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Vegetation structure and plant species composition of the valley bottom wetland Gangtey-Phobji, Wangdue Phodrang, Bhutan

Jigme Tshewang[1, 2, *] & Kitichate Sridith[1]

[1] Division of Biological Science, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand

[2] Tang Central School, Ministry of Education, Bumthang, Bhutan

Abstract. Understanding wetland vegetation and plant species composition are crucial for wetland ecosystem restoration and sustainable biodiversity conservation. The floristic composition was collected with 170 stratified quadrat sampling of 1 × 1 m^2, 4 × 4 m^2 and 10 × 10 m^2 for herbs, shrubs and trees. The results showed that a total of 241 species belonging to 173 genera and 75 families were found. Of these, they are 220 angiosperms, 3 gymnosperms, 5 bryophytes and 13 monilophytes. The most abundant life forms were herbaceous with 87%, shrub with 9% and 2% of trees and climbers in the wetland. The three different schematic profile diagram represents general vegetation structure and unique habitats of Gangtey-Phobji wetland, one of the largest high-altitude wetland. The conservation agencies can use the study findings for appropriate conservation of wetlands in the Himalayan, Bhutan.

Keywords: conservation, ecosystem, high altitude, Himalayan, schematic profile

Introduction

Wetlands are crucial for humankind across the globe as they provide many valuable ecosystem services; freshwater supply, water storage, flood control, climate regulation, carbon sequestration and greenhouse gas emissions (Maltby & Acreman, 2011). In addition, wetlands support a diverse array of floral and faunal species and are critical habitats for world migratory faunal species (Skeffington *et al.,* 2006; Hebb *et al.,* 2013; Wetser *et al.,* 2015). Wetland plants are defined as having

* Corresponding author: jtshewang@education.gov.bt

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an ability to inhabit wet places and adapt to different ecological tolerances like flooded or saturated soils (Cronk & Fennessy, 2001). In addition to a rich diversity of vascular plants, wetlands also serve as essential habitat for bryophytes, mostly peat mosses (*Sphagnum* sp.) that dominantly thrive in bogs. Mosses have high water retaining capacity, creating waterlogged conditions and generating acidity in wetlands (Cornelissen *et al.,* 2007; Turetsky *et al.,* 2012). The occurrence of trait variation patterns within habitats, and broader ecological conditions partly reflects different species adaptation (Reich *et al.,* 2003). Due to unique features, wetlands are ecologically sensitive systems that significantly impact ecosystem services if disturbed (Turner *et al.,* 1998). The disturbances of pristine natural wetlands at an alarming rate lead to the loss of global species higher than the estimated figures and have become a global concern (Greuter, 1994; Pimm *et al.,* 1995). Besides, habitat depletion and species extinction in biodiversity hotspots are crucial globally (Underwood *et al.,* 2009).

The Himalayan region is known for the world's top biodiversity hotspots with a rich repository of native and endemic species of both flora and fauna (Dar & Sundarapandian, 2016). Bhutan being in the part of Eastern Himalaya, 5,603 vascular plants are documented in the Flora of Bhutan, with 94% being native species (Chhetri & Tenzin, 2012). However, studies revealed numerous wetland plant species are threatened and endangered (Meng *et al.,* 2017; Tendar & Sridith, 2021). Hence, the inevitable step to conserve and protect the world's biodiversity can be scientific exploration and collection of baseline data for the vital identification of conservation strategies (Hove & Chapungu, 2013). Further, studies of plant species composition and vegetation structure in wetlands are keys to ensuring their conservation and sustainable management, which is challenging to understand the status of wetland vegetation (National Biodiversity Centre, 2015).

However, the scientific studies of vegetation in Bhutan have only been limited to vegetation zonation (Ohsawa, 1987), grassland vegetation (Ohsawa, 1987; Dorji & Gurung, 2018), alpine vegetation (Jamtsho & Sridith, 2015), lower montane vegetation (Jamtsho & Sridith, 2017) and distribution pattern of the genus *Rhododendron* in Himalayan range (Namgay & Sridith, 2020).

Specifically, scientific studies on wetlands remain significantly less with only a handful of previous studies on wetland plant communities and vegetation structure of the eastern Himalayan highlands in northern Bhutan (Tendar *et al.,* 2020), impact on plant diversity in the wetlands of Gangtey-Phobji by human settlement (Lhamo *et al.,* 2020) and the change of land cover and ecosystem services in Phobjikha valley (Chaudhary *et al.,* 2017). Therefore, the goal of the study in Gangtey-Phobji valley bottom wetlands was to: (1) investigate the species composition of the valley bottom wetland and (2) describe the vegetation structures of valley bottom wetland of Gangtey-Phobji, Wangdue Phodrang, Bhutan.

Materials and Methods

Study area

The Gangtey-Phobji valley bottom wetland is in the central part of Bhutan at an average elevation of 3,500 m above sea level between latitude 27°26'46"N and longitude 90°11'08"E (Fig. 1). The valley is one of the most extensive high-altitude valley bottom wetlands in Bhutan situated on the western slopes of Jigme Singye Wangchuk National Park with approximately 97,000 hectares and designated as Ramsar wetland site in the year 2012 (International Centre for Integrated Mountain Development & Royal Society for Protection of Nature, 2014). The wetland hosts rich floral and faunal species, including endangered, Black-necked crane (*Grus nigricollis*), which migrates during winter from the Tibetan Plateau (Royal Society for Protection of Nature, 2007; Pradhan, 2010).

The wetland is surrounded by the people of two gewogs (the smallest geographic administrative unit), Gangtey and Phobji, with 701 households, and the landscape's panoramic view has made core attraction for domestic and international tourists' sites (International Centre for Integrated Mountain Development & Royal Society for Protection of Nature, 2014). People mainly depend on their livelihood on agriculture and livestock, especially with large scale potato cultivation. The intense cultivating of potatoes and continuous grazing by yaks, cows and horses may significantly threaten wetland's vegetation and ecosystem services (Phuntsho, 2010).

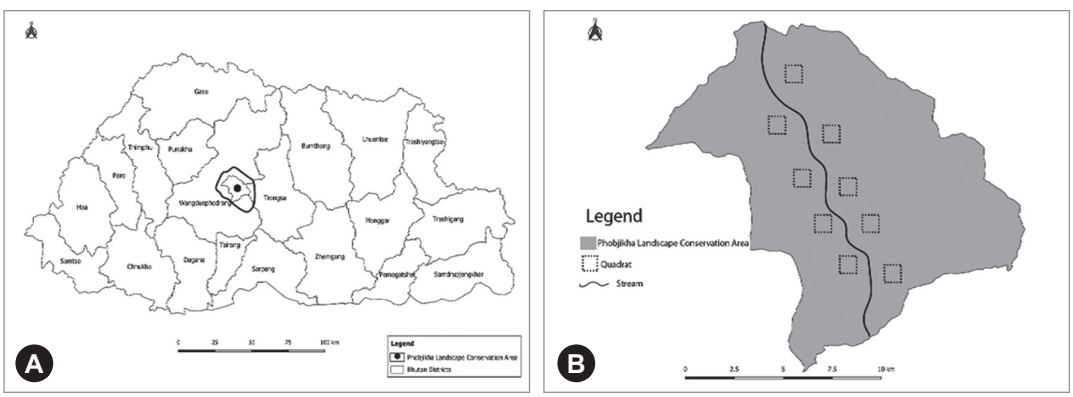

Figure 1. Bhutan with Wangdue Phodrang district (A) and study sites with sampling plots in Gangtey-Phobji valley bottom wetland (B).

Data collection and analysis

The floristic composition was assessed biweekly (February to November 2020) to record accurate flowering seasons and detailed plant specimen collection for identification. Voucher specimens of each species were prepared according to the guidelines of the herbarium handbook (Bridson & Forman, 1998). A total of 170 stratified quadrat sampling of 1×1 m^2, 4×4 m^2 and 10×10 m^2 for herbs, shrubs and trees

were used respectively to assess the presence-absence of species (Kent, 2012) and collected species adjacent to the plots to obtain the comprehensive list of plant species in the wetland. Specimens were identified following available taxonomic literature (Pearce & Cribb, 2002; Shi *et al.*, 2011) and Flora of Bhutan (Grierson & Long, 1983, 1984, 1987, 1991, 1999, 2001).

The families, life forms and groups, were updated following the Angiosperm Phylogeny Group based on the Tropicos database (tropicos.org). The vegetation structure of the whole wetland was represented in a schematic profile diagram based on the height of plant species and species composition in different wetlands sites. The number of cattle dung was recorded in each quadrat and visually estimated the grazing intensity (Collins, 2004). Finally, the voucher specimens were deposited at the Herbarium, National Biodiversity Center, Serbithang, Thimphu District, Bhutan.

RESULTS

A total of 241 plant species belonging to 173 genera and 75 families were recorded in the study within the wetland. Among them, 87% herbs (210 species), 9% shrubs (21 species), 2% trees (6 species) and 2% climbers (4 species) formed the plant species composition of the wetland (Fig. 2A). From the 241 species, 220 were angiosperms, 3 were gymnosperms, 5 were bryophytes and 13 were monilophytes (Table 1). The most diverse family was Asteraceae (24 species and 16 genera), followed by Rosaceae (18 species and 10 genera), Poaceae (14 species and 10 genera), Cyperaceae (12 species and 6 genera), Ranunculaceae (12 species and 6 genera), Polygonaceae (12 species and 5 genera), Lamiaceae (7 species and 7 genera), Fabaceae (7 species and 6 genera) and Ericaceae (6 species and 4 genera) (Fig. 2B). The herbs begin their flowerings from April to July, extending to September and October. However, trees and climbers mostly bloom from June to September (Table 2).

The types of vegetation structure and habitats

The high-altitude valley bottom wetland of Gangtey-Phobji, Eastern Himalayan, Bhutan and their vegetation structures were identified based on topographic features, grazing intensity, and human settlement around the wetland (Figs. 3–5). Weedy species and short species were the indicators of anthropogenic activities and higher grazing intensity in the wetland. The vegetation structure found in the upper part of the wetland (Pangkarpo) was taller and recorded with less weedy species as human settlements. As a result, grazing impacts were less compared to other areas. Species such as *Berberis aristata, Rhododendron thomsonii* and *Sphagnum palustre* were usually found in poor fen habitats near the stream and gentle slope areas (Fig. 6).

The small stream that runs through the valley bottom wetland was associated with, *Aster neoelegans*, *Chenopodium album*,

Primula denticulata, *Rhododendron arboreum*, *Roscoea alpina*, *Rosa sericea*, *Urtica dioica* and *Yushania microphylla.* In open habitats that are temporarily wet during monsoon, plant species like*, Carex diandra*, *Chusua pauciflora*, *Juncus thomsonii*, *Pedicularis siphonantha* and *Prunella vulgaris*, were characterizing species. The vegetation in this wetland is indicated by more shrubs and taller species (Fig. 3).

The vegetation in this wetland area were abundantly characterised by herb species such as *Juncus prismatocarpus*, *Poterium filiforme*, *Urticularia recta* and *Xyris indica,* seasonally inundated habitats (Fig. 7). However, in the drained and open site habitats near the human settlement and grazing sites, species such as *Cirsium falconeri*, *Rumex nepalensis*, *Sambucus adnata* and *Senecio laetus.* The area in the wetland was observed with an average of 7–8 number of faecal mats per quadrat, showing higher than the other parts of the wetland. A maximum number of cattle ranging from 50–60 every day were found in this wetland. It is mainly due to the accessibility and convenience for the cattle to graze in this wetland site. Poor fen habitats were located near small streams and bottomlands in which the vegetation was characterised by *A. neoelegans*, *Impatiens radiata, Rh. thomsonii* and *Sp. palustre.* Sphagnum mosses formed mats, contributed water holding capacity to the wetlands and created peat formation with slightly acidic conditions (Fig. 4).

The middle part of the wetland vegetation was dominantly characterised by the herbaceous plant species with a few *R. sericea* shrubs along the meandering stream edges (Fig. 8). Besides, this wetland was recorded with a greater number of weed species and maximum cattle grazing. Another feature of the vegetation in this area was stunted herbs, shrubs and especially dwarf bamboo (*Y. microphylla).* Flooded basins usually occur in the bottomland of wetlands and habitats, usually marked by species such as *Persicaria hydropiper*, *Potamogeton* sp. and *Schoenoplectus mucronatus*. On the other side, tiny and rare patches of bog habitats were characterised by dwarf *Rh. thomsonii* and *Sp. palustre.*

Table 1. Floristic composition of Gangtey-Phobji valley bottom wetland of Wangdue Phodrang, Bhutan.

Taxonomic group	Families	Genera	Species	Trees	Shrubs	Herbs	Climbers
Angiosperms	62	153	220	3	21	192	4
Gymnosperms	2	3	3	3	–	–	–
Bryophytes	5	5	5	–	–	5	–
Monilophytes	6	12	13	–	–	13	–

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan.

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Alismataceae	*Sagittaria graminea* Michx.	Monocot	Herb	May–October	JTs196
Amaranthaceae	*Chenopodium album* L.	Eudicot	Herb	February–August	JTs175
Amaryllidaceae	*Allium wallichii* Kunth	Monocot	Herb	July–October	JTs191
Amblystegiaceae	*Campylium protensum* (Brid.) Kindb.	Moss	Herb	–	JTs097
Apiaceae	*Bupleurum candollei* Wall. ex DC.	Eudicot	Herb	June–August	JTs032
Apiaceae	*Carum carvi* L.	Eudicot	Herb	June–August	JTs109
Apiaceae	*Scandix pecten-veneris* L.	Eudicot	Herb	May–September	JTs039
Apiaceae	*Oenanthe javanica* (Blume) DC.	Eudicot	Herb	April–October	JTs106
Apiaceae	*Sinocarum wolffianum* (Fedde ex H. Wolff) A. K. Mukh. & Constance	Eudicot	Herb	August–September	JTs142
Apocynaceae	*Cynanchum auriculatum* Royle ex Wight	Eudicot	Climber	June–September	JTs059
Apocynaceae	*Vincetoxicum auriculatum* (Royle ex Wight) Kuntze	Eudicot	Herb	May–October	JTs185
Apocynaceae	*V. hirundinaria* Medik.	Eudicot	Herb	April–August	JTs204
Araceae	*Arisaema consanguineum* Schott	Monocot	Herb	May–June	JTs192
Araceae	*Ar. jacquemontii* Blume	Monocot	Herb	June–August	JTs199
Araceae	*Sauromatum diversifolium* (Wall. ex Schott) Cusimano & Hett.	Monocot	Herb	May–August	JTs231
Araliaceae	*Panax pseudoginseng* Wall.	Eudicot	Herb	May–September	JTs098
Asparagaceae	*Maianthemum tatsienense* (Franch.) LaFrankie	Monocot	Herb	May–June	JTs162
Asparagaceae	*Ophiopogon intermedius* D. Don	Monocot	Herb	May–July	JTs015
Asparagaceae	*Polygonatum cirrhifolium* (Wall.) Royle	Monocot	Herb	April–June	JTs018
Asparagaceae	*P. verticillatum* (L.) All.	Monocot	Herb	June–July	JTs048
Asteraceae	*Anaphalis busua* (Buch.-Ham.) DC.	Eudicot	Herb	April–November	JTs088
Asteraceae	*An. contorta* (D. Don) Hook. f.	Eudicot	Herb	July–November	JTs089
Asteraceae	*An. margaritacea* (L.) Benth. & Hook. f.	Eudicot	Herb	July–December	JTs121
Asteraceae	*An. royleana* DC.	Eudicot	Herb	June–September	JTs102

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Asteraceae	*An. triplinervis* (Sims) Sims ex C. B. Clarke	Eudicot	Herb	July–October	JTs099
Asteraceae	*Artemisia verlotiorum* Lamotte	Eudicot	Herb	July–November	JTs105
Asteraceae	*Aster albescens* (DC.) Wall. ex Hand.-Mazz.	Eudicot	Herb	May–September	JTs156
Asteraceae	*As. neo-elegans* Grierson	Eudicot	Herb	May–September	JTs004
Asteraceae	*Bidens tripartita* L.	Eudicot	Herb	August–October	JTs228
Asteraceae	*Carpesium nepalense* Less.	Eudicot	Herb	July–October	JTs056
Asteraceae	*Cirsium falconeri* (Hook. f.) Petr.	Eudicot	Herb	July–October	JTs148
Asteraceae	*Dubyaea hispida* (D. Don) DC.	Eudicot	Herb	July–October	JTs100
Asteraceae	*Galinsoga ciliata* (Raf.) S. F. Blake	Eudicot	Herb	July–September	JTs080
Asteraceae	*Hieracium silhetense* DC.	Eudicot	Herb	July–September	JTs131
Asteraceae	*Inula hookeri* C. B. Clarke	Eudicot	Herb	August–October	JTs101
Asteraceae	*Launaea aspleniifolia* (Willd.) Hook. f.	Eudicot	Herb	May–July	JTs115
Asteraceae	*Ligularia fischeri* (Ledeb.) Turcz.	Eudicot	Herb	July–September	JTs180
Asteraceae	*Pseudognaphalium affine* (D. Don) Anderb.	Eudicot	Herb	March–November	JTs037
Asteraceae	*Saussurea* sp.	Eudicot	Herb	–	JTs238
Asteraceae	*Senecio laetus* Edgew.	Eudicot	Herb	May–September	JTs029
Asteraceae	*Se. mortonii* C. B. Clarke	Eudicot	Herb	July–October	JTs031
Asteraceae	*Se. scandens* Buch.-Ham. ex D. Don	Eudicot	Herb	September–November	JTs094
Asteraceae	*Synotis cappa* (Buch.-Ham. ex D. Don) C. Jeffrey & Y. L. Chen	Eudicot	Herb	October–March	JTs136
Asteraceae	*S. wallichii* (DC.) C. Jeffrey & Y. L. Chen	Eudicot	Herb	August–November	JTs206
Balsaminaceae	*Impatiens grandiflora* Hemsl.	Eudicot	Herb	May–October	JTs149
Balsaminaceae	*Im. radiata* Hook. f.	Eudicot	Herb	May–October	JTs154
Balsaminaceae	*Im. urticifolia* Wall.	Eudicot	Herb	July–October	JTs133
Berberidaceae	*Berberis aristata* DC.	Eudicot	Shrub	April–May	JTs045
Berberidaceae	*Be. praecipua* C. K. Schneid.	Eudicot	Shrub	April–June	JTs046

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Brassicaceae	*Cardamine flexuosa* With.	Eudicot	Herb	March–July	JTs210
Brassicaceae	*C. loxostemonoides* O. E. Schulz	Eudicot	Herb	June–September	JTs209
Campanulaceae	*Campanula pallida* Wall.	Eudicot	Herb	June–September	JTs009
Caprifoliaceae	*Dipsacus inermis* Wall.	Eudicot	Herb	August–September	JTs151
Caprifoliaceae	*Lonicera acuminata* Wall.	Eudicot	Shrub	June–September	JTs108
Caprifoliaceae	*Valeriana hardwickii* Wall.	Eudicot	Herb	June–September	JTs188
Caryophyllaceae	*Silene nepalensis* Majumdar	Eudicot	Herb	June–July	JTs229
Caryophyllaceae	*Spergula arvensis* L.	Eudicot	Herb	May–August	JTs143
Caryophyllaceae	*Stellaria gyangtseensis* F. N. Williams	Eudicot	Herb	June–September	JTs083
Caryophyllaceae	*St. media* (L.) Vill.	Eudicot	Herb	February–November	JTs034
Caryophyllaceae	*St. vestita* Kurz	Eudicot	Herb	May–June	JTs062
Celastraceae	*Parnassia nubicola* Wall. ex Royle	Eudicot	Herb	July–September	JTs200
Commelinaceae	*Cyanotis vaga* (Lour.) Schult. & Schult. f.	Monocot	Herb	June–October	JTs021
Cupressaceae	*Juniperus recurva* Buch.-Ham. ex D. Don	Gymnosperm	Tree	April–August	JTs006
Cyperaceae	*Carex alopecuroides* D. Don ex Tilloch & Taylor	Monocot	Herb	April–May	JTs005
Cyperaceae	*Ca. diandra* Schrank	Monocot	Herb	April–July	JTs123
Cyperaceae	*Ca. notha* Kunth	Monocot	Herb	April–July	JTs240
Cyperaceae	*Ca. nubigena* D. Don ex Tilloch & Taylor	Monocot	Herb	April–July/May–October	JTs189
Cyperaceae	*Ca. rara* Boott	Monocot	Herb	April–July	JTs239
Cyperaceae	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Presl	Monocot	Herb	July–August	JTs177
Cyperaceae	*Fimbristylis schoenoides* (Retz.) Vahl	Monocot	Herb	September–October	JTs176
Cyperaceae	*Isolepis setacea* (L.) R. Br.	Monocot	Herb	June–October	JTs117
Cyperaceae	*Pycreus diaphanus* (Schrad. ex Roem. & Schult.) S. S. Hooper & T. Koyama	Monocot	Herb	August–September	JTs128
Cyperaceae	*Schoenoplectus juncoides* (Roxb.) Palla	Monocot	Herb	February–October	JTs096

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Cyperaceae	*Sc. mucronatus* (L.) Palla	Monocot	Herb	August–October	JTs224
Cyperaceae	*Sc. triqueter* (L.) Palla	Monocot	Herb	July–September	JTs182
Dennstaedtiaceae	*Hypolepis* sp.	Monilophyte	Herb	–	JTs181
Dennstaedtiaceae	*Microlepia* sp.	Monilophyte	Herb	–	JTs137
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	Monilophyte	Herb	–	JTs159
Dicranaceae	*Leucobryum glaucum* (Hedw.) Ångstr.	Moss	Herb	–	JTs184
Droseraceae	*Drosera peltata* Thunb.	Eudicot	Herb	June–September	JTs065
Elaeagnaceae	*Elaeagnus parvifolia* Wall. ex Royle	Eudicot	Shrub	March–June	JTs167
Ericaceae	*Enkianthus deflexus* (Griff.) C. K. Schneid.	Eudicot	Shrub	May–June	JTs070
Ericaceae	*Gaultheria nummularioides* D. Don	Eudicot	Shrub	August–September	JTs020
Ericaceae	*Lyonia villosa* (Wall. ex C. B. Clarke) Hand.-Mazz.	Eudicot	Tree	June–August	JTs119
Ericaceae	*Rhododendron arboreum* Sm.	Eudicot	Shrub	March–June	JTs134
Ericaceae	*R. ciliatum* Hook. f.	Eudicot	Shrub	April–May	JTs091
Ericaceae	*R. thomsonii* Hook. f.	Eudicot	Shrub	April–July	JTs027
Eriocaulaceae	*Eriocaulon viride* Körn.	Monocot	Herb	September–November	JTs173
Euphorbiaceae	*Euphorbia griffithii* Hook. f.	Eudicot	Herb	April–July	JTs074
Fabaceae	*Alysicarpus vaginalis* (L.) DC.	Eudicot	Herb	June–August	JTs104
Fabaceae	*Astragalus sikkimensis* Bunge	Eudicot	Herb	May–July	JTs111
Fabaceae	*Parochetus communis* D. Don	Eudicot	Herb	March–September	JTs053
Fabaceae	*Piptanthus nepalensis* (Hook.) D. Don	Eudicot	Shrub	April–May	JTs017
Fabaceae	*Tibetia himalaica* (Baker) H. P. Tsui	Eudicot	Herb	May–July	JTs067
Fabaceae	*Trifolium dubium* Sibth.	Eudicot	Herb	May–June	JTs064
Fabaceae	*Tr. repens* L.	Eudicot	Herb	April–June	JTs078
Funariaceae	*Funaria* sp.	Moss	Herb	–	JTs179

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Gentianaceae	*Crawfurdia angustata* C. B. Clarke	Eudicot	Shrub	November–February	JTs107
Gentianaceae	*Gentiana capitata* Buch.-Ham. ex D. Don	Eudicot	Herb	May–July	JTs013
Gentianaceae	*Halenia elliptica* D. Don	Eudicot	Herb	May–September	JTs124
Gentianaceae	*Swertia macrosperma* (C. B. Clarke) C. B. Clarke	Eudicot	Herb	August–September	JTs035
Geraniaceae	*Geranium nepalense* Sweet	Eudicot	Herb	April–July	JTs084
Geraniaceae	*G. polyanthes* Edgew. & Hook. f.	Eudicot	Herb	June–August	JTs118
Geraniaceae	*G. procurrens* Yeo	Eudicot	Herb	June–September	JTs038
Hydrangeaceae	*Hydrangea heteromalla* D. Don	Eudicot	Shrub	July–September	JTs193
Hypericaceae	*Hypericum choisianum* Wall. ex N. Robson	Eudicot	Shrub	June–July	JTs092
Hypericaceae	*H. elodeoides* Choisy	Eudicot	Herb	June–August	JTs014
Hypericaceae	*H. himalaicum* N. Robson	Eudicot	Herb	July–August	JTs026
Hypericaceae	*H. japonicum* Thunb.	Eudicot	Herb	May–August	JTs095
Hypoxidaceae	*Hypoxis aurea* Lour.	Monocot	Herb	April–August	JTs165
Juncaceae	*Juncus articulatus* L.	Monocot	Herb	July–August	JTs221
Juncaceae	*J. effusus* L.	Monocot	Herb	July–October	JTs234
Juncaceae	*J. leucomelas* Royle ex D. Don	Monocot	Herb	May–July	JTs236
Juncaceae	*J. prismatocarpus* R. Br.	Monocot	Herb	April–August	JTs198
Juncaceae	*J. thomsonii* Buchenau	Monocot	Herb	May–August	JTs172
Juncaceae	*Luzula multiflora* (Ehrh.) Lej.	Monocot	Herb	April–July	JTs218
Lamiaceae	*Ajuga integrifolia* Buch.-Ham.	Eudicot	Herb	May–July	JTs033
Lamiaceae	*Clinopodium umbrosum* (M. Bieb.) Kuntze	Eudicot	Herb	May–September	JTs150
Lamiaceae	*Elsholtzia fruticosa* (D. Don) Rehder	Eudicot	Herb	August–October	JTs169
Lamiaceae	*Origanum vulgare* L.	Eudicot	Herb	June–September	JTs233
Lamiaceae	*Phlomis macrophylla* Benth.	Eudicot	Herb	July–August	JTs195

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Lamiaceae	*Prunella vulgaris* L.	Eudicot	Herb	May–August	JTs043
Lamiaceae	*Salvia nubicola* Wall. ex Sweet	Eudicot	Herb	August–October	JTs205
Lauraceae	*Lindera obtusiloba* Blume var. *heterophylla* (Meisn.) H. B. Cui	Eudicot	Shrub	May–July	JTs011
Lentibulariaceae	*Utricularia aurea* Lour.	Eudicot	Herb	August–December	JTs079
Lentibulariaceae	*U. recta* P. Taylor	Eudicot	Herb	June–October	JTs073
Marchantiaceae	*Marchantia polymorpha* L.	Liverwort	Herb	–	JTs217
Mazaceae	*Mazus surculosus* D. Don	Eudicot	Herb	April–August	JTs147
Melanthiaceae	*Paris polyphylla* Sm.	Monocot	Herb	April–June	JTs044
Nartheciaceae	*Aletris gracilis* Rendle	Monocot	Herb	May–July	JTs187
Onagraceae	*Circaea alpina* L.	Eudicot	Herb	July–October	JTs047
Onagraceae	*Epilobium kingdonii* P. H. Raven	Eudicot	Herb	August–October	JTs171
Ophioglossaceae	*Botrychium lanuginosum* Wall. ex Hook. & Grev.	Monilophyte	Herb	–	JTs130
Orchidaceae	*Chusua pauciflora* (Lindl.) P. F. Hunt	Monocot	Herb	June–September	JTs146
Orchidaceae	*Liparis rostrata* Rchb. f.	Monocot	Herb	June–August	JTs212
Orchidaceae	*Peristylus elisabethae* (Duthie) R. K. Gupta	Monocot	Herb	July–August	JTs042
Orchidaceae	*Pleione hookeriana* (Lindl.) Rollisson	Monocot	Herb	May–July	JTs085
Orchidaceae	*Satyrium nepalense* D. Don	Monocot	Herb	August–October	JTs141
Orchidaceae	*Spiranthes sinensis* (Pers.) Ames	Monocot	Herb	March–October	JTs183
Orobanchaceae	*Euphrasia bhutanica* Pugsley	Eudicot	Herb	May–September	JTs012
Orobanchaceae	*Pedicularis siphonantha* D. Don	Eudicot	Herb	May–September	JTs060
Osmundaceae	*Osmunda claytoniana* L.	Monilophyte	Herb	–	JTs235
Osmundaceae	*Osmunda* sp.	Monilophyte	Herb	–	JTs223
Oxalidaceae	*Oxalis corniculata* L.	Eudicot	Herb	March–August	JTs082
Papaveraceae	*Corydalis bracteata* (Steph. ex Willd.) Pers.	Eudicot	Herb	June–August	JTs051

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Papaveraceae	*C. crispa* Prain	Eudicot	Herb	July–September	JTs125
Papaveraceae	*C. juncea* Wall.	Eudicot	Herb	June–September	JTs153
Phrymaceae	*Mimulus nepalensis* Benth.	Eudicot	Herb	March–September	JTs061
Pinaceae	*Larix griffithiana* (Lindl. & Gordon) Carrière	Gymnosperm	Tree	April–May	JTs241
Pinaceae	*Pinus wallichiana* A. B. Jacks.	Gymnosperm	Tree	April–May	JTs036
Plantaginaceae	*Digitalis purpurea* L.	Eudicot	Herb	May–July	JTs063
Plantaginaceae	*Hemiphragma heterophyllum* Wall.	Eudicot	Herb	March–June	JTs077
Plantaginaceae	*Plantago erosa* Wall.	Eudicot	Herb	April–August	JTs211
Poaceae	*Agrostis micrantha* Steud.	Monocot	Herb	May–November	JTs002
Poaceae	*Ag. nervosa* Nees ex Trin.	Monocot	Herb	July–September	JTs003
Poaceae	*Anthoxanthum odoratum* L.	Monocot	Herb	April–October	JTs222
Poaceae	*Arundinella hookeri* Munro ex Keng	Monocot	Herb	June–October	JTs202
Poaceae	*Dactylis glomerata* L.	Monocot	Herb	August–October	JTs160
Poaceae	*Eragrostis tenella* (L.) P. Beauv. ex Roem. & Schult.	Monocot	Herb	April–October	JTs072
Poaceae	*Holcus lanatus* L.	Monocot	Herb	July–September	JTs190
Poaceae	*Oryzopsis aequiglumis* Duthie ex Hook. f.	Monocot	Herb	September–November	JTs144
Poaceae	*Poa nemoralis* L.	Monocot	Herb	May–October	JTs152
Poaceae	*P. nepalensis* (Wall. ex Griseb.) Duthie	Monocot	Herb	April–July	JTs161
Poaceae	*P. polycolea* Stapf	Monocot	Herb	June–September	JTs157
Poaceae	*P. pratensis* L.	Monocot	Herb	April–August	JTs127
Poaceae	*Trisetum flavescens* (L.) P. Beauv.	Monocot	Herb	June–September	JTs213
Poaceae	*Yushania microphylla* (Munro) R. B. Majumdar	Monocot	Herb	–	JTs219
Polygonaceae	*Aconogonon molle* (D. Don) H. Hara	Eudicot	Herb	May–November	JTs232
Polygonaceae	*Bistorta affinis* (D. Don) Greene	Eudicot	Herb	June–September	JTs129

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Polygonaceae	*Persicaria glacialis* (Meisn.) H. Hara	Eudicot	Herb	July–September	JTs007
Polygonaceae	*Pe. humilis* (Meisn.) H. Hara	Eudicot	Herb	July–September	JTs174
Polygonaceae	*Pe. hydropiper* (L.) Delarbre	Eudicot	Herb	April–September	JTs158
Polygonaceae	*Pe. runcinata* (Buch.-Ham. ex D. Don) H. Gross	Eudicot	Herb	May–October	JTs163
Polygonaceae	*Pe. sagittata* (L.) H. Gross	Eudicot	Herb	May–August	JTs194
Polygonaceae	*Pe. strigosa* (R. Br.) Nakai	Eudicot	Herb	June–August	JTs016
Polygonaceae	*Polygonum aviculare* L.	Eudicot	Herb	May–September	JTs114
Polygonaceae	*Po. plebeium* R. Br.	Eudicot	Herb	March–May	JTs110
Polygonaceae	*Rumex acetosella* L.	Eudicot	Herb	June–August	JTs197
Polygonaceae	*Ru. nepalensis* Spreng.	Eudicot	Herb	May–July	JTs086
Polypodiaceae	*Drynaria mollis* Bedd.	Monilophyte	Herb	–	JTs068
Polypodiaceae	*Lepisorus* sp.	Monilophyte	Herb	–	JTs112
Polypodiaceae	*Microsorum* sp.	Monilophyte	Herb	–	JTs126
Polypodiaceae	*Pichisermollodes malacodon* (Hook.) Fraser-Jenk.	Monilophyte	Herb	–	JTs237
Polypodiaceae	*Polypodiodes amoena* (Wall. ex Mett.) Ching	Monilophyte	Herb	–	JTs215
Potamogetonaceae	*Potamogeton* sp.	Monocot	Herb	–	JTs057
Primulaceae	*Bryocarpum himalaicum* Hook. f. & Thomson	Eudicot	Herb	April–June	JTs132
Primulaceae	*Lysimachia prolifera* Klatt	Eudicot	Herb	March–July	JTs120
Primulaceae	*Primula denticulata* Sm.	Eudicot	Herb	February–June	JTs030
Pteridaceae	*Pteris biaurita* L.	Monilophyte	Herb	–	JTs230
Ranunculaceae	*Aconitum ferox* Wall. ex Ser.	Eudicot	Herb	July–September	JTs201
Ranunculaceae	*Anemone rivularis* Buch.-Ham. ex DC.	Eudicot	Herb	April–August	JTs001
Ranunculaceae	*Clematis montana* Buch.-Ham. ex DC. var. *grandiflora* Hook.	Eudicot	Herb	July–September	JTs178
Ranunculaceae	*Delphinium cooperi* Munz	Eudicot	Herb	August–October	JTs010

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Ranunculaceae	*Ranunculus brotherusii* Freyn	Eudicot	Herb	April–August	JTs019
Ranunculaceae	*Ra. diffusus* DC.	Eudicot	Herb	April–August	JTs049
Ranunculaceae	*Ra. sceleratus* L.	Eudicot	Herb	April–August	JTs071
Ranunculaceae	*Ra. tricuspis* Maxim.	Eudicot	Herb	June–August	JTs090
Ranunculaceae	*Thalictrum chelidonii* DC.	Eudicot	Herb	June–September	JTs135
Ranunculaceae	*T. foetidum* L. var. *foetidum*	Eudicot	Herb	June–July	JTs138
Ranunculaceae	*T. reniforme* Wall.	Eudicot	Herb	June–August	JTs066
Ranunculaceae	*T. virgatum* Hook. f. & Thomson	Eudicot	Herb	July–September	JTs087
Rosaceae	*Agrimonia pilosa* Ledeb.	Eudicot	Herb	May–July	JTs024
Rosaceae	*Cotoneaster bacillaris* Wall. ex Lindl.	Eudicot	Shrub	May–June	JTs054
Rosaceae	*Co. microphyllus* Wall. ex Lindl.	Eudicot	Shrub	April–July	JTs055
Rosaceae	*Co. simonsii* Baker	Eudicot	Shrub	May–July	JTs113
Rosaceae	*Fragaria nubicola* (Lindl. ex Hook. f.) Lacaita	Eudicot	Herb	April–June	JTs226
Rosaceae	*Maddenia himalaica* Hook. f. & Thomson	Eudicot	Tree	April–May	JTs139
Rosaceae	*Potentilla fulgens* Wall. ex Sims	Eudicot	Herb	June–August	JTs022
Rosaceae	*P. griffithii* Hook. f.	Eudicot	Herb	June–September	JTs155
Rosaceae	*P. kleiniana* Wight & Arn.	Eudicot	Herb	June–August	JTs093
Rosaceae	*P. leuconota* D. Don	Eudicot	Herb	May–July	JTs040
Rosaceae	*P. polyphylla* Wall. ex Lehm.	Eudicot	Herb	June–August	JTs140
Rosaceae	*P. saundersiana* Royle	Eudicot	Herb	May–September	JTs025
Rosaceae	*Poterium filiforme* Hook. f.	Eudicot	Herb	May–July	JTs023
Rosaceae	*Prunus rufa* Wall. ex Hook. f.	Eudicot	Tree	April–May	JTs164
Rosaceae	*Rosa macrophylla* Lindl.	Eudicot	Shrub	June–July	JTs168
Rosaceae	*Ro. sericea* Wall. ex Lindl.	Eudicot	Shrub	March–June	JTs028

Table 2. Wetland plant species with a taxonomic group, life form, flowering season / gametophyte phase and voucher number in Gangtey-Phobji, Wangdue Phodrang, Bhutan (Cont.).

Family	Scientific name	Group	Life form	Flowering season / Gametophyte phase	Voucher number
Rosaceae	*Rubus fockeanus* Kurz	Eudicot	Herb	May–June	JTs052
Rosaceae	*Spiraea bella* Sims	Eudicot	Shrub	May–August	JTs145
Rubiaceae	*Galium aparine* L.	Eudicot	Herb	July–September	JTs081
Saxifragaceae	*Astilbe rivularis* Buch.-Ham. ex D. Don	Eudicot	Herb	July–October	JTs122
Saxifragaceae	*Tiarella polyphylla* D. Don	Eudicot	Herb	April–July	JTs069
Scrophulariaceae	*Verbascum thapsus* L.	Eudicot	Herb	June–October	JTs227
Selaginellaceae	*Selaginella chrysorrhizos* Spring.	Monilophyte	Herb	–	JTs116
Smilacaceae	*Smilax elegans* Wall. ex Kunth	Monocot	Climber	April–June	JTs050
Smilacaceae	*Sm. menispermoidea* A. DC.	Monocot	Climber	May–November	JTs076
Solanaceae	*Anisodus luridus* Link	Eudicot	Herb	July–September	JTs225
Sphagnaceae	*Sphagnum palustre* L.	Moss	Herb	–	JTs220
Thymelaeaceae	*Daphne bholua* Buch.-Ham. ex D. Don	Eudicot	Shrub	February–May	JTs166
Typhaceae	*Sparganium erectum* L.	Monocot	Herb	July–September	JTs186
Urticaceae	*Laportea terminalis* Wight	Eudicot	Herb	June–August	JTs203
Urticaceae	*Pilea symmeria* Wedd.	Eudicot	Herb	May–July	JTs008
Urticaceae	*Urtica dioica* L.	Eudicot	Herb	June–September	JTs075
Viburnaceae	*Sambucus adnata* Wall. ex DC.	Eudicot	Herb	June–September	JTs170
Violaceae	*Viola bhutanica* H. Hara	Eudicot	Herb	April–June	JTs207
Violaceae	*Vi. biflora* L.	Eudicot	Herb	June–September	JTs214
Violaceae	*Vi. hookeri* Thomson	Eudicot	Herb	April–June	JTs216
Violaceae	*Vi. wallichiana* Ging.	Eudicot	Herb	June–July	JTs208
Vitaceae	*Parthenocissus semicordata* (Wall.) Planch.	Eudicot	Climber	May–July	JTs041
Xyridaceae	*Xyris indica* Willd. ex Kunth	Monocot	Herb	July–September	JTs103
Zingiberaceae	*Roscoea alpina* Royle	Monocot	Herb	June–August	JTs058

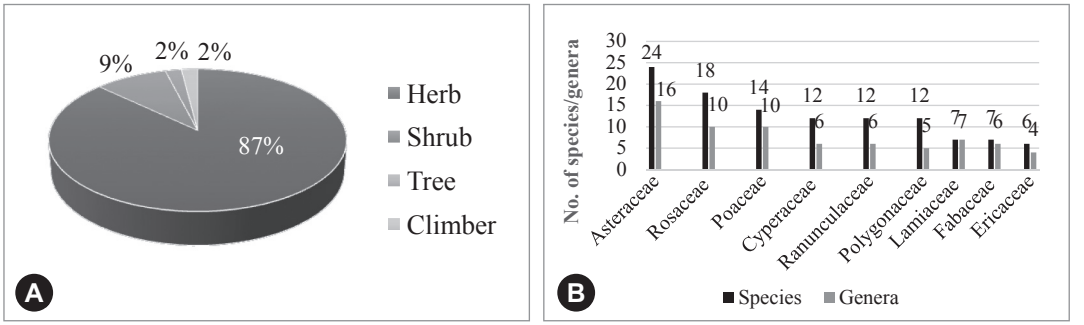

FIGURE 2. A. Life forms of herb, shrub, tree and climber; B. Proportion of nine dominant families with genera and species.

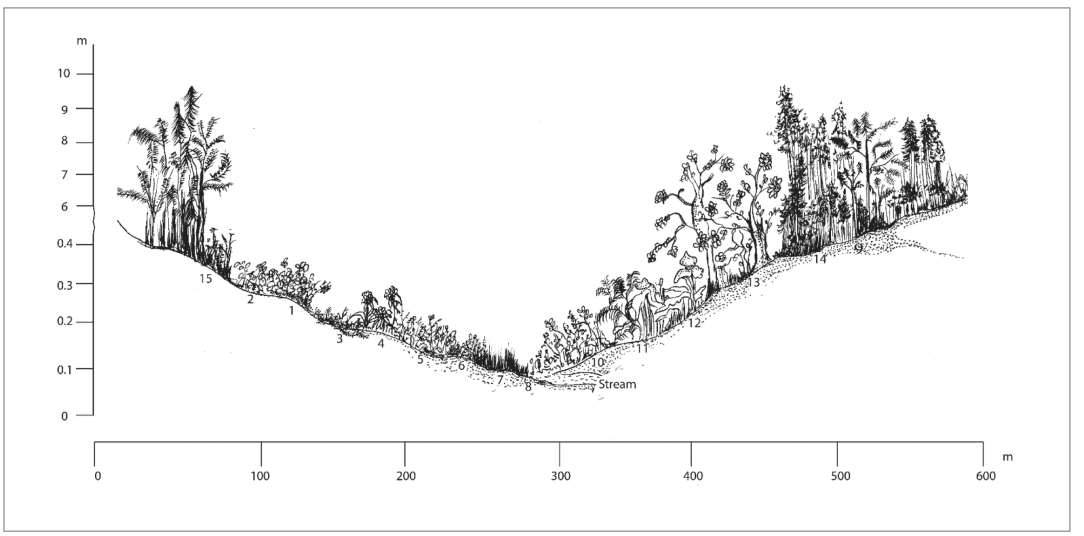

FIGURE 3. Schematic profile diagram at Pangkarpo (upper site of wetland vegetation): 1. *Sphagnum palustre*; 2. *Rhododendron thomsonii*; 3. *Cotoneaster microphylla*; 4. *Larix griffithiana*; 5. *Rosa sericea*; 6. *Rh. ciliatum*; 7. *Yushania microphylla*; 8. *Urtica dioica*; 9. *Spiraea bella*; 10. *Berberis aristata*; 11. *Hypericum choisianum*; 12. *Roscoea alpina*; 13. *Rh. arboreum*; 14. *Pinus wallichiana*; 15. *Abies densa.*

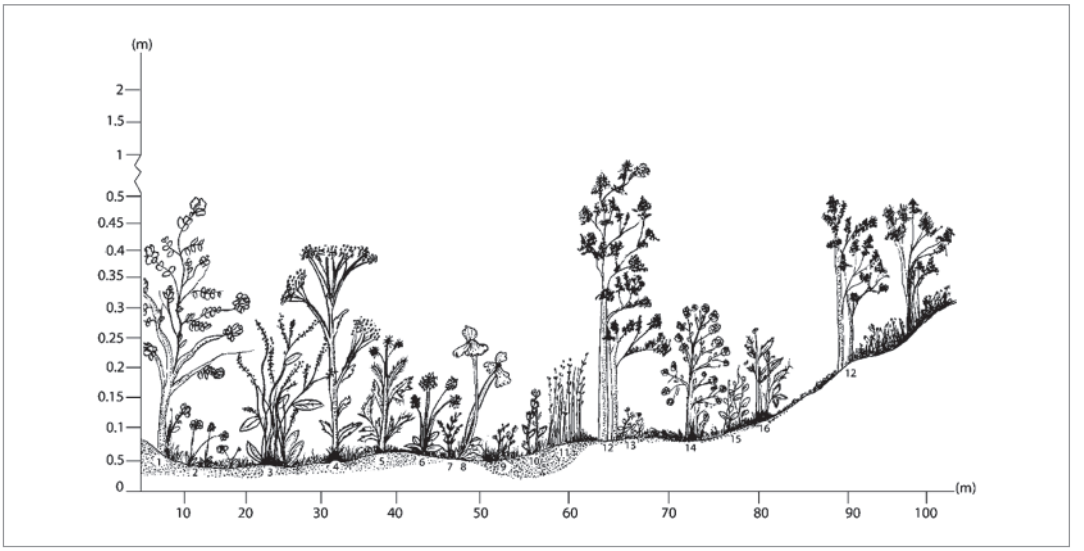

Figure 4. Schematic profile diagram of Kela Shama (wetland vegetation below Aman site): 1. *Rhododendron thomsonii*; 2. *Aster neoelegans*; 3. *Rumex nepalensis*; 4. *Senecio laetus*; 5. *Cirsium falconeri*; 6. *Primula denticulata*; 7. *Euphrasia bhutanica*; 8. *Xyris indica*; 9. *Pedicularis siphonantha*; 10. *Poterium filiforme*; 11. *Juncus prismatocarpus*; 12. *Pinus wallichiana*; 13. *Impatiens radiata*; 14. *Rh. thomsonii*; 15. *Arisaema consanguineum*; 16. *Sambucus adnata*.

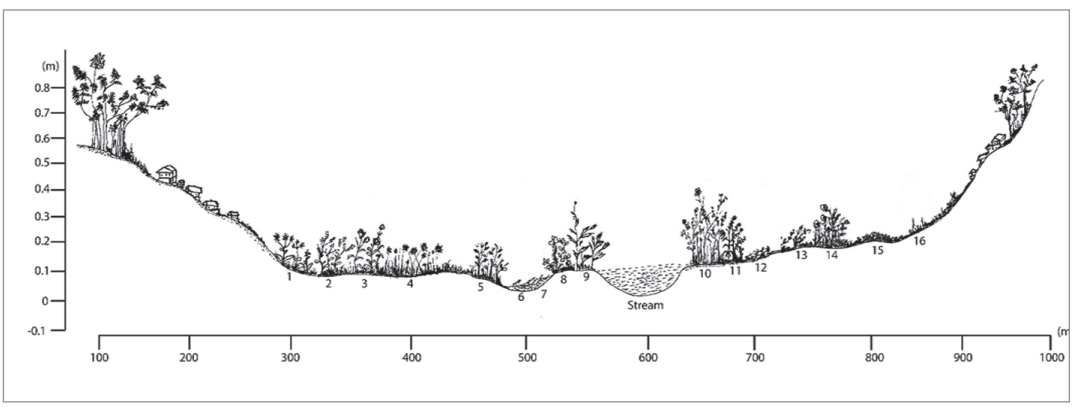

Figure 5. Schematic profile diagram at Tabayting and middle part of wetlands: 1. *Anaphalis triplenervis*; 2. *Rumex acetosella*; 3. *Persicaria runcinata*; 4. *Trifolium repens*; 5. *Halenia elliptica*; 6. *Potamogeton* sp.; 7. *Pe. hydropiper*; 8. *Epilobium kingdonii*; 9. *Agrimonia pilosa*; 10. *Rosa sericea*; 11. *Euphorbia griffithii*; 12. *Anthoxanthum odoratum*; 13. *Senecio mortonii*; 14. *Rhododendron thomsonii*; 15. *Juncus thomsonii*; 16. *Arundinella hookeri*.

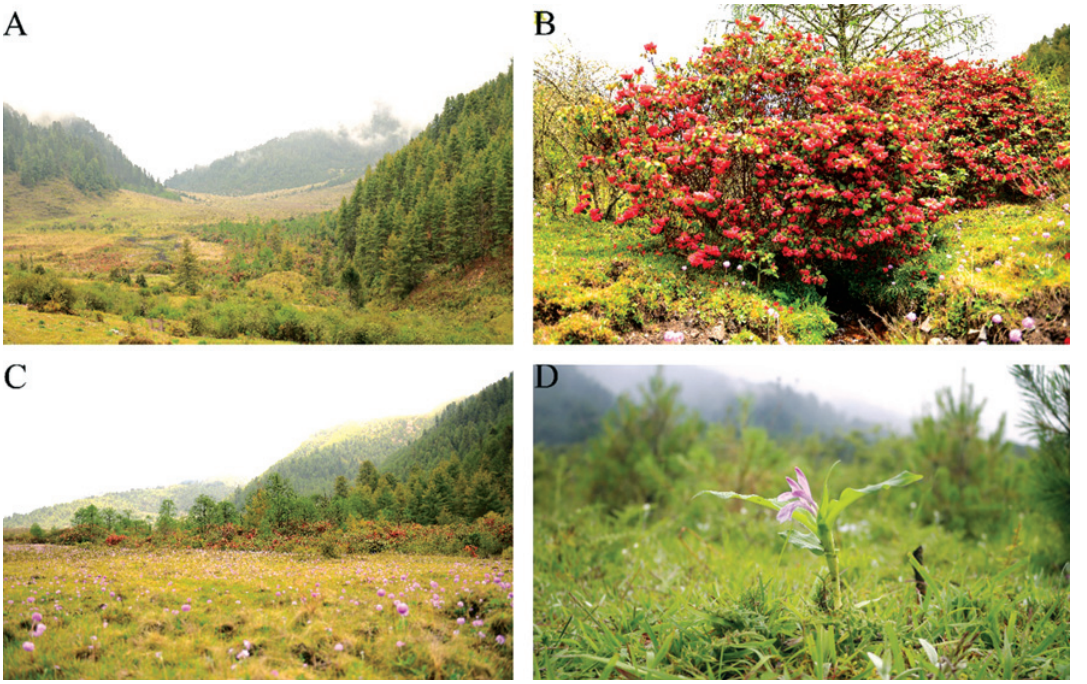

FIGURE 6. A. Vegetation view of upper part of wetland; B. *Rhododendron thomsonii*; C. *Larix griffithiana* and *Pinus wallichiana*; D. *Roscoea alpina*.

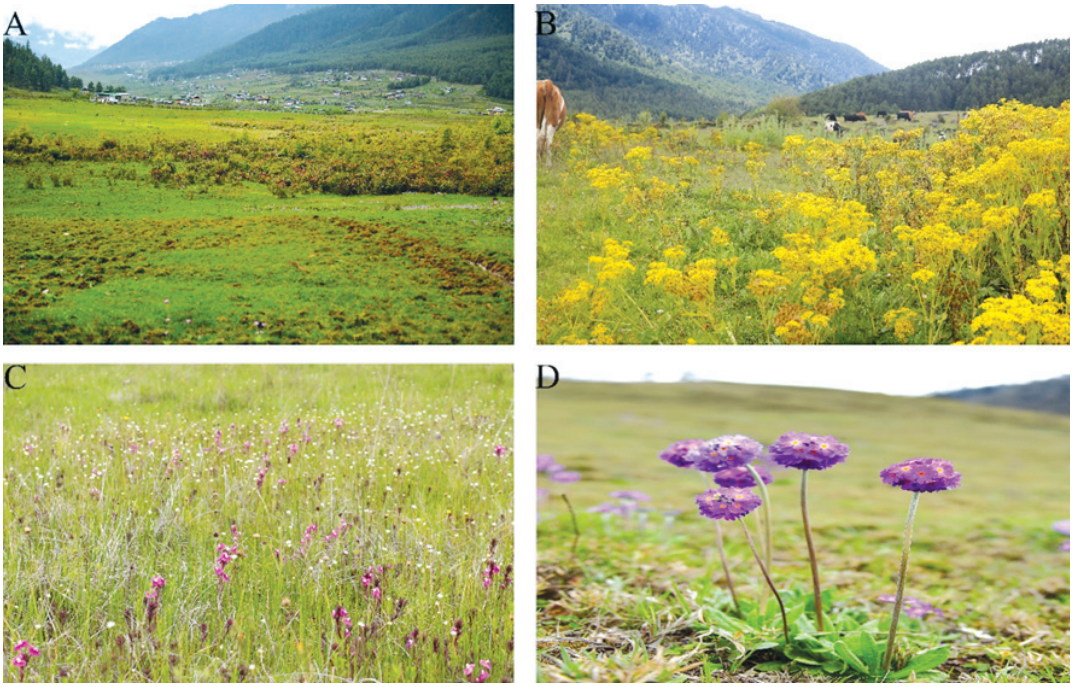

FIGURE 7. A. Vegetation view of Kela Shama; B. *Senecio laetus* and *Cirsium falconeri*; C. *Juncus prismatocarpus, Pedicularis siphonantha, Poterium filiforme* and *Xyris indica* in wet habitats; D. *Primula denticulata.*

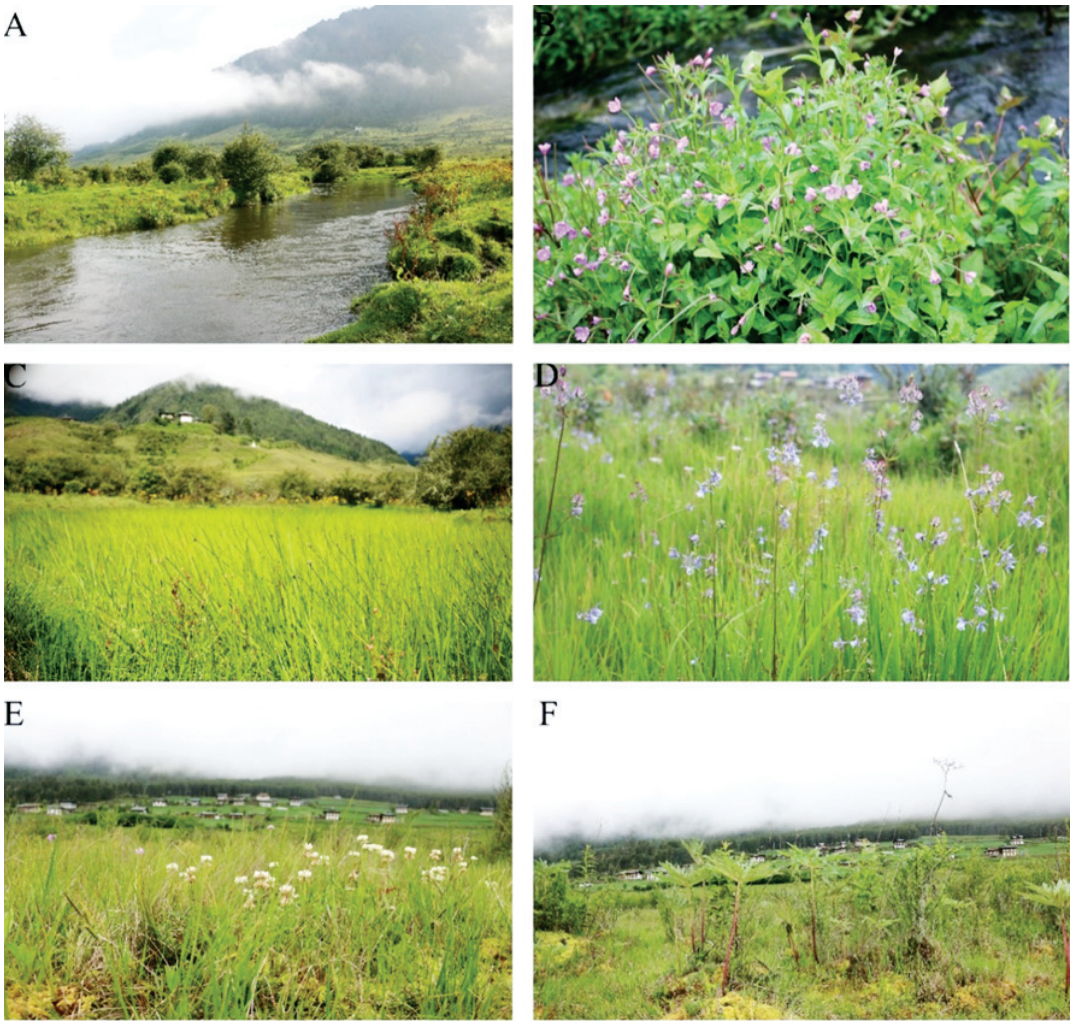

Figure 8. A. Vegetation view of Tabayting and middle part of wetlands; B. *Epilobium kingdonii*; C. *Persicaria hydropiper* and *Schoenoplectus mucronatus*; D. *Halenia elliptica*; E. *Trifolium repens*; F. *Arundinella hookeri, Juncus thomsonii* and *Senecio mortonii*.

Discussion

The Gangtey-Phobji valley bottom wetland is a dynamic landscape with rich species composition of high conservation value. The present study documented 241 species with 173 genera and 75 families. Within the Himalayan Regions, most of the family represented families varies and topmost dominant family in the wetland, Asteraceae with 24 species that comprised 9.8 % of total species 244 (Chhetri & Tenzin, 2012) in the country. The abundant occurrence of such species in the wetlands maybe because of its better adaptative features and distribution abilities (Christenhusz & Byng, 2016). However, these results from the present study only and

may not represent natural Asteraceae family diversity in the wetlands of Bhutan.

In the study conducted by Tendar & Sridith (2021) on high altitude wetlands of Eastern Himalayan, Bhutan, the Ericaceae family was the most dominant family with 17 species, including 21% of total species in the country. Hence, further investigations on other wetlands are necessary to address the occurrence of the abundant Asteraceae family. The next dominant family was Rosaceae, with 18 species comprised 12.76% of total species 141 in Bhutan (Chhetri & Tenzin, 2012). Similar results were also documented by Tendar & Sridith (2021) from their studies in high altitude wetlands. Poaceae family, which positioned third with 14 species, comprised 4.9% out of 288 species in Bhutan. An abundance of Poaceae could be due to its ability to tolerate grazing herbivores and their various means of reproduction and distribution due to the open area (Jakobsson & Eriksson, 2003; Jafarpour & Manohar, 2014).

Cyperaceae, Ranunculaceae and Polygonaceae were the families with 12 species each in the wetlands in the abundant fourth position. These families have a close affinity with the Flora of Bhutan, which recorded fifth, eighth and twentieth positions in Bhutan, respectively (Chhetri & Tenzin, 2012). Lamiaceae and Fabaceae ranked fifth position in their dominance with seven species in the wetland. However, Ericaceae constitutes only six species and it was not the most dominant family in the present study. These Ericaceous may be acid affinity plants since they usually thrive in acidic habits of wetlands (Richardson & Vepraskas, 2001). On the contrary, studies conducted in less disturbed wetlands by Tendar & Sridith (2021) had observed Ericaceae as the topmost dominant family with 17 species, contributing 21% of the total 81 species in the country (Chhetri & Tenzin, 2012). Therefore, the present study infers possible reasons for the less diverse occurrence of Ericaceous species due to the alteration of wetland habitats by various anthropogenic activities (Jamtsho & Sridith, 2013).

The abundance of lifeforms varied from the region and the highest proportion of abundance was herbs with 87%, followed by shrubs with 9%, trees and climbers with 2%. The anthropogenic activities and cattle grazing might create short vegetation and lead to the extinction of native species (Xiong *et al.,* 2003; Harris *et al.,* 2005). It might be the one reason finding herb dominance vegetation in the wetlands. The vegetation structure of different parts of wetland and habitat depicts different grazing levels, disturbances, and uniqueness in supporting diverse species in habitat (Figs. 3–5). Considering that the wetland's location is in the same valley with no differences in altitude, the plant species were the same in all the wetlands. However, the occurrence of a few habitats, such as seasonally inundated basins, poor fen, and other microhabitats, might be the one possible reason supporting unique species (Tendar & Sridith, 2021).

In the seasonally flooded habitats, permanent water usually supports species like *J. prismatocarpus*, *Per. hydropiper*, *Potamogeton* sp., *Sc. mucronatus*, *U. recta*

and *X. indica* (Figs. 4–5). The hydrological period influences vegetation types in a wetland (Mitsch *et al.,* 2009; Rossi *et al.,* 2014) and tends to remain in a zone and adapted in anoxic or reduce conditions with a small number of species (Keddy, 2000; Corry, 2012). The poor fen habitats are primarily found in patches of vegetation indicated by *Cotoneaster microphylla*, *J. thomsonii*, *Rh. thomsonii* and *Sp. palustre.* Sphagnum moss contributes to the deposition of thicker peat, creating the slightly acidic condition (Smith, 1966) and ericaceous shrubs such as *Gaultheria nummulariodes* and *Rh. thomsonii* were notable features of such habitats in the wetland (Fig. 3).

The most threatening to the wetland is the maximum number of weed species such as *Cyanotis vaga, Galinsoga ciliata*, *Per. runcinata*, *Ru. acetosella*, *Stellaria vistata*, *Trifolium dubium* and *T. repens* with shorter height in drained habitats and middle part of the wetland (Fig. 5). Unfortunately, the invasion of weedy species is an indicator of degrading wetland and habitat change, leading to the loss of many wetland species (National Biodiversity Centre, 2015). This part of the wetland is situated near the most populated human settlement with maximum anthropogenic activities and a higher level of grazing intensity.

Conclusion

Wetland research has observed important understanding implications for conservation and management of biodiversity in the world. Maximum conservation efforts focused on faunal species and limited the floral components of the wetland, which is equally important in an ecosystem existence (Tendar *et al.,* 2020). Wetland is also under challenges from an escalation of farming practices, land cover and use changes, fertilisers and pesticides, increasing population and land fragmentation, farm mechanization, new and unplanned infrastructure, and businesses. There is growing pressure to convert the Gangtey-Phobji wetland for economic development, particularly for roads, hotels, and other tourism infrastructure. Another immense threat to the wetland is continuous grazing. These are evident by drained habitats, reduced land cover and land use patterns, invasive species, and waste management issues (Chaudhary *et al.,* 2017; Lhamo *et al.,* 2020). Therefore, policymakers, planners, communities and organizations concerned need to work collaboratively and develop appropriate action plans for wetland protection and conservation for sustainable and appropriate conservation strategies.

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