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Floral biodiversity of Pangateng Tso (PTSO) high-altitude wetland of Eastern Himalaya

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ABSTRACT

The current study was carried out around the Pangateng Tso (PTSO) high-altitude wetland area of Tawang district of Eastern Himalaya. A total 93 higher plant species belonging to 58 genus and 31 families were recorded from the PTSO lake area. A total 74 herbs followed by 16 shrubs and 3 tree species recorded from the study area. The largest number of species was noted from the family Asteraceae (13 spp.), followed by Ericaceae (11 spp.), Rosaceae (8 spp.), Primulaceae (6 spp.), Gentianaceae and Polygonaceae (5 spp. each), Papaveraceae & Campanulaceae (4 spp. each), Apiaceae (3 spp.). The genus *Rhododendron* exhibited highest diversity with 9 species followed by *Primula* (6 species), *Potentila* (4 spp.), *Berberis* (3 spp.), *Cremanthodium* (3 spp.), *Meconopsis* (2 spp.). Local Monpa communities of study area utilized various plant species such as *Rhododendron, Picrorhiza, Primula, Potentilla, Meconopsis, Swertia* for different ethnomedicinal purposes. A total 15 species were recorded as endemics restricted to the Eastern Himalayan Region, whereas 70 species were identified as near-endemics. Conservation and management strategy has also been suggested for the preservation of unique floral diversity of PTSO high-altitude wetland area.

Keywords: Floral biodiversity, PTSO wetland, high-altitude wetland, Himalaya, Biodiversity Conservation

1. INTRODUCTION

The high-altitude wetlands (HAWs) are very unique, rich and fragile ecosystems mainly found at an altitude higher than 3000 meter above mean sea level in the mountains (Chatterjee et al., 2010). They are mainly faded by glacier water, rainfall and springs. Himalayan region is harbour different types of wetlands of diverse geological origin. HAWs support unique floral biodiversity due to the extreme climatic regime and unique ecosystem position. Arunachal Pradesh is ranked second in India after Jammu & Kashmir with 1672 HAWs covering a total area of 11,864 ha, accounting for about 7.6% of total wetland area of the state. Maximum number of wetlands are of small size (below 10 ha). Only 3 wetlands having an area of 100-500 ha have been observed in the state (Anonymous, 2012). The HAWs of Himalaya play important role in hydrological and ecological regulation in the upper and lower reaches of the regions (Panigrahy et al. 2012). However, very limited

scientific details are available about the status of floral biodiversity for the most of these wetlands due to the remoteness and inaccessibility of the terrain of the region. At present, the floral biodiversity of HAWs is facing multiple anthropogenic threats ranging from degradation, fragmentation, unsustainable collection of bioresources and emerging climate change impact (Kanwal et al., 2013). HAWs support very rich and unique diversity of flowering and ethnobotanical important plant species. Some valuable plants species recorded from HAWs are *Aconitum* sp., *Aconogonum*sp, *Rheum* sp., *Rhododendron* spp., *Gentiana* sp., *Bistorta sp. Gaultheria spp., Fragaria sp., Pedicularis sp., Aster* sp. etc. HAWs also provide conducive adobe to threatened high altitude wildlife such as snow leopard, musk deer, red panda, takin, Chinese goral, red goral (Mazumdar et al., 2011). They are also considered as sacred for their cultural, religious and traditional belief by local Monpa (Buddhist community) of Tawang district, Arunachal Pradesh.

Currently, comprehensive very limited scientific information about the floral biodiversity of high-altitude wetland areas of Arunachal Pradesh due to remotes and harsh climatic conditions of high-altitude areas (Dutta et al., 2013). Therefore, researchers have observed an urgent need to carry out in-depth studies for assessment floral diversity of high-altitude regions of the state (Bharali & Khan, 2011 & Dutta et al., 2013). The floral biodiversity assessment study will help to frame a comprehensive conservation and management strategy for protection of rich biodiversity of HAW landscape. Keeping in view of above, the present study was carried out to document the floral diversity of Pangateng Tso (PTSO) high altitude wetland. Pangateng Tso (PTSO) is located around is located at 3912 masl of Tawang district of Arunachal Pradesh.

Study area

Pangateng Tso (PTSO) high altitude wetland

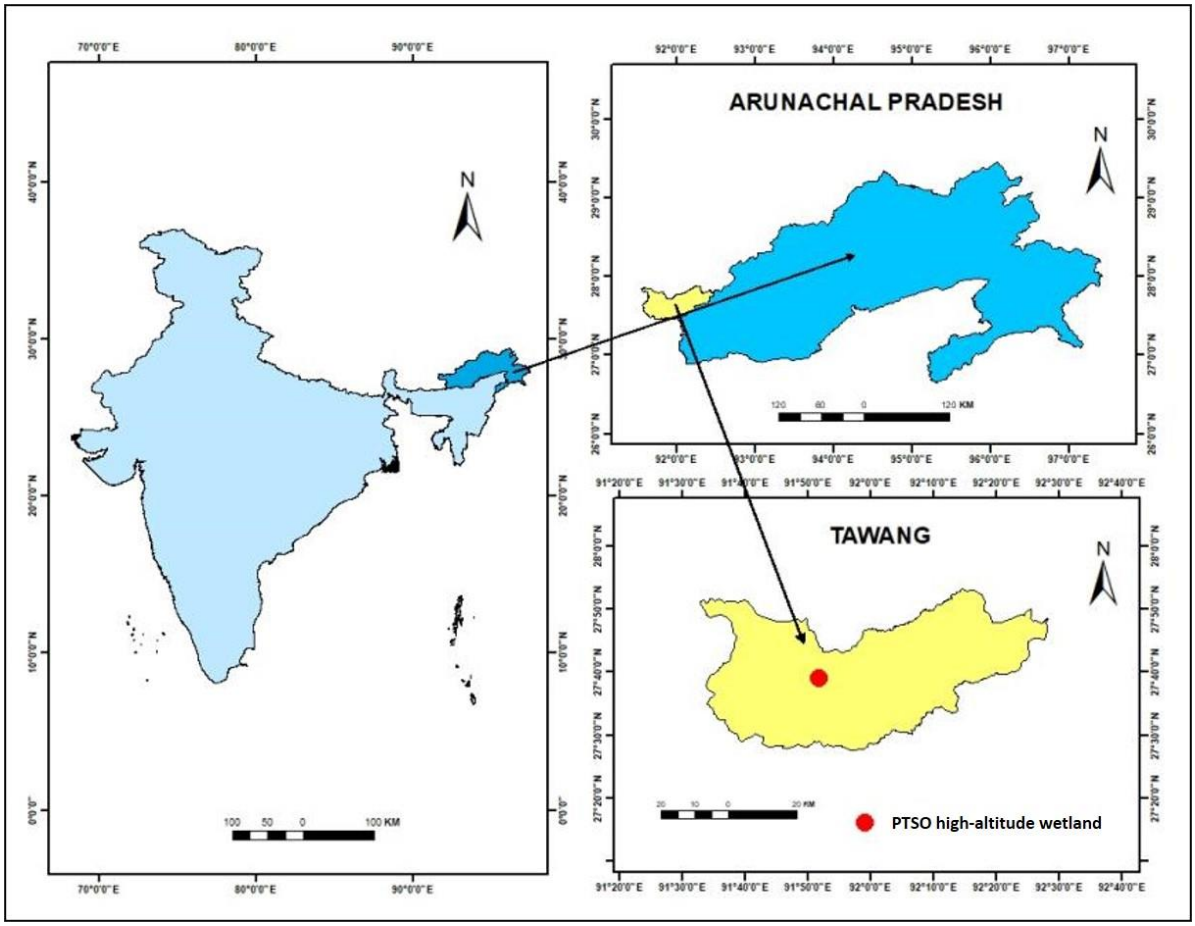

Figure 1. Location map of PTSO high-altitude wetland of Tawang district, Arunachal Pradesh

There are around 253 HAWs exists in the Tawang district covering an area around 1139 ha. There are mainly two wetland complexes in the Tawang district viz. Nagula and Bhagajang wetland complex. Nagula wetland complex is located towards the northern side of Tawang Town. There are around 100 permanent high-altitude wetlands located between 3000 to 4420 m above sea level. Theses wetland receives water from snow melt glaciers and. Pangateng Tso Lake Lake which is famously known as PTSO

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Lake is located in Nagula Wetland complex. It is situated around 18 km from Tawang town (figure 1). The lake remains frozen during winter. The total area of PTSO lake is around 34550 sq.m., and total perimeter is 1068 meter (figure 2). The depth of lake is 5.6 meter. The PTSO lake area has been dominated by *Rhododendron, Primula, Codonopsis, Gentiana Pedicularis, Meconopsis* species.

Figure 2: Pangateng Tso (PTSO) high altitude wetland (a) winter season (b) monsoon season

2. MATERIAL AND METHODS

Extensive and intensive field survey was carried out during the 2016 to 2019 to assess the status of terrestrial floral diversity of PTSO wetland area of Tawang district. Standard herbarium techniques were followed for collection and preservation of the plant

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specimens (Jain & Rao 1976). High-resolution photographs of the plants was also be taken for identification and pictorial documentation. Experts of BSI Itanagar, SFRI Itanagar, BSI Shillong was consulted for plant identification. For the identification of rare, threatened and endangered species, inventory of flora was prepared and their conservation status was evaluated from IUCN Red list, Red Data Book of Indian Plants and CITES criteria. The information on ethnobotanical uses of plant species was collected through community consultation.

3. RESULTS AND DISCUSSION

During the seasonal field surveys, a detail inventory of plant species of different groups was prepared. Available secondary published literatures (Mahapatra 2010, Dutta et al. 2013, Bharali & Liden, 2018) were also consulted for compilation of floral diversity of the study area. In the present study a total 93 higher plant species belonging to 58 genera and 31families were recorded from PTSO lake area (Table 1). A total 74 herbs followed by 16 shrubs and 3 tree species were recorded from the wetland area. The Dicotyledons represented by 80 species. Whereas, Monocotyledons comprised by 10 species. 3 gymnosperms species were also recorded from the study areaThe largest number of species was noted from the family Asteraceae (13 spp.), followed by Ericaceae (11 spp.), Rosaceae (8 spp.), Primulaceae (6 spp.), Gentianaceae and Polygonaceae (5 spp. each), Papaveraceae&Campanulaceae (4 spp. each), Apiaceae (3 spp.) (Figure 3). The genus *Rhododendron* exhibited highest diversity with 9 species followed by *Primula* (6 species), *Potentila* (4 spp.), *Berberis* (3 spp.), *Cremanthodium* (3 spp.), *Meconopsis* (2 spp.). The high altitude climatic and edaphic conditions provide suitable niche for many species of *Rhododendron, Primula, Potentilla, Pedicularis, Meconopsis, Swertia, Rhodiola,* etc . Photographs of some important plant species of PTSO lake area is presented at figure 4.

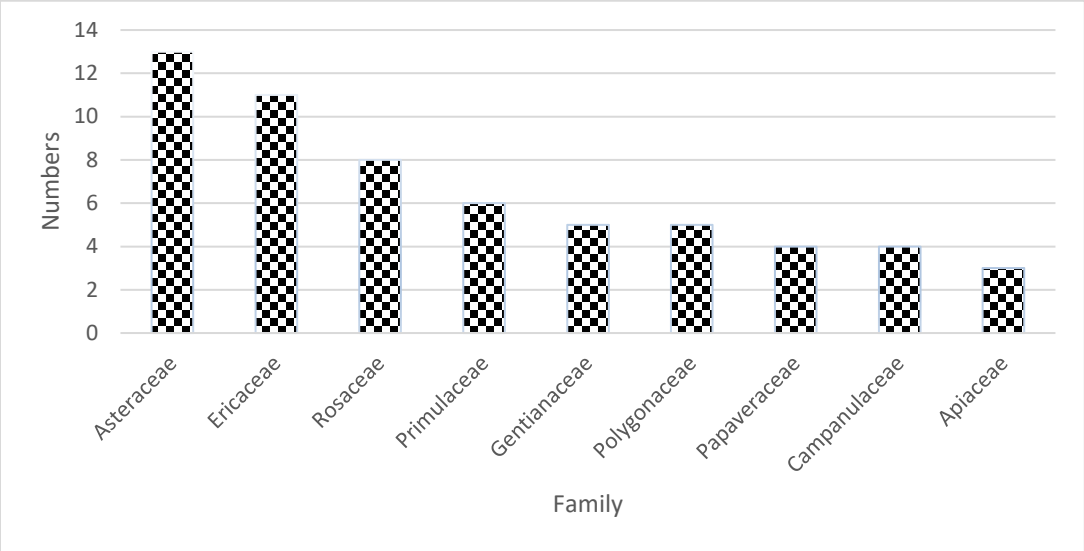

Figure 3: Dominant families of recorded plant species at PTSO lake

Table 1: List of species recorded from the PTSO high-altitude wetland area

Species	Family	Habit	Nativity	Endemism
Abies densa Griffith ex R. Parker	Pinnaceae	Tree	Reg Himal	NE
Anaphalis nepalensis (Spreng.) Hand.-Mazz.	Asteraceae	Herb	Reg Himal	NE
Arisaema speciosum var. *mirabile* (Schott) Eng	Araceae	Herb	Reg Himal	NE
Aster albescens (DC.) Wall. ex Hand.-Mazz.	Asteraceae	Herb	Reg Himal	NE
Berberis angulosa Wallich ex Hook f. & Thoms	Berberidaceae	Shrub	Ind Or	

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Berberis concinna Hook. f.	Berberidaceae	Shrub	Reg Himal	NE
Berberis mucrifolia Ahrendt	Berberidaceae	Shrub	Nepal	NE
Bistorta macrophylla (D. Don) Soják	Polygonaceae	Herb	Reg Himal	NE
Caltha palustris L.	Rananculaceae	Herb	Reg Bor Temp et Arct	
Campanula pallida Wall.	Campanulaceae	Herb	Reg Himal Afghanistan	NE
Cardamine macrophylla Willd.	Brassicaceae	Herb	Reg Himal Sibir Japon	NE
Cassiope fastigiata (Wall.) D. Don	Ericaceae	Herb	Reg Himal	NE
Chrysosplenium forrestii Diels	Saxifragaceae	Herb	China (Yunnan)	NE
Cirsium eriophoroides (Hook.f.) Petr.	Asteraceae	Herb	Reg Himal	NE
Cirsium griffithii Boiss	Asteraceae	Herb	Afghanistan	NE
Cortia depressa (D. Don) C. Norman	Apiaceae	Herb		NE
Corydalis cashmeriana Royle = *Corydalis cashmariana* Royle	Papaveraceae	Herb	Reg Himal	NE
Corydalis juncea Wall.	Papaveraceae	Herb	Reg Himal	NE
Cremanthodium oblongatum C.B. Clarke	Asteraceae	Herb	Reg Himal	NE
Cremanthodium reniforme (DC.) Benth	Asteraceae	Herb	Reg Himal	NE
Cremanthodium thomsonii C.B. Clarke	Asteraceae	Herb	Reg Himal	NE
Cyananthus lobatus Wall. ex Benth.	Campanulaceae	Herb	Reg Himal	NE
Cyananthus macrocalyx ssp. *spathulifolius* (Nannf.) K.K. Shrestha	Campanulaceae	Herb	China (Szechuan)	NE
Cyananthus sherriffii Cowan	Campanulaceae	Herb	Tibet	NE
Cynoglossum wallichii var. *glochidiatum* (Wall. ex Benth.) Kazmi	Boraginaceae	Herb	Reg Himal	NE
Epilobium angustifolium L.	Onagraceae	Herb	As Trop	
Eremogone depauperata (Edgew.) Rabeler & W.L. Wagner	Caryophyllaceae	Herb	Reg Himal	NE
Fragaria nubicola (Hook.f.) Lindl. ex Lacaita	Rosaceae	Herb	Ind Or (Sikkim)	NE
Gaultheria trichophylla Royle	Ericaceae	Herb	Reg Himal	NE
Gentiana depressa D. Don	Gentianaceae	Herb	Reg Himal	NE
Gentiana doxiongshangensis T.N. Ho	Gentianaceae	Herb	Tibet	NE
Geranium nepalense Sweet	Geraniaceae	Herb	Ind Or China	NE
Hedychium ellipticum Buch.-Ham. ex Sm.	Zingiberaceae	Herb	Reg Himal	NE
Juncus benghalensis Kunth	Juncaceae	Herb	Reg Himal China	NE
Juncus chrysocarpus Buchenau	Juncaceae	Herb	Reg Himal	NE
Juniperus indica Bertol	Cupressaceae	Shrub	Reg Himal China	NE
Juniperus recurva Buch.-Ham. ex D.Don	Cupressaceae	Tree	Reg Himal	NE
Leontopodium himalayanum DC.	Asteraceae	Herb	Reg Himal China	NE
Ligularia amplexicaulis DC.	Asteraceae	Herb	Nepal	NE
Ligularia discoidea S.W. Liu	Asteraceae	Herb	Tibet	NE
Maianthemum purpureum (Wall.) LaFrankie = *Smilacina purpurea* Wall.	Liliaceae	Herb	Reg Himal	NE
Meconopsis grandis Prain	Papaveraceae	Herb	Reg Himal	E

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Meconopsis merakensis var. *albolutea* T. Yoshida, R. Yangzom & D. G. Long	Papaveraceae	Herb	Bhutan	E
Ophiopogon intermedius D. Don	Liliaceae	Herb	Ind Or	NE
Pedicularis alaschanica Maxim.	Scrophulariaceae	Herb	Reg Himal Mangolia	NE
Pedicularis roylei Maxim.	Scrophulariaceae	Herb	Reg Himal China	NE
Persicaria capitata (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	Herb	Reg Himal China	NE
Persicaria vivipara (L.) Ronse Decr. = *Bistorta vivipara* (L.) Delarbre	Polygonaceae	Herb	Reg Himal	NE
Physospermopsis kingdon-wardii (H. Wolff) C.	Apiaceae	Herb	Tibet	NE
Picrorhiza kurrooa Royle ex Benth	Plantaginaceae	Herb	Reg Himal	NE
Platanthera bhutanica K. Inoue	Orchidaceae	Herb	Bhutan	E
Poa pagophila Bor	Poaceae	Herb	Reg Himal China	NE
Poa sikkimensis (Stapf) Bor	Poaceae	Herb	Reg Himal China	E
Polygonatum verticillatum (L.) All.	Asparagaceae	Herb	Europ As Bor	NE
Polygonum molle D. Don = *Aconogonum molle* (D. Don) H. Hara	Polygonaceae	Shrub	Reg Himal	NE
Ponerorchis chusua (D. Don) Soó	Orchidaceae	Herb	Reg Himal	NE
Potentila microphylla D. Don	Rosaceae	Herb	Reg Himal	NE
Potentila polyphylla Wall ex. Lehm	Rosaceae	Herb	Himal	NE
Potentilla bryoides Soják	Rosaceae	Herb	Bhutan	E
Potentilla peduncularis D. Don	Rosaceae	Herb	Reg Himal	NE
Primula capitata ssp. *sphaerocephala* (Balf.f. & Forrest) W.W. Sm. & Forrest	Primulaceae	Herb	Reg Himal China	NE
Primula denticulata Sm.	Primulaceae	Herb	Reg Himal	NE
Primula edgeworthii (Hook.f.) Pax	Primulaceae	Herb	Reg Himal	NE
Primula kingii Watt	Primulaceae	Herb	Reg Himal	E
Primula occlusa W.W. Sm.	Primulaceae	Herb	Tibet	E
Primula sikkimensis Hook.f	Primulaceae	Herb	Reg Himal	E
Ranunculus diffusus DC.	Ranunculaceae	Herb	Ind Or Malaya	
Rheum acuminatum Hook. f. & Thomson	Polygonaceae	Herb	Reg Himal	NE
Rhodiola himalensis (D. Don) S.H. Fu	Crassulaceae	Herb	Reg Himal	NE
Rhododendron antopogon D. Don	Ericaceae	Shrub	Reg Himal As Bor	NE
Rhododendron baileyi Balf. f.	Ericaceae	Shrub	Tibet	E
Rhododendron bhutanense S. D. Long	Ericaceae	Shrub	Bhutan	E
Rhododendron campanulatum X bararatum	Ericaceae	Shrub	Reg Himal China	NE
Rhododendron edgeworthii Hook.f.	Ericaceae	Shrub	Reg Himal China	NE
Rhododendron flinckii Davidian	Ericaceae	Shrub	Reg Himal Bhutan	NE
Rhododendron hodgsonii Hook.f.	Ericaceae	Shrub	Reg Himal	NE
Rhododendron sinogrande Balf. f. & W.W. Sm.	Ericaceae	Shrub	China (Yunnan)	NE
Rhododendron thomsonii Hook. f.	Ericaceae	Shrub	Reg Himal	NE
Rubus ellipticus Smith	Rosaceae	Shrub	Ind Or	
Rubus paniculatus Smith	Rosaceae	shrub	Reg Himal	

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Salvia hians Royle ex Benth.	Lamiaceae	Herb	Reg Himal	
Saussurea nepalensis Sprengel	Asteraceae	Herb	Reg Himal	NE
Saussurea pachyneura Franch.	Asteraceae	Herb	China Occ	
Sedum trullipetalum Hook.f. & Thomson	Crassulaceae	Herb	Reg Himal	NE
Senecio raphanifolius Wall. ex DC.	Asteraceae	Herb	Nepal (Indian Subcontinent, Asia-Tropical)	E
Silene nigrescens (Edgew.0 Majumder	Caryophyllaceae	Herb	Reg Himal China	NE
Sinocarum wolffianum (Fedde ex H. Wolff) A.K. Mukh. & Constance	Apiaceae	Herb	Ind Or (Sikkim)	E
Sorbus microphylla (Wall. ex J. D. Hooker) Wenz.	Rosaceae	Tree	Reg Himal China	NE
Strobilanthes penstemenoides (Nees) T. Anderson var. *dalhousieana* Kuntze	Acanthaceae	Herb	Reg Himal China	NE
Swertia grandiflora Harry Sm.	Gentianaceae	Herb	Bhutan Illus	E
Swertia hookeri C. B Clarke	Gentianaceae	Herb	Reg Himal	NE
Thalictrum foetidum L.	Ranunculaceae	Herb	Europ Sibir	
Veratrilla baillonii Franch.	Gentianaceae	Herb	China (Yunnan)	E

Abbreviations: T= tree, S=Shrub, H=herb, E=endemic, NE=near endemic

Native and endemic species

A total of 60 species were native to the Himalayan region, while 33 species were non-native, from biogeographic regions including Africa, China, Java, Japan, New Zealand, Malaya, Australia, America, Oriental India, Europe, Tropical Asia, and Sri Lanka. A total of 15 spp. were recorded as endemics, those were restricted to the Eastern Himalayan Region, whereas 70 spp. identified as near-endemic.

Conservation status of floral diversity in study area:

Conservation status of plant species was evaluated following IUCN Red List of Threatened Species, Version 2017.3, Red Data Book of Indian Plants (Nayar and Shastry 1988, 1989, 1990), Conservation Assessment and Management Prioritisation (CAMP), 2003 and CITES criteria's. *Picrorhiza kurrooa, Platanthera bhutanica, Ponerorchis chusua* recorded under Appendix-II of CITES. *Abies densa, Rhododendron anthopogon,* were categorized as near threatened, endangered threat categories as per CAMP, 2003. These species are facing more threat and vulnerability due to illegal collection, over-harvesting and habitat destruction in the region. Therefore, these species along with other rare, endangered and threatened species (RET), endemic species need to be prioritized for conservation.

Medicinal plants

Loacl Monpa community of the Tawang uses various plant species for the treatment of range of ailments and diseases. *Swertia, Gentiana, Rhododendron,, Meconopsis, Rhodiola,, Saussurea, Artemisia* species are mainly used for preparation of herbal remedies for cure. Medicinal plants were mainly used for curing gastro intestinal diseases, cold & cough, fever, head ache, dermatological problems, respiratory/bronchitis diseases, reproductive/gynaecological disorders, antipoisnous, urogenital, cardiovascular and other ailments. The most frequent type of preparation was decoction and paste of plant parts.

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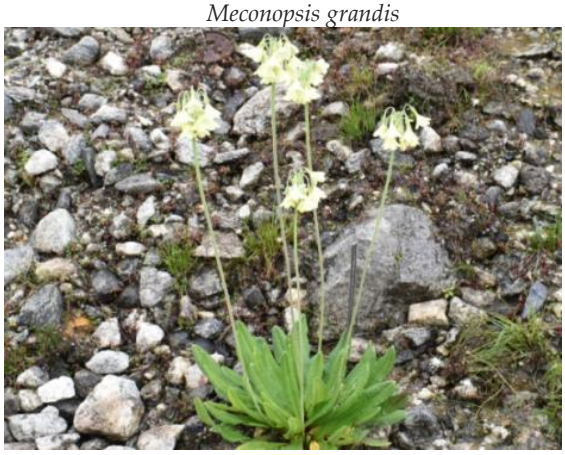
Meconopsis grandis

Primula kingii



Primula sikkimensis

Saussurea nepalensis

Potentilla bryoides

Rhododendron antopogon

Corydalis cashmeriana

Pedicularis roylei

Figure 4: Floral diversity of PTSO high-altitude wetland area

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4. DISCUSSION

HAWs of Himachal Pradesh, Ladakh, Sikkim and Arunachal Pradesh regions are studied by few workers on status of floral and faunal biodiversity, conservation and management issues & challenges, ecosystem service of wetlands related aspects (Chandan et al., 2008; Gogoi et al., 2010; Attri and Santvan, 2012). Very limited research work has been carried out to document the floral diversity of high altitude wetland of Eastern Himalaya so far (Majumdar et al., 2011; Jayachandran, 2013; Dutta et al., 2013). The high-altitude region of Himalaya is rich in representative and endemic biodiversity elements (Dhar and Kachroo, 1983; Dhar et al., 1997&1998, Kanwal et al. 2019). Although, researchers have conducted several studies on general vegetation types of the state, comprehensive documentation of plant diversity from the higher altitude wetland is still lacking from the region (Mahapatra, 2010; Dutta et al., 2013). At present, floral diversity of Arunachal Pradesh particularly high-altitude regions is being affected by climate change and diverse anthropogenic threats (Kanwal and Lodhi, 2018). They are under multiple stresses today due various developmental interventions. This is leading to a reduction in the ecosystem goods and services and biological diversity, which not only threatens the livelihoods of local tribal communities, but also ultimately threatens the sustainability of the whole region. The rapid destruction, fragmentation and depletion of HAWs ecosystem directly affect the floral biodiversity of high-altitude region of Himalaya. Shrinking of vegetation cover and habitat of flora and fauna due to various population pressure has become a serious concern for conservation of biodiversity. Unplanned and rapid infrastructure development and unregulated tourism are merging threats for ecological health of HAWs of the region. There is a lack of knowledge and information on the status of HAWs ecosystem and their ecological role and functions particularly for Eastern Himalayan region. HAWs are not covered under any specific administrative jurisdiction in the state government of Arunachal. Indigenous communities are the primarily accountable for the management of these wetlands (Jayachandran, 2013). Therefore, community participation is play important role in the conservation and wise use of wetlands of the state. Keeping in view the above, comprehensive information is urgently required for developing and implementing plans for conservation of HAWs and sustainable management of these fragile ecosystems of Himalayas. The collection of fire wood by herders, unregulated grazing, unregulated tourism, infrastructure development and NTFP collection have also been observed for exerting pressure on the plant diversity of the wetland area.

5. CONCLUSION

High altitude wetlands of Tawang are store house of many valuable and endemic species such as *Aconitum* spp., *Rhododendron Sikkimense, Panax pseudoginseng, Meconopsis, Rhododendron dalhousiae, Nardostachys jatamansi, Picrorhiza kurrooa, Podophyllum hexandrum.* These species are facing threat due to various anthropogenic disturbance aggravated with changing climate impact in the region. The species may face severe endangerment under the impact of climate change because of their narrow biogeographical range of distribution. There is therefore, an urgent need to carry out interdisciplinary in-depth research such as documentation of terrestrial and aquatic floral biodiversity, assessment of medicinal diversity & status, population dynamics study, phenological study, timber line change and change in structure & composition of community studies to assess and monitor the climate change impacts on floral biodiversity particularly for RET and endemics species of the HAWs of Himalaya. These studies will help to frame inclusive climate change mitigation and adaptation strategies for conservation of rich floral diversity of HAWs. Community particularly women and youth participation would play crucial role in conservation floral biodiversity under changing climate scenario of the HAWs. Outcome of long-term monitoring research work will further help in framing an integrated conservation and management strategy for protection of floral biodiversity of HAWs of Himalayan region.

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Author contribution:

K.S. Kanwal conceptualize and prepare the manuscript, carryout the field survey and data analysis.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

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Conflicts of interest:
The authors declare no conflict of interest.

Data and materials availability
All data associated with this study are present in the paper.

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