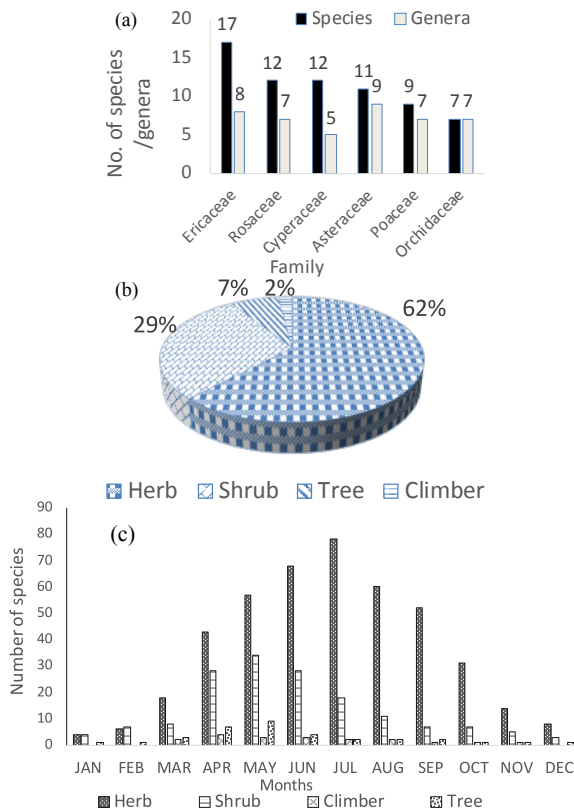


Fig. 2 Vegetation diversity structures found at Highland wetlands of Gasa were as follows: (a) proportion of six dominant families with different genus and species, (b) proportion of life forms of herb, shrub, climber and tree, and (c) growing seasons year around of different life forms.

and eFloras of China [29]) were followed for the identification of species and families. The species' names and families were updated in an online data base, the *Tropicos*. The Angiosperm Phylogeny Group IV classification was followed for the classification of families [30]. All the voucher specimens were deposited at the Herbarium, National Biodiversity Center, Thimphu, Bhutan.

RESULTS

Floristic composition

A total of 201 species of plants, distributed in 149 genera and 81 families, of which 55% (111 species) were within quadrat ($1 \times 1 \text{ m}^2$) sampling plots (226) and 45% (90 species) occurred adjacent to sampling plots (Tables 1 and S1). Among the total species, 6 species of bryophytes, 20 species of monilophytes, 2 species of gymnosperms, and 173 species of angiosperms (125 eudicots, 4 mag-

noliids, and 44 monocots) are presented in Table 1. The three most dominant families of eudicots were Ericaceae (17 species), Rosaceae (12 species), and Asteraceae (11 species) that comprised 8.5%, 6.0%, and 5.5% of the total flora, respectively. The three most diverse group of monocots were Cyperaceae (12 species), Poaceae (9 species), and Orchidaceae (7 species) that consisted of 6.0%, 4.5%, and 3.5% of the total recorded species, respectively. Dryopteridaceae (4 species, 2.0%), Polypodiaceae (4 species, 2.0%), and Selaginellaceae (3 species, 1.5%) were the largest families represented in the group in monilophytes. In bryophytes group, single species was represented in each family. In the group of gymnosperms, Pinaceae and Taxaceae represented one species each. The six most dominant families are Ericaceae, Rosaceae, Cyperaceae, Asteraceae, Poaceae, and Orchidaceae (Fig. 2a). Altogether, they comprise about 34% of the total number of species in the studied areas. In this study, every species recorded is provided with taxonomic group, lifeform, flowering season, and voucher number (Table S2).

Lifeform and flowering seasons

The herbaceous and shrub lifeform were the most abundant species, recorded with 62% (125 species) and 29% (59 species), respectively; while the trees and climbers were least represented, at 7% (13 species) and 2% (4 species), respectively (Fig. 2b). The flowering for herbs mostly occurred in April to September, but peaked in July. The shrubs flowered mostly in April to July with the peak month in May. May and April months were the peak flowering seasons for trees and climbers, respectively (Fig. 2c).

The habitat types and vegetation

Based on the topographic features and vegetation of the wetlands, four most characteristic habitat types inhabited by plants were identified (Figs. 3 and 4).

Shallow fresh marsh was usually located near small streams and bottomlands. There is only one aquatic species, *Potamogeton crispus* L. occurred in such open pools (Fig. 3a). The characteristic species, i.e. *Enkianthus deflexus* (Griff.) C.K. Schneid., *Persicaria nepalensis* (Meisn.) H. Gross and *Rhododendron dalhousiae* var. *rhabdotum* (Balf. f. & R.E. Cooper) Cullen, were prominently found adjacent to the habitat. The *Acorus calamus* L. was abundant; and this characteristic species created a mat of vegetation that allowed small streams to run through channeling underneath. These channels

Table 1 Results showing the floristic composition in wetlands of Gasa.

Taxonomic group	Families	Genera	Species	Trees	Shrubs	Herbs	Climbers
Angiosperms	61	126	173	11	59	99	4
Gymnosperms	2	2	2	2	–	–	–
Bryophytes	6	6	6	–	–	6	–
Monilophytes	12	15	20	–	–	20	–
Total	81	149	201	13	59	125	4

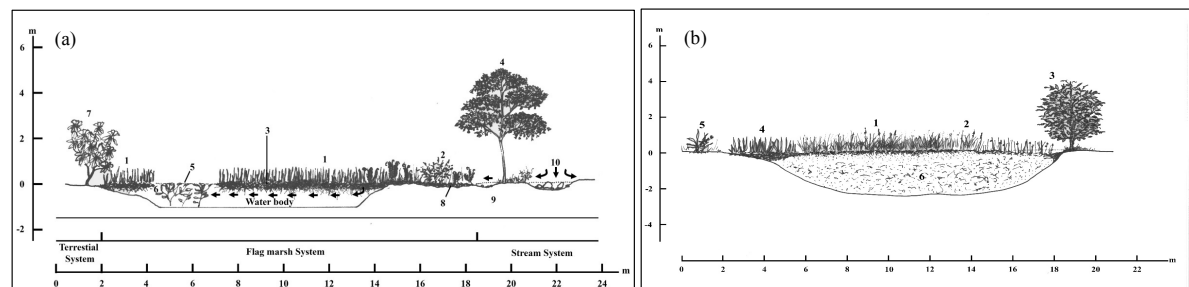


Fig. 3 Schematic profile diagram at Gasa. (a) *Flag marsh* vegetation: 1. *Acorus calamus*, 2. *Persicaria nepalensis*, 3. firm mat of flag marsh vegetation with water channel underneath, 4. *Enkianthus deflexus*, 5. open pool with aquatic vegetation, 6. *Potamogeton crispus*, 7. *Rhododendron dalhousiae* var. *rhabdotum*, 8. soil (organic matter) with firm mat of sweet flags' spreading rhizomes, 9. soil (loamy sand) with arrow showing the movement of underground water, and 10. channeled stream water and its movement (arrow showing its flow direction). (b) *Carex diandra* vegetation: 1. *Carex diandra*, 2. *Schoenoplectus mucronatus*, 3. *Lyonia ovalifolia*, 4. *Acorus calamus*, 5. *Cymbidium iridioides*, and 6. moderately decomposed sedge peat.

run on the side of the habitat ensuring minimal entry into the surface of habitat. During rainy seasons, these habitats were partially submerged, but well drained within few weeks.

Seasonally flooded basin of flat usually occurred in open bottomlands with floating mats dominated by *Carex diandra* Schrank. In fact, this habitat usually occurred in narrow zone where there is water

underneath. This characteristic species was found only in the wettest part of this filled basin including *Schoenoplectus mucronatus* (L.) Palla (Fig. 3b). The *Acorus calamus* L. vegetation inhabited next to this *C. diandra* Schrank vegetation, followed by *Lyonia ovalifolia* (Wall.) Drude, *Malus baccata* (L.) Borkh, and *Enkianthus deflexus* (Griff.) C.K. Schneid towards edge of forest. The epiphytic orchid, *Cymbid-*

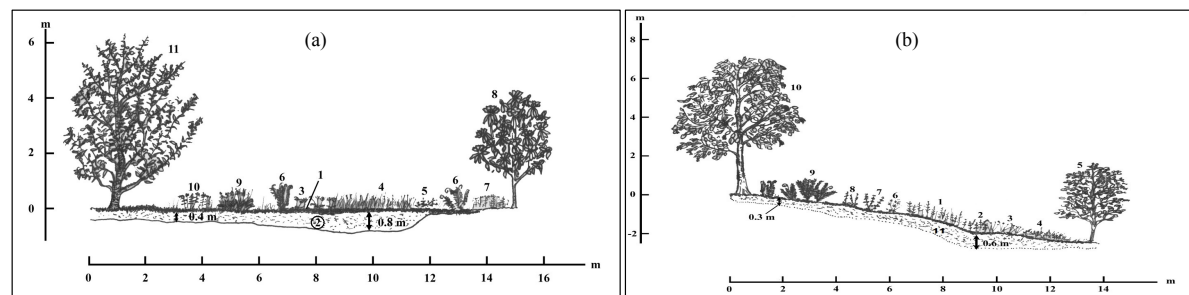


Fig. 4 Schematic profile diagram at Gasa. (a) *Poor fen* vegetation: 1. *Sphagnum palustre*, 2. undecomposed moss peat, 3. *Primula denticulata*, 4. *Carex capillacea*, 5. *Gentiana cephalodes*, 6. *Osmunda japonica*, 7. *Anaphalis margaritacea*, 8. *Rhododendron arboreum*, 9. *Luzula effusa*, 10. *Halenia elliptica*, and 11. *Malus baccata*. (b) *Fresh water meadow*: 1. *Equisetum ramosissimum*, 2. *Neanotis calycina*, 3. *Xyris capensis* var. *schoenoides*, 4. *Galium aparine*, 5. *Lyonia villosa*, 6. *Ixeridium beauverdianum*, 7. *Pedicularis gracilis* subsp. *stricta*, 8. *Spiranthes sinensis*, 9. *Matteuccia struthiopteris*, 10. *Alnus nepalensis*, and 11. wet soil with small sedge peat.

ium iridioides D. Don, was also inhabited on lifeless tree at the edge of the habitat.

Poor fen habitat occurred in open and forest fragments of slightly higher elevations (2433 m and above). Some patches of *Sphagnum palustre* L. vegetation were confined to this habitat and a thick layer of undecomposed peat within this vegetation was also prominent. Another characteristic species inhabited was *Osmunda japonica* Thunb. that occurred in some patches. The ericaceous shrubs were prominent in such habitats, e.g. *Rhododendron arboreum* Sm. and *Malus baccata* (L.) Borkh. (Fig. 4a). The climber species, *Holboellia latifolia* Wall., was also recorded on the *M. baccata* (L.) Borkh. shrub that occurred in the open habitat. This vegetation was usually influenced by precipitation in the area lacking groundwater and upstream components.

Fresh water meadow usually occurred on the slopes, open heath forests and, sometimes, even in fallow lands. This habitat usually has no standing water but remained waterlogged most of the year. The diverse and characteristic species, such as *Lyonia villosa* (Wall. ex C.B. Clarke) Hand.-Mazz., *Spiranthes sinensis* (Pers.) Ames, *Matteuccia struthiopteris* (L.) Tod. and *Alnus nepalensis* D. Don, are inhabited in this habitat. Mostly the characteristic species of herbs in this habitat are stunted (Fig. 4b).

DISCUSSION

Most of represented families differed within Himalayan Regions. The topmost dominant family, Ericaceae with 17 species, comprised 21% of total species (81 species) in the country [23]. However, this family was not even appeared in top ten dominant families in the Western and Eastern Himalayas [31] indicating that this family occurred mostly in the wetlands and its surroundings (ecotone). These ericaceous shrubs may be acid loving plants since they are mostly inhabited in the acidic soil/peat of wetlands [32]. Therefore, the diversity of ericaceous shrubs is high and topped the family representation in the wetlands (Fig. 2a). This result is limited to present study and may not represent the actual status of ericaceous plant diversity in the country. Hence further study on quantitative assessment of wetland plants are required to further confirm this result in the country and the region. The second dominant family was Rosaceae (12 species) represented 8.5% of total species (141 species) of the flora of Bhutan. However, in the Eastern and Western Himalayas, the family dominance stood at eighth position and might be changed if similar

studies are undertaken there. The third dominant family is Cyperaceae (12 species) which was fourth and fifth in the Eastern and Western Himalayas, respectively. This family has close affinity with the flora of western region and the family may have represented mostly from wetlands (Fig. 2a). Asteraceae (11 species) represented fourth position in the Eastern Himalayas and, therefore, their suitable habitats could be in wetlands of lower montane areas in the region. In the Western Himalayas, this family represented second position and may indicate diverse habitat preferences. However, this family included one invasive species, *Ageratina adenophora* (Spreng.) R.M. King & H. Rob. which is almost a threat to wetlands; and habitat loss may occur, thereby, threatening many wetland species [7]. Fortunately, this species occurred only in one site due to anthropogenic disturbances since being closed to road and human settlement. Therefore, understanding plants and its habitats may be first step in combating species losses. Orchidaceae presented sixth position, which is topmost dominant family in the country as well as in the Eastern Himalayas (Fig. 2a). These orchids represented 1.5% (7 species) of the total orchids (469 species) in the country [28,33]. The wetland habitats have favored these epiphytic and ground orchids to inhabit in and around the wetlands, thereby diversifying species in the wetlands. Amongst the least represented families, Potamogetonaceae showed unique species in the region. *Potamogeton crispus* L. is only aquatic plant represented in the wetlands and inhabited in small pools and running stream. However, this species was found frequent in Western Himalaya [34]. Altogether, the diversity of species in the wetlands represented 14% of the total flora in Jigme Dorji National Park and 3.6% of flora of Bhutan (Table S2).

The proportion of abundant species in the life-form group varied within the region. The proportion order of abundant species, i.e. herbs (62%), shrubs (29%), trees (7%), and climbers (2%) were recorded with similar pattern in the region (Fig. 2b). However, proportion of herbs and shrubs species were slightly higher compared to other parts of the country [16,35] and the Western Himalaya [36] that may be an indicator that the species representations are from wetlands including ecotone. Similarly, the proportion of trees and climbers under study are two to three folds lesser, as these wetlands usually are located at edge or open forest fragments, hence less trees and climbers (Fig. 2b).

The flowering seasons of lifeform groups also

varied in the wetlands. The peak flowering seasons for herbs, shrubs and trees, and climbers were in July, May and April months, respectively (Fig. 2c). These data may be useful for the science education programs (e.g. excursions) in schools and colleges to learn about pollination and floral ecology of diverse wetland plants.

The vegetation structure of habitat indicates its uniqueness in supporting the diverse species in each habitat. The species represented in the figures are the ones that are unique and abundant in such habitats. These species differed among habitats may be due to different microhabitats supporting such unique species. Therefore, these natural vegetation profile clearly displayed various structures of the unique vegetation and species composition in each habitat (Figs. 3 and 4).

The only submerged species, *Potamogeton crispus* L., occurred only in *Shallow fresh marsh* (Fig. 3a) and, in open pools due to light reaching into the bottom (depth of approximately 1 to 1.5 m) of habitat. The continuous discharge of water from bottom of the pools indicated water table (arrow showing flow of water towards pool) connected by small stream flowing under the firm mat vegetation. This species also occurred in flowing water towards south of the pools indicating undisturbed vegetation. However, there were no ponds nor proper drainage for flowing water to support this species in other three sites of this type of habitat. The abundant and characteristic species, *Acorus calamus* L., had created a mat (0.1–0.4 m depth of peat and soil) of vegetation and the small stream flowing underneath the mat vegetation at few points (about 4 to 6 m distance) (Fig. 3a). This channel may minimize entry of excess water into the surface of habitat. The characteristic species, i.e. *Enkianthus deflexus* (Griff.) C.K. Schneid., *Persicaria nepalensis* (Meisn.) H. Gross, and *Rhododendron dalhousieae* var. *rhabdotum* (Balf. f. & R.E. Cooper) Cullen may have added local species richness in the wetlands. Therefore, such intact pools, stream running underneath of mat vegetation and adjacent (ecotone) vegetation may have supported diverse species in such habitats (Fig. 3a).

The *seasonally flooded basin of flat* habitat occurred where there is permanent water underneath that supported the floating mats (*Carex diandra* Schrank.) vegetation indicating specific habitat (narrow zone) (Fig. 3b). This characteristic species was found only in the wettest part of this filled basin with the depth of about 2 to 2.5 meters of moderately decomposed sedge peat. The *Acorus*

calamus L. and other species inhabited towards edge of forest next to *C. diandra* Schrank vegetation, which may represent an ecotone for this habitat (Fig. 3b). Therefore, supported unique species may be available due to its differences in availability of water underneath, open space, and flat surface of habitats.

The *poor fen* habitat occurred slightly at higher elevations with thick layer of partial or undecomposed peat (about 0.4–0.8 m) of *Sphagnum palustre* L., which indicates the slower biological activity because of cold temperature (Fig. 4a). The ericaceous shrubs, *Rhododendron arboreum* Sm. and *Malus baccata* (L.) Borkh., were characteristic species in such habitat; and that may indicate unique composition of species. The *Osmunda japonica* Thunb. including ericaceous shrubs occurred in some patches that may indicate territorializing the wetland habitats and supporting diverse species.

The *fresh water meadow* usually occurred on the slopes and open heath forests indicating no standing water during growing seasons. Due to this unique habitat, diverse species of herbs, shrub and trees are supported, including characteristic species such as *Spiranthes sinensis* (Pers.) Ames, *Matteucia struthiopteris* (L.) Tod., *Lyonia villosa* (Wall. ex C.B. Clarke) Hand.-Mazz. and *Alnus nepalensis* D. Don (Fig. 4b). The characteristic species of herbs in this habitat, such as *Equisetum ramosissimum* Desf., *Neanotis calycina* (Wall. ex Hook. f.) W. H. Lewis, *Galium aparine* L., *Ixeridium beauverdianum* (H. Lév.) Spring., *Pedicularis gracilis* subsp. *stricta* (Prain) P.C. Tsoong, and *Spiranthes sinensis* (Pers.) Ames, are stunted. This may be due to less nutrients in soil and anthropogenic disturbances since they are located close to human settlements.

CONCLUSION

Wetland study has seen few important implications for conservation and management of biodiversity. Firstly, it shows that wetlands within the heath forests, forest fragments and bottomlands are truly a valuable resource for the conservation of plant diversity due to presence of large number of local species richness and several local rare species. In addition, high conservation priority could be given for wetlands with indicator species in the sites. These small wetland habitats supported both upland forest species and wetland species, which upland landscapes would not support the wetland species. Therefore, such small wetland habitats deserve protection. Secondly, to protect these wetlands, ecotone should also be considered to keep

the wetlands functionally intact. The study suggests protecting ecotone as part of the measures to protect wetlands. Lastly, the lack of IUCN assessment makes it challenging to understand the status of the native species of national/international concern. Therefore, species-based conservation action plans are required to improve their conservation status in the country.

Appendix A. Supplementary data

Supplementary data associated with this article can be found at <http://dx.doi.org/10.2306/scienceasia1513-1874.2021.007>.

Acknowledgements: The Graduate School of Prince of Songkla University, Hat Yai, Songkhla, Thailand's Education Hub for ASEAN Countries and Center of Excellence on Biodiversity (BDC), Office of Higher Education Commission (BDC-PG3-160016), Ministry of Higher Education, Science, Research and Innovation, Thailand supported this research. Authors would like to extend appreciation to Mr. Kezang Tobgay, Herbarium, National Biodiversity Centre for helping in authentication of specimens, Mr. Sangay Namgay, teacher of Wanakha Centre School, Paro for preparing schematic profile diagrams, Mr. Tshering Dendup (CiD-1090500086), teacher for preparing our study map and Mr. Sangay Tenzin (EiD-20190113354), teacher of CAFPS, Haa for his field assistance during sample collections.

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Appendix A. Supplementary data

Table S1 Total plots sampled and species recorded (in 1 × 1 m² plot and adjacent plot) in each site.

Site/site code	Gasa1 (S1)	Gasa2 (S2)	Gasa3 (S3)	Damji1 (S4)	Damji2 (S5)	Damji3 (S6)	Tashithang (S7)	Total
Plots/site	44	31	45	48	22	18	18	226
Species/site	45	33	37	40	29	32	34	250
Species recorded from 7 sites (plot)								111
Species recorded from adjacent plots (including shrub, liana, fern and tree)								90

Table S2 List of wetland plant species recorded with taxonomic group, lifeform, flowering seasons and voucher number in Gasa, Bhutan. Species in the list are arranged in alphabetical order of families.

Scientific name	Family	Group	Life form	Flowering season	Voucher No.
<i>Strobilanthes auriculata</i> Nees	Acanthaceae	Eudicot	Shrub	Oct–Feb	PTndar211
<i>Acorus calamus</i> L.	Acoraceae	Monocot	Herb	Apr–Jul	PTndar003
<i>Viburnum erubescens</i> Wall.	Adoxaceae	Eudicot	Shrub	Apr–May	PTndar223
<i>Viburnum mullaha</i> Buch.-Ham. ex D. Don	Adoxaceae	Eudicot	Shrub	Jul–Sep	PTndar225
<i>Sagittaria tengtsungensis</i> H. Li	Alismataceae	Monocot	Herb	May–Oct	PTndar192
<i>Centella asiatica</i> (L.) Urb.	Apiaceae	Eudicot	Herb	Mar–Apr	PTndar037
<i>Oenanthe hookeri</i> C.B. Clarke	Apiaceae	Eudicot	Herb	Jul–Sep	PTndar137
<i>Oenanthe javanica</i> (Blume) DC.	Apiaceae	Eudicot	Herb	Apr–Oct	PTndar138
<i>Arisaema concinnum</i> Schott	Araceae	Monocot	Herb	Apr–Jul	PTndar013
<i>Arisaema flavum</i> (Forssk.) Schott	Araceae	Monocot	Herb	Jun–Jul	PTndar014
<i>Colocasia esculenta</i> (L.) Schott	Araceae	Monocot	Herb	Jul–Sep	PTndar043
<i>Hedera nepalensis</i> K. Koch	Araliaceae	Eudicot	Liana	Oct–Nov	PTndar094
<i>Hydrocotyle nepalensis</i> Hook.	Araliaceae	Eudicot	Herb	May–Jul	PTndar098
<i>Hydrocotyle sibthorpioides</i> Lam.	Araliaceae	Eudicot	Herb	Mar–Apr	PTndar099
<i>Schefflera roxburghii</i> Gamble	Araliaceae	Eudicot	Liana	Apr–Jul	PTndar195
<i>Ageratina adenophora</i> (Spreng.) R.M. King & H. Rob.	Asteraceae	Eudicot	Shrub	Jan–Jun	PTndar005
<i>Ainsliaea latifolia</i> (D. Don) Sch. Bip.	Asteraceae	Eudicot	Herb	Mar–Jun	PTndar008
<i>Anaphalis margaritacea</i> (L.) Benth. & Hook. f.	Asteraceae	Eudicot	Herb	Jul–Dec	PTndar010
<i>Artemisia indica</i> Willd.	Asteraceae	Eudicot	Herb	Jul–Sep	PTndar015
<i>Artemisia verlotiorum</i> Lamotte	Asteraceae	Eudicot	Herb	Aug–Oct	PTndar016
<i>Artemisia austroyunnanensis</i> Y. Ling & Y.-R. Ling	Asteraceae	Eudicot	Shrub	Aug–Oct	PTndar017
<i>Aster neoelegans</i> Grierson	Asteraceae	Eudicot	Herb	May–Sep	PTndar018
<i>Cirsium falconeri</i> (Hook. fil.) Petr.	Asteraceae	Eudicot	Herb	Jul–Oct	PTndar040
<i>Crassocephalum crepidioides</i> (Benth.) S. Moore	Asteraceae	Eudicot	Herb	Apr–Dec	PTndar048
<i>Ixeridium beauverdianum</i> (H. Lév.) Spring.	Asteraceae	Eudicot	Herb	Mar–Aug	PTndar112
<i>Pseudognaphalium affine</i> (D. Don) Anderb.	Asteraceae	Eudicot	Herb	Mar–Dec	PTndar166
<i>Diplazium taiwanense</i> Tagawa	Athyriaceae	Monilo	Herb		PTndar059
<i>Impatiens arguta</i> Hook. f. & Thomson	Balsaminaceae	Eudicot	Herb	May–Oct	PTndar107
<i>Impatiens racemosa</i> DC.	Balsaminaceae	Eudicot	Herb	May–Nov	PTndar108
<i>Berberis aristata</i> DC.	Berberidaceae	Eudicot	Shrub	Apr–May	PTndar020
<i>Mahonia nepalensis</i> DC.	Berberidaceae	Eudicot	Shrub	Apr	PTndar131
<i>Alnus nepalensis</i> D. Don	Betulaceae	Eudicot	Tree	Jul–Oct	PTndar009
<i>Cynoglossum lanceolatum</i> Forssk.	Boraginaceae	Eudicot	Herb	Year round	PTndar051
<i>Cirriphyllum</i> sp.	Brachytheciaceae	Moss	Herb		PTndar039
<i>Cardamine flexuosa</i> With.	Brassicaceae	Eudicot	Herb	Jan–Jun	PTndar027
<i>Nasturtium officinale</i> W.T. Aiton	Brassicaceae	Eudicot	Herb	Jun	PTndar134
<i>Rhodobryum giganteum</i> (Schwägr.) Paris	Bryaceae	Moss	Herb		PTndar174
<i>Sarcococca hookeriana</i> Baill.	Buxaceae	Eudicot	Shrub	Apr–Jun	PTndar194
<i>Lobelia erectiuscula</i> H.Hara	Campanulaceae	Eudicot	Herb	Jul–Sep	PTndar125
<i>Cannabis sativa</i> L.	Cannabaceae	Eudicot	Herb	Jun–Aug	PTndar026
<i>Dipsacus inermis</i> Wall.	Caprifoliaceae	Eudicot	Herb	Aug–Sep, Dec	PTndar060
<i>Sagina japonica</i> (Sw.) Ohwi	Caryophyllaceae	Eudicot	Herb	May–Jun	PTndar191
<i>Stellaria reticulivena</i> Hayata	Caryophyllaceae	Eudicot	Herb	Apr–May	PTndar210
<i>Commelina diffusa</i> Burm. f.	Commelinaceae	Monocot	Herb	Apr–Oct	PTndar044
<i>Commelina paludosa</i> Blume	Commelinaceae	Monocot	Herb	May–Nov	PTndar045
<i>Cyanotis vaga</i> (Lour.) Roem. & Schult.	Commelinaceae	Monocot	Herb	Jun–Oct	PTndar049
<i>Toricellia tilifolia</i> DC.	Cornaceae	Eudicot	Shrub	Apr–May	PTndar216
<i>Carex condensata</i> Nees	Cyperaceae	Monocot	Herb	Apr–Aug	PTndar028
<i>Carex filicina</i> Nees	Cyperaceae	Monocot	Herb	Apr–Aug	PTndar029
<i>Carex capillacea</i> Boott	Cyperaceae	Monocot	Herb	Apr–Jul	PTndar030
<i>Carex diandra</i> Schrank	Cyperaceae	Monocot	Herb	May–Jun	PTndar031
<i>Carex rara</i> Boott	Cyperaceae	Monocot	Herb	Apr–Jul	PTndar034
<i>Carex rostrata</i> Hoppe ex Schkuhr	Cyperaceae	Monocot	Herb	Apr–Aug	PTndar035
<i>Carex setigera</i> D. Don	Cyperaceae	Monocot	Herb	Apr	PTndar036
<i>Fimbristylis ovata</i> (Burm. f.) J. Kern	Cyperaceae	Monocot	Herb	Aug–Sep	PTndar079

Table S2 Continued ...

Scientific name	Family	Group	Life form	Flowering season	Voucher No.
<i>Pycnus flavidus</i> (Retz.) T. Koyama	Cyperaceae	Monocot	Herb	Jun-Jul	PTndar169
<i>Pycnus sanguinolentus</i> (Vahl) Nees ex C.B. Clarke	Cyperaceae	Monocot	Herb	Jul-Sep	PTndar170
<i>Schoenoplectus mucronatus</i> (L.) Palla	Cyperaceae	Monocot	Herb	May-Jun	PTndar197
<i>Scirpus wichurai</i> Kom.	Cyperaceae	Monocot	Herb	Jul-Aug	PTndar198
<i>Acystopteris</i> sp.	Cystopteridaceae	Monilo	Herb		PTndar004
<i>Daphniphyllum himalayense</i> subsp. <i>macropodium</i> (Miq.) T.C.Huang	Daphniphyllaceae	Eudicot	Shrub	Mar-May	PTndar055
<i>Daphniphyllum himalayense</i> (Benth.) Mull.Arg.	Daphniphyllaceae	Eudicot	Tree	May-Sep	PTndar056
<i>Hypolepis polypodioides</i> (Blume) Hook.	Dennstaedtiaceae	Monilo	Herb		PTndar106
<i>Pteridium revolutum</i> (Blume) Nakai	Dennstaedtiaceae	Monilo	Herb		PTndar167
<i>Dryopteris juxtaposita</i> Christ	Dryopteridaceae	Monilo	Herb		PTndar063
<i>Dryopteris</i> sp.	Dryopteridaceae	Monilo	Herb		PTndar064
<i>Dryopteris uniformis</i> (Makino) Makino	Dryopteridaceae	Monilo	Herb		PTndar066
<i>Polystichum piceopaleaceum</i> Tag.	Dryopteridaceae	Monilo	Herb		PTndar157
<i>Elaeagnus parvifolia</i> Wall. ex Royle	Elaeagnaceae	Eudicot	Herb	Mar-Jun	PTndar067
<i>Equisetum ramosissimum</i> Desf.	Equisetaceae	Monilo	Herb		PTndar073
<i>Enkianthus deflexus</i> (Griff.) C.K. Schneid.	Ericaceae	Eudicot	Shrub	May-Jun	PTndar070
<i>Gaultheria semi-infera</i> (C.B. Clarke) Airy Shaw	Ericaceae	Eudicot	Shrub	May-Jun	PTndar082
<i>Gaultheria nummularioides</i> D. Don	Ericaceae	Eudicot	Shrub	Aug-Sep	PTndar083
<i>Leucothoe griffithiana</i> C.B. Clarke	Ericaceae	Eudicot	Shrub	Jun-Aug	PTndar121
<i>Lyonia ovalifolia</i> (Wall.) Drude	Ericaceae	Eudicot	Shrub	May-Aug	PTndar127
<i>Lyonia villosa</i> (Wall. ex C.B. Clarke) Hand.-Mazz.	Ericaceae	Eudicot	Shrub	Jun-Aug	PTndar128
<i>Pieris formosa</i> (Wall.) D. Don	Ericaceae	Eudicot	Shrub	Feb-Jun	PTndar150
<i>Rhododendron arboreum</i> Sm.	Ericaceae	Eudicot	Shrub	Mar-Jun	PTndar175
<i>Rhododendron dalhousiae</i> var. <i>rhabdotum</i> (Balf. f. & R.E. Cooper) Cullen	Ericaceae	Eudicot	Shrub	Apr-Jul	PTndar176
<i>Rhododendron edgeworthii</i> Hook. f.	Ericaceae	Eudicot	Shrub	Apr-May	PTndar177
<i>Rhododendron lindleyi</i> T. Moore	Ericaceae	Eudicot	Shrub	Apr-May	PTndar178
<i>Rhododendron maddenii</i> Hook. f.	Ericaceae	Eudicot	Shrub	May-Jul	PTndar179
<i>Rhododendron triflorum</i> Hook. f.	Ericaceae	Eudicot	Shrub	Apr-Jun	PTndar180
<i>Rhododendron virgatum</i> Hook. f.	Ericaceae	Eudicot	Shrub	Apr-May	PTndar181
<i>Vaccinium dunalianum</i> Wight	Ericaceae	Eudicot	Shrub	Apr-May	PTndar220
<i>Vaccinium glaucoalbum</i> Hook. f. ex C. B. Clarke	Ericaceae	Eudicot	Shrub	May-Jul	PTndar221
<i>Vaccinium retusum</i> (Griff.) Hook. f. ex C. B. Clarke	Ericaceae	Eudicot	Shrub	Apr-Jun	PTndar222
<i>Eriocaulon viride</i> Körn.	Eriocaulaceae	Monocot	Herb	Jul-Oct	PTndar074
<i>Macaranga pustulata</i> King ex Hook.f.	Euphorbiaceae	Eudicot	Tree	Nov-Mar	PTndar129
<i>Parochetus communis</i> Buch.-Ham. ex D. Don	Fabaceae	Eudicot	Herb	Mar-Sep	PTndar142
<i>Trifolium repens</i> L.	Fabaceae	Eudicot	Herb	Apr-Jun	PTndar217
<i>Quercus griffithii</i> Hook.f. & Thomson ex Miq.	Fagaceae	Eudicot	Tree	Apr	PTndar171
<i>Gentiana cephalodes</i> Edgew.	Gentianaceae	Eudicot	Herb	Aug-Oct	PTndar084
<i>Gentiana capitata</i> Buch.-Ham. ex D. Don	Gentianaceae	Eudicot	Herb	Feb-Jun	PTndar085
<i>Gentiana maeulchanensis</i> Franch.	Gentianaceae	Eudicot	Herb	Apr-Jun	PTndar086
<i>Gentiana pedicellata</i> (Wall. ex D. Don) Griseb.	Gentianaceae	Eudicot	Herb	Feb-May	PTndar087
<i>Halenia elliptica</i> D. Don	Gentianaceae	Eudicot	Herb	May-Sep	PTndar093
<i>Swertia bimaculata</i> (Siebold & Zucc.) Hook. f. & Thomson ex C.B. Clarke	Gentianaceae	Eudicot	Herb	Jul-Oct	PTndar212
<i>Geranium lambertii</i> Sweet	Geraniaceae	Eudicot	Herb	Jul-Sep	PTndar088
<i>Geranium procurrans</i> Yeo	Geraniaceae	Eudicot	Herb	Jul-Sep	PTndar089
<i>Gonocarpus micranthus</i> Thunb.	Haloragaceae	Eudicot	Herb	Jul-Sep	PTndar092
<i>Dichroa febrifuga</i> Lour.	Hydrangeaceae	Eudicot	Shrub	May-Nov	PTndar058
<i>Hypericum gramineum</i> G. Forst.	Hypericaceae	Eudicot	Herb	Jun-Aug	PTndar100
<i>Hypericum hookerianum</i> Wight & Arn.	Hypericaceae	Eudicot	Shrub	Jun-Aug	PTndar101
<i>Hypericum petiolulatum</i> Hook. f. & Thomson ex Dyer	Hypericaceae	Eudicot	Herb	Jul-Aug	PTndar103
<i>Hypnum</i> sp.	Hypnaceae	Moss	Herb		PTndar104
<i>Juglans regia</i> L.	Juglandaceae	Eudicot	Tree	Apr-May	PTndar114
<i>Juncus bufonius</i> L.	Juncaceae	Monocot	Herb	Apr-Aug	PTndar115
<i>Juncus inflexus</i> L.	Juncaceae	Monocot	Herb	Apr-Aug	PTndar116
<i>Juncus prismatocarpus</i> R. Br.	Juncaceae	Monocot	Herb	Apr-Aug	PTndar117
<i>Luzula effusa</i> Buchenau	Juncaceae	Monocot	Herb	May-Aug	PTndar126
<i>Elsholtzia fruticosa</i> (D. Don) Rehder	Lamiaceae	Eudicot	Shrub	Aug-Oct	PTndar069
<i>Isodon hispidus</i> (Benth.) Murata	Lamiaceae	Eudicot	Herb	Oct-Nov	PTndar110
<i>Leucas ciliata</i> Benth.	Lamiaceae	Eudicot	Herb	Jun-Oct	PTndar119
<i>Phlomis macrophylla</i> Benth.	Lamiaceae	Eudicot	Herb	Jul-Aug	PTndar149
<i>Prunella vulgaris</i> L.	Lamiaceae	Eudicot	Herb	May-Aug	PTndar165
<i>Holboellia latifolia</i> Wall.	Lardizabalaceae	Eudicot	Liana	Apr-Jun	PTndar096
<i>Lindera pulcherrima</i> (Nees) Hook. f.	Lauraceae	Magno	Shrub	Apr-Jun	PTndar124
<i>Utricularia bifida</i> L.	Lentibulariaceae	Eudicot	Herb	Jul-Sep	PTndar219
<i>Scurrula elata</i> (Edgew.) Danser	Loranthaceae	Eudicot	Shrub	Apr-Jun	PTndar199
<i>Magnolia campbellii</i> Hook.f. & Thomson	Magnoliaceae	Magno	Tree	Mar-May	PTndar130
<i>Leucolepis acanthoneura</i> (Schwagr.) Lindb.	Mniaceae	Moss	Herb		PTndar120
<i>Jasminum humile</i> L.	Oleaceae	Eudicot	Shrub	May-Jul	PTndar113
<i>Ligustrum confusum</i> Decne.	Oleaceae	Eudicot	Shrub	Apr-Jul	PTndar123
<i>Oleandra undulata</i> (Willd.) Ching	Oleandraceae	Monilo	Herb		PTndar139
<i>Epilobium sikkimense</i> Hausskn.	Onagraceae	Eudicot	Herb	Jul-Sep	PTndar071

Table S2 Continued . . .

Scientific name	Family	Group	Life form	Flowering season	Voucher No.
<i>Epilobium wallichianum</i> Hausskn.	Onagraceae	Eudicot	Herb	Jul-Sep	PTndar072
<i>Matteuccia struthiopteris</i> (L.) Tod.	Onocleaceae	Monilo	Herb	PTndar133	
<i>Bulbophyllum striatum</i> (Griff.) Rchb. f.	Orchidaceae	Monocot	Herb	Oct-Nov	PTndar023
<i>Calanthe griffithii</i> Lindl. & Paxton	Orchidaceae	Monocot	Herb	Apr-Jul	PTndar024
<i>Coelogyne stricta</i> (D. Don) Schltr.	Orchidaceae	Monocot	Herb	Mar-Jun, Oct-Nov	PTndar042
<i>Cymbidium iridioides</i> D. Don	Orchidaceae	Monocot	Herb	Oct-Nov	PTndar050
<i>Dendrobium fimbriatum</i> Hook.	Orchidaceae	Monocot	Herb	Mar-May	PTndar057
<i>Pleione praecox</i> (Sm.) D. Don	Orchidaceae	Monocot	Herb	Sep-Nov (Dec)	PTndar156
<i>Spiranthes sinensis</i> (Pers.) Ames	Orchidaceae	Monocot	Herb	Mar-Oct	PTndar209
<i>Euphrasia bhutanica</i> Pugsley	Orobanchaceae	Eudicot	Herb	May-Sep	PTndar076
<i>Pedicularis gracilis</i> subsp. <i>stricta</i> (Prain) P.C. Tsoong	Orobanchaceae	Eudicot	Herb	Jun-Sep	PTndar143
<i>Osmunda japonica</i> Thunb.	Osmundaceae	Monilo	Herb		PTndar141
<i>Tsuga dumosa</i> (D. Don) Eichler	Pinaceae	Gymno	Tree	May-Jun	PTndar218
<i>Piper suiwigua</i> Buch.-Ham. ex D. Don	Piperaceae	Magno	Liana	May-Aug	PTndar154
<i>Ellisiophyllum pinnatum</i> (Wall. Ex Benth.) Makino	Plantaginaceae	Eudicot	Herb	Apr-Aug	PTndar068
<i>Plantago erosa</i> Wall.	Plantaginaceae	Eudicot	Herb	Mar-Aug	PTndar155
<i>Agrostis micrantha</i> Steud.	Poaceae	Monocot	Herb	May-Nov	PTndar006
<i>Agrostis zenkeri</i> Trin.	Poaceae	Monocot	Herb	Sep-Oct	PTndar007
<i>Brachypodium</i> sp.	Poaceae	Monocot	Herb	Jun-Oct	PTndar021
<i>Bromus hordeaceus</i> L.	Poaceae	Monocot	Herb	May-Jun	PTndar022
<i>Festuca arundinacea</i> Schreb.	Poaceae	Monocot	Herb	May-Sep	PTndar077
<i>Festuca gigantea</i> Krock.	Poaceae	Monocot	Herb	Jul-Sep	PTndar078
<i>Isachne albens</i> Trin.	Poaceae	Monocot	Herb	Jul-Feb	PTndar109
<i>Saccharum sikkimense</i> (Hook. f.) Nayar ex Bor	Poaceae	Monocot	Herb	Jul-Jan	PTndar189
<i>Thamnocalamus spathiflorus</i> (Trin.) Munro	Poaceae	Monocot	Shrub		PTndar215
<i>Persicaria hydropiper</i> (L.) Delarbre	Polygonaceae	Eudicot	Herb	Apr-Sep	PTndar145
<i>Persicaria nepalensis</i> (Meisn.) H. Gross	Polygonaceae	Eudicot	Herb	Apr-Oct	PTndar146
<i>Persicaria perfoliata</i> (L.) H. Gross	Polygonaceae	Eudicot	erb	May-Oct	PTndar147
<i>Rumex nepalensis</i> Spreng.	Polygonaceae	Eudicot	Herb	May-Jul	PTndar188
<i>Drynaria parishii</i> (Bedd.) Bedd.	Polypodiaceae	Monilo	Herb		PTndar061
<i>Drynaria propinqua</i> (Wall. ex Mett.) Bedd	Polypodiaceae	Monilo	Herb		PTndar062
<i>Goniophlebium formosanum</i> (Baker) Rodl-Linder	Polypodiaceae	Monilo	Herb		PTndar091
<i>Lepisorus thunbergianus</i> (Kaulf.) Ching	Polypodiaceae	Monilo	Herb		PTndar118
<i>Potamogeton crispus</i> L.	Potamogetonaceae	Monocot	Herb	Apr (-Jun)	PTndar158
<i>Ardisia macrocarpa</i> Wall.	Primulaceae	Eudicot	Shrub	May-Jul	PTndar012
<i>Primula denticulata</i> Sm.	Primulaceae	Eudicot	Herb	Feb-Jun	PTndar162
<i>Prionodon</i> sp.	Prionodontaceae	Moss	Herb		PTndar164
<i>Pteris wallichiana</i> J. Agardh	Pteridaceae	Monilo	Herb		PTndar168
<i>Clematis montana</i> Buch.-Ham. ex DC.	Ranunculaceae	Eudicot	Shrub	Apr-Jul	PTndar041
<i>Ranunculus diffusus</i> DC.	Ranunculaceae	Eudicot	Herb	Apr-Aug	PTndar173
<i>Thalictrum foliolosum</i> DC.	Ranunculaceae	Eudicot	Herb	Jun-Aug	PTndar214
<i>Cotoneaster bacillaris</i> Wall. ex Lindl.	Rosaceae	Eudicot	Tree	May-Jun	PTndar046
<i>Fragaria nubicola</i> (Hook. f.) Lindl. ex Lacaite	Rosaceae	Eudicot	Herb	Apr-Jun	PTndar080
<i>Malus baccata</i> (L.) Borkh.	Rosaceae	Eudicot	Shrub	Apr-May	PTndar132
<i>Prinsepia utilis</i> Royle	Rosaceae	Eudicot	Shrub	Mar-Apr	PTndar163
<i>Rosa brunonii</i> Lindl.	Rosaceae	Eudicot	Shrub	May-Jul	PTndar182
<i>Rosa sericea</i> Lindl.	Rosaceae	Eudicot	Shrub	Apr-Jun	PTndar183
<i>Rubus biflorus</i> Buch.-Ham. ex Sm.	Rosaceae	Eudicot	Shrub	May-Jul	PTndar185
<i>Rubus ellipticus</i> Sm.	Rosaceae	Eudicot	Liana	Feb-Apr	PTndar186
<i>Rubus paniculatus</i> Sm.	Rosaceae	Eudicot	Liana	Jun-Nov	PTndar187
<i>Sorbus foliolosa</i> (Wall.) Spach	Rosaceae	Eudicot	Tree	May-Jun	PTndar205
<i>Sorbus thomsonii</i> (King ex Hook.f.) Rehder	Rosaceae	Eudicot	Tree	Apr-May	PTndar206
<i>Sorbus wallichii</i> (Hook.f.) T.T. Yu	Rosaceae	Eudicot	Tree	Apr-May	PTndar207
<i>Neanotis calycina</i> (Wall. ex Hook. f.) W. H. Lewis	Rubiaceae	Eudicot	Herb	Jun-Sep	PTndar081
<i>Galium aparine</i> L.	Rubiaceae	Eudicot	Herb	Jul-Sep	PTndar135
<i>Rubia wallichiana</i> Decne.	Rubiaceae	Eudicot	Herb	Apr-Sep	PTndar184
<i>Zanthoxylum acanthopodium</i> DC.	Rutaceae	Eudicot	Shrub	Oct-Feb	PTndar227
<i>Salix stomatophora</i> Flod.	Salicaceae	Eudicot	Shrub	Apr	PTndar193
<i>Acer campbellii</i> Hook.f. & Thomson	Sapindaceae	Eudicot	Tree	Apr-May	PTndar001
<i>Houttuynia cordata</i> Thunb.	Saururaceae	Magno	Herb	Jun-Aug	PTndar097
<i>Astilbe rivularis</i> Buch.-Ham. ex D. Don	Saxifragaceae	Eudicot	Herb	Jul-Oct	PTndar019
<i>Selaginella monospora</i> Spring	Selaginellaceae	Monilo	Herb		PTndar200
<i>Selaginella helvetica</i> (L.) Spring	Selaginellaceae	Monilo	Herb		PTndar201
<i>Selaginella remotifolia</i> Spring	Selaginellaceae	Monilo	Herb		PTndar202
<i>Smilax perfoliata</i> Lour.	Smilacaceae	Monocot	Liana	Mar-Aug	PTndar203
<i>Smilax myrtillosa</i> var. <i>rigida</i> Noltie	Smilacaceae	Monocot	Shrub	Sep-Oct	PTndar204
<i>Sphagnum palustre</i> L.	Sphagnaceae	Moss	Herb		PTndar208
<i>Taxus baccata</i> L.	Taxaceae	Gymno	Tree	Mar-Apr	PTndar213
<i>Daphne bholua</i> Buch.-Ham. ex D. Don	Thymelaeaceae	Eudicot	Shrub	Feb-May	PTndar052
<i>Daphne involucrata</i> Wall.	Thymelaeaceae	Eudicot	Shrub	Nov-Feb	PTndar053
<i>Girardinia diversifolia</i> (Link) Friis	Urticaceae	Eudicot	Herb	Jul-Sep	PTndar090
<i>Pilea symmeria</i> Wedd.	Urticaceae	Eudicot	Herb	May-Jul	PTndar151
<i>Pilea anisophylla</i> (Hook. f.) Wedd.	Urticaceae	Eudicot	Herb	Apr-Jun	PTndar152
<i>Pilea approximata</i> C.B. Clarke	Urticaceae	Eudicot	Herb	Jun-Jul	PTndar153
<i>Xyris capensis</i> var. <i>schoenoides</i> (Mart.) Nilsson	Xyridaceae	Monocot	Herb	Jun-Sep	PTndar226

Abbreviation for group: Monilo, Monilophytes; Gymno, Gymnosperm; and Magno, Magnoliids.