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Plant Species Composition of Shingkhar High Altitude Wetland in Bumthang, Bhutan

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ABSTRACT.– The present study was conducted in Shingkhar wetland to evaluate species composition for a year. The elevation of the study area is 3215 to 3600 m above sea level. Vegetation was sampled using the random quadrat of 10 x 10 m^2, 4 x 4 m^2, and 1 x 1 m^2 for trees, shrubs, and herbs respectively. The wetland composed of 252 life forms from 149 genera and 64 families. Cluster and indicator species analysis was used to characterise the vegetation within the high-altitude wetland, and this analysis was compared to plant communities' composition. Environmental variables such as elevation, slope, available Nitrogen, available Phosphorus, available Potassium, and pH were analysed to find the relationship with the plant communities using Canonical Correspondence Analysis (CCA). The indicator analysis grouped the observed sample into four plant communities. In community I, *Roscoea alpina*, *Halenia elliptica* and *Poterium filiforme* dominated all other species. Comparatively, community II was dominated by *Urtica dioica, Allium wallichii* and *Saxifraga harry-smithii*; Community III by *Pseudostellaria heterantha, Melanoseris bracteate,* and *Parnassia chinensis*; Community IV was dominated by *Athyrium filix-femina, Athyrium spinulosum,* and *Athyrium niponicum*. Elevation, pH, available Potassium, and available Nitrogen were the main environmental variables that support the wetland plants species of the study area. Understanding the importance of plant communities and species composition may provide the baseline information about the ecosystem for any conservationist.

KEY WORDS: wetland composition, high altitude, Shingkhar, Bhutan

INTRODUCTION

Wetlands differ broadly because of regional and local differences in edaphic factors, topography, microclimate, hydrology, and other factors (Ramsar Convention Secretariat, 2011; Mulatu et al., 2014). Therefore, wetlands do not have a commonly accepted definition, and it has long been a subject of debate (Ewart-Smith et al., 2006; Davis and Brock, 2008; Brand et al., 2013). Generally, the Ramsar Convention is a globally accepted framework on the wetland (Mulatu et al., 2014). The Ramsar Convention had defined wetland as a land saturated with water as a dominant factor that determines the nature of soil development, e.g., marsh, fen, peatland, or any water bodies that include the depth of water of six meters and below (Ramsar Convention Secretariat, 2011). Wetlands are found from the tundra to the tropic regions and on every continent except Antarctica (Ramsar Convention Secretariat, 2013).

Throughout human civilization, wetlands have been perceived as a valuable natural resource (Rebelo et al., 2010; Costanza et al.,2014). It provides freshwater supply, helps in erosion control, recreation, education and offers an appropriate ecosystem for both flora and fauna in the world (Ayalew, 2010; McCartney et al., 2010; Junk et al., 2013; Mulatu et al., 2014; Tendar et al., 2020). Through several physical, chemical, and biological processes, wetlands are recognized as a living filter between the terrestrial and aquatic zones contributing to water quality (Mitsch and Gosselink 2000). It is also considered a sink or wastewater discharge site as many anthropogenic pollutants are absorbed (Kadlec and Knight, 1996; Vymazal, 1998).

Bhutan has 0.26 percent of the total land cover of high-altitude wetland (Sherub et al. 2011) which harbours many threatened and vulnerable flora and fauna (Lhamo et al. 2020). The change in environmental condition due to climate change has posed an immense threat to the state of plant ecosystem of the wetland. The influx of alien species may also increase the risk on the overall plant diversity of the wetland (Abila et al., 2008; Ruto et al., 2012; Lhamo et al., 2020). Additionally, anthropogenic, and developmental activities have caused variation in wetland plant diversity over the years (Allen et al., 2005; Abila et al., 2008; Lhamo et al., 2020). The study concerning the wetlands in Bhutan is limited to surveying lakes and glacial water bodies. The wetland survey on the lower valley-bottom and new fragmented bottomland wetland under national parks were also studied (Lhamo et al., 2020; Tendar et al., 2020). However, the study on lower slope of highland wetland which holds excellent biological diversity and forms the critical mountain ecosystem component is least explored. The plant species composition on the highland wetland and interaction with the environmental variables on the Himalayan Mountain, which is sensitive to climate change is rarely assessed. Therefore, this research was conducted to assess the plant species composition and diversity in the vulnerable highlands of Shingkhar wetland.

MATERIALS AND METHODS

Study site

The survey was conducted along the hydrological gradient at Shingkhar, which is under Wangchuk Centennial National Park in Northern Bhutan (27° 30ˈ0 to 27º40ˈ0 N, 90° 40ˈ0 to 91° 0ˈ0 E) (Fig.1). *Abies densa* Griff. characterises the study site at a higher elevation, followed by herbs, shrubs, and *Rosa sericea* Lindl. at lower elevation. The average maximum temperature for one year was recorded 12°C, and the minimum temperature of 2.4°C. The area receives very little amount of rainfall during summer and winter remains extremely cold with snow cover and frost in the study sites.

Study surveys

The study samples were collected on the gentle slope of 16.12° permanent stream from the month of March to December 2020 to ensure the complete coverage of the flowering seasons. Environmental parameters such as geographical position, coordinates, altitude, slope, and aspects were measured using the standard instrument to obtain accurate results. All plant forms were measured and recorded. Temperature records were collected from National Center for Hydrology and Meteorology, Thimphu, Bhutan.

Vegetation study

Random sampling was used by laying an imaginary X and Y-axis length of 100 m at every interval of 50 m along the altitudinal gradient. The quadrat of 10 x 10 m^2, 4 x 4 m^2 and 1 x 1 m^2 for trees, shrubs, and herbs were laid respectively (Kent, 2012; Demin et al., 2012; Li et al., 2016; Wassens et al., 2017). A total of six study areas were sampled with 125 sampling plots of herbs, shrubs, and trees. Braun-Blanquet cover scale (Kent 2012), + (<1%), 1 (1-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), 5 (76-100%) was used to estimate the species in each quadrat visually. The specimens were collected from all the quadrats and identified using information from the Flora of Bhutan (Grierson and Long, 1983; Grierson and Long, 1984; Grierson and Long, 1987; Grierson and Long, 1991; Grierson and Long, 1999; Grierson and Long, 2001). Any other unknown voucher specimens were later confirmed at National Biodiversity Center, Serbithang, Thimphu, Bhutan. The temperature data were collected from National Hydrological Center, Thimphu. Soil sample with 30 cm depth was collected

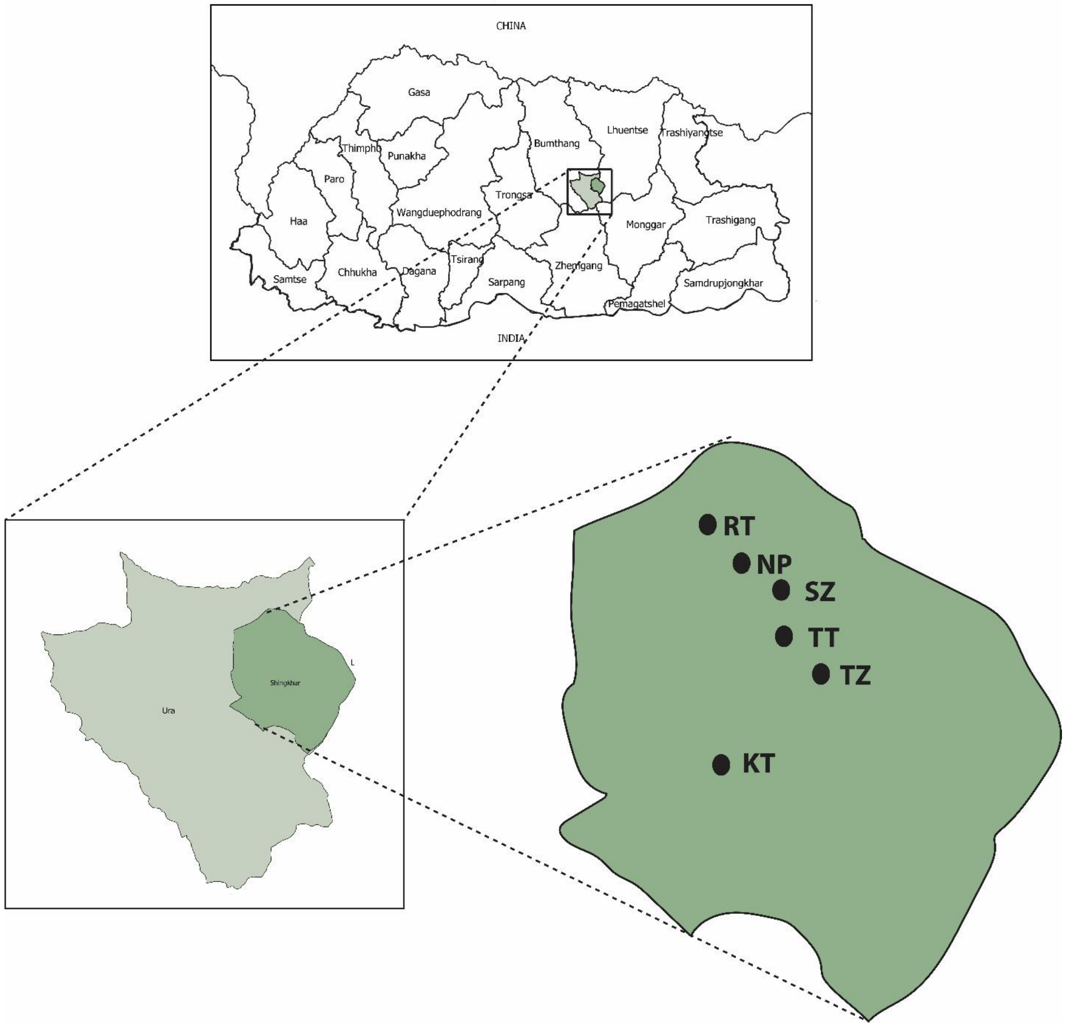

FIGURE 1. Map of Bhutan showing the location of study area in Wangchuck Centennial National Park, Bumthang, Bhutan. Black dots (●) represent sampling sites (RT, Rethangtokor; NP, Nangkaipong; SZ, Shamzor; TZ, Tangzurung; TT, Tarshingthang; KT, Kotogaithang)

from four vertices of selected quadrats and from the centre of sampling quadrats to get the accurate result using soil auger (Tendar et al., 2020). Soil samples were air-dried under laboratory condition and sent to Soil and Plant Analytical Laboratory, Department of Agriculture, Thimphu to analyse available Nitrogen, Phosphorus, Potassium, Total Nitrogen, Phosphorus, Potassium, and soil pH.

Data analysis

The PC-ORD version 7.07 program was applied to analysis data in the present study. Species cover was used as the main data input in the hierarchical cluster analysis with flexible beta linkage method with β= –0.25 and Sorensen similarity (Bray-Curtis). The cluster analysis was performed using indicator species analysis to characterise the plant communities (Dufrẽne and Legendre 1997). The community types and the cluster analysis were as per Dufrẽne and Legendre (1997). Monte Carlo test was done using the statistical significance of the indicator with 4999 permutations. Maximum observed indicator value and the maximum significance value was selected to ensure the number of species with significant indicator value (McCune and Grace 2002). Three species with the highest indicator value were named from vegetation types with maximum significance indicator values ($p<0.0001$). The relationship between environmental variables and plant species were analysed using Canonical Correspondence Analysis (Fan et al., 2017; Tendar et al., 2020).

RESULTS

Community composition

A total of 252 life forms were collected which belonged to 64 families and 149 genera including 86% herbs, 9% shrubs, 4% tree, and only 1% of the climber. The wetland plant communities were composed of 215 species of vascular plants with 60 families which includes 23 species of shrubs with 9 families, 9 species of trees with 6 families, and 3 climbers with 2 families. Plant communities were identified using Hierarchical cluster and indicator species with three prominent species named from the highest indicator value (Table 1) and (Fig. 2).

Community types

Four plant communities through cluster analysis were achieved as follows.

Community I comprise of *Roscoea alpina* Royle, *Prunella vulgaris* L., *Drosera peltata* Thunb., *Halenia elliptica* D. Don and *Poterium filiforme* Hook. f. It occurs in both dry and wet conditions where some of the species like *Poterium filiforme* Hook. f can survive. This community is present at the extreme left side of axis 1 (Fig.3), associated with a steep slope and influenced by altitude.

TABLE 1. Three indicator species with highest indicator value (IV) in each plant community from the indicator species analysis

Community types	Family	Indicator species	Code	IV	p value
Community I	Zingiberaceae	*Roscoea alpina* Royle	RosAlp	29.7	0.0002
	Gentianaceae	*Halenia elliptica* D. Don	HalEli	27.1	0.0004
	Rosaceae	*Poterium filiforme* Hook. f.	PotFil	26.6	0.0002
Community II	Urticaceae	*Urtica dioica* L.	UrtDio	42.9	0.0002
	Amaryllidaceae	*Allium wallichii* Kunth	AllWal	41.3	0.0002
	Saxifragaceae	*Saxifraga harry-smithii* Wadhwa	SaxSmi	39.9	0.0002
Community III	Asteraceae	*Pseudognaphalium hypoleucum* (DC.) Hilliard & B.L. Burtt	PseHyp	38.1	0.0002
	Asteraceae	*Melanoseris bracteata* (Hook. f. & Thomson ex C.B. Clarke) N. Kilian	MelBra	28.6	0.0002
	Celastraceae	*Parnassia chinensis* Franch.	ParChi	28.6	0.0002
Community IV	Athyriaceae	*Athyrium filix-femina* (L.) Roth	AthFem	65.4	0.0002
	Athyriaceae	*Athyrium spinulosum* (Maxim.) Milde	AthSpi	62.6	0.0002
	Athyriaceae	*Athyrium niponicum* (Mett.) Hance	AthNip	61.6	0.0002

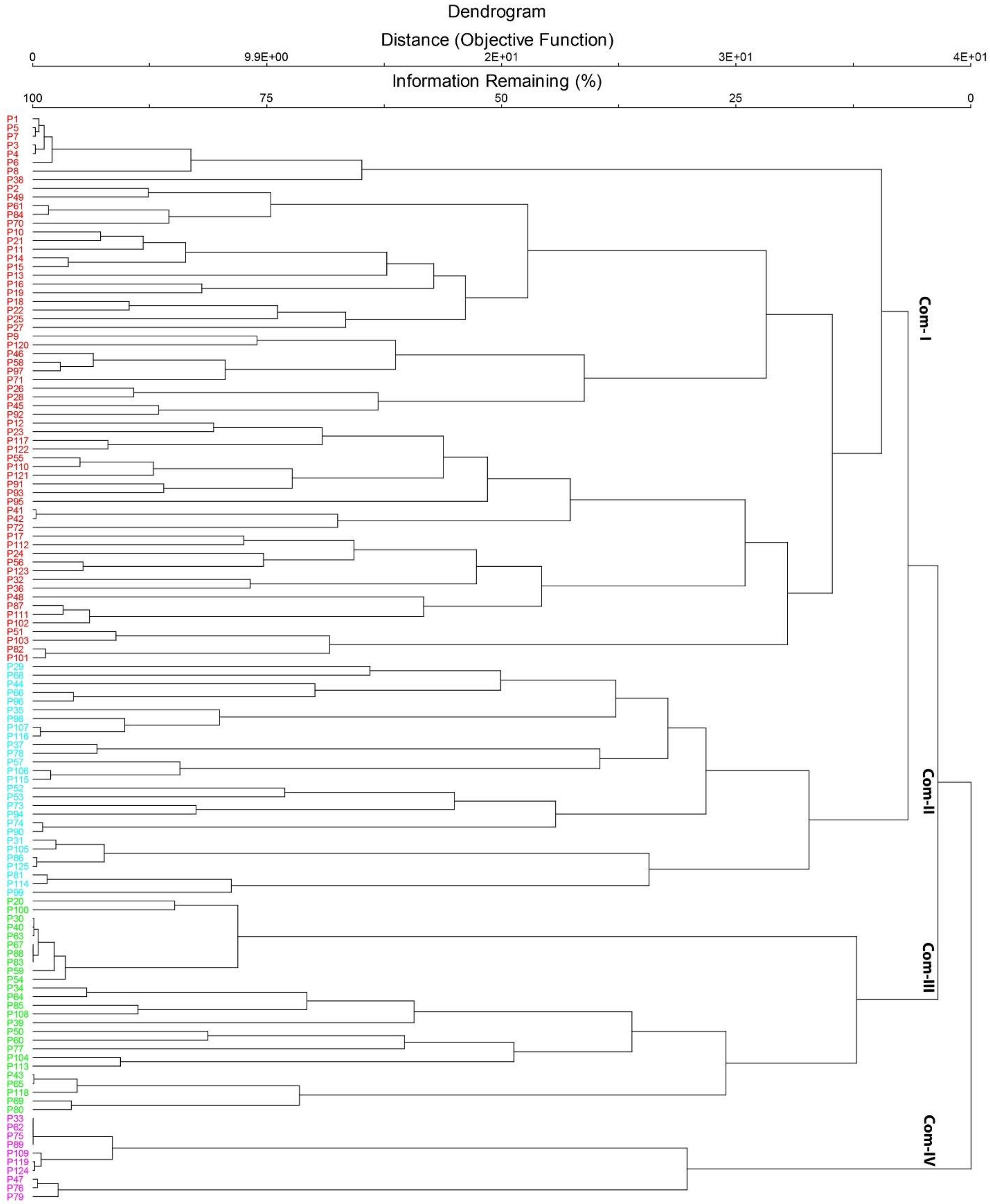

FIGURE 2. Dendrogram showing four plant communities from the hierarchical cluster analysis based on Sorensen (Bray-Curtis) measure.

Community II comprises of different plant species that can survive in both terrestrial and aquatic habitats. *Urtica dioica* L. dominated the community. Similarly, *Allium wallichii*

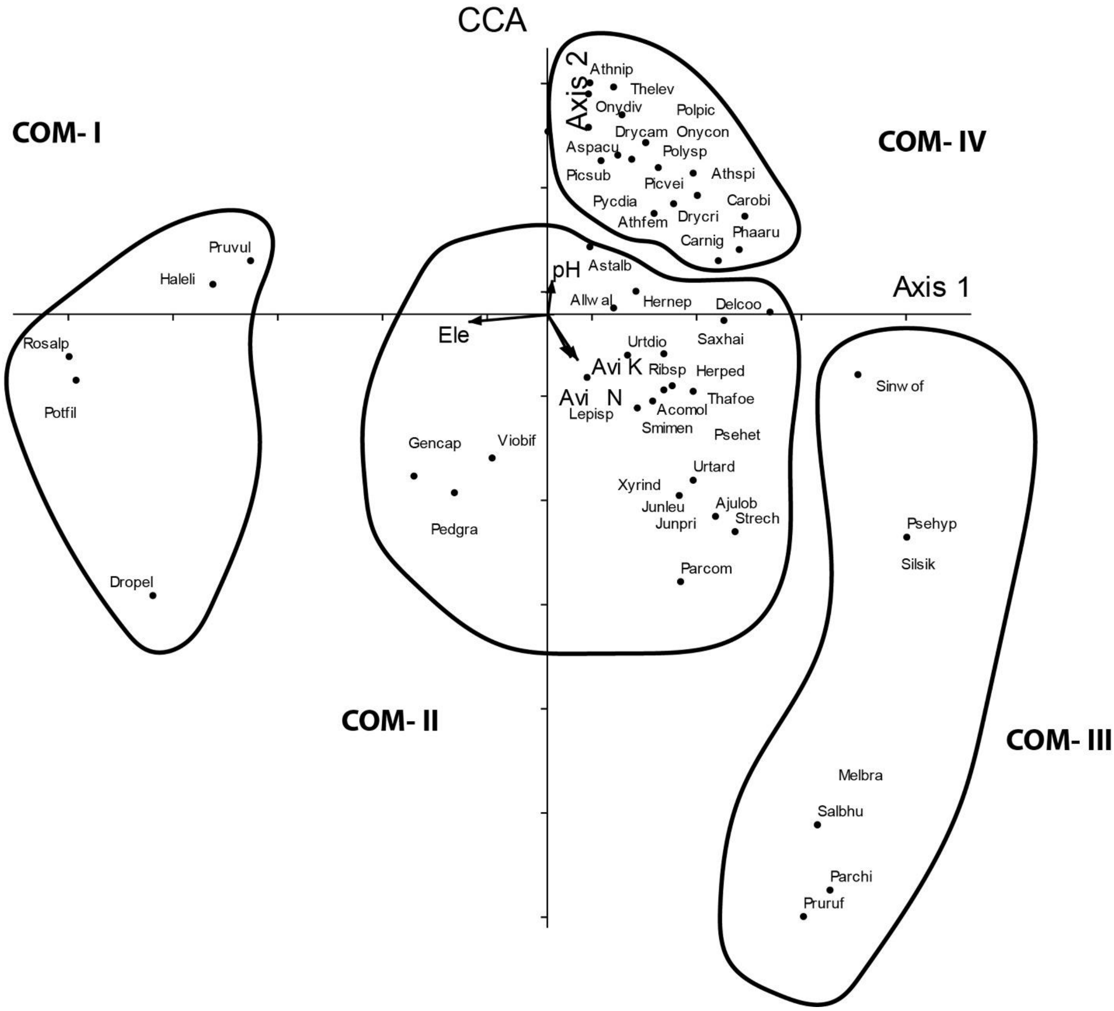

FIGURE 3. Canonical Correspondence Analysis (CCA) showing plant communities in relation to environmental factors in high altitude wetland of Shingkhar, Bumthang Bhutan

Kunth and *Saxifraga harry-smithii* Wadhwa (endemic species) were found in dry terrestrial habitat whereas, *Juncus leucomelas* Royle ex D. Don, *Juncus prismatocarpus* R. Br. and *Xyris indica* L. were found in bog area along the nearby "permanent" stream. This marsh area close to the permanent stream helps to feed the community continuously during the summer season, and they are seasonally flooded. This community is presented at the centre of the biplot axis 1 and axis 2 as illustrated in Fig. 3. The observed diversity of plant species in this community might be influenced by the available Nitrogen, as well as available Potassium. Probably, it depends much on the soil pH, however, more study needs to be carried out to affirm the impact of these variables.

Community III supports vast plant species such as *Pseudognaphalium hypoleucum* (DC.) Hilliard and B.L. Burtt, *Melanoseris bracteata* (Hook. f. and Thomson ex C.B. Clarke) N.

Kilian and *Parnassia chinensis* Franch. This community was found near the stream located on the "gentle" slope. The community is illustrated below on the right side of axis 1 in CCA (Fig. 3). This area is a temporarily flooded area.

Community IV is composed of *Athyrium filix-femina* (L.) Roth, *Athyrium spinulosum* (Maxim.) Milde and *Athyrium niponicum* (Mett.). This community lies in a low wetland below the settlement surrounded by trees, giving comfortable shade for the species and is illustrated on above axis 2 in the biplot. This area was observed to be in a rarely flooded condition (Fig. 3).

DISCUSSION

The community analysis shows that different plant species are able to grow in a different wetland habitat type. Four different plant community types were distinguished from the present study. The average soil pH values vary in the range of 4.1- 5.8 among the four plant community types (Table 2). The pH value was higher in the plant community on the middle elevation than soil pH in upper and lower areas. Overall, the highland wetland community of Shingkhar is dominated mainly by the Asteraceae, Rosaceae and Poaceae family. A similar observation was reported in other studies (Gichuki et al., 2001; Chawla et al., 2008; Mulatu et al., 2014).

In the community I, *Roscoea alpina* Royle, *Halenia elliptica* D. Don, and *Poterium filiforme* Hook. f. was dominant with a maximum number of life forms found at a higher elevation. Other lifeforms like *Agrostis micrantha* Steud. and *Sphagnum palustre* L. could also be found, which can indicate undisturbed vegetation. This plant community type is characterized by relatively low soil pH (5.8) compared to other plant community types with dry soil condition and steep slope supporting a higher number of plant species (Tendar and Sridith 2020). The low soil pH could provide a favorable soil microbial community which may increase the nutrient pools for the microorganisms, thus improving the germination of herbaceous plants (Franklin and Bergman 2011). Further, the emergence of higher plant species could be due to minor anthropogenic disturbances and landscape structure, as proposed by Jamtsho and Sridith (2015). It could be plausibly inferred and confirmed here that the steep landscape of the wetland inhibits the flooding or waterlogged system, providing other plant life forms to grow (Dwire et al., 2006; Tendar et al., 2020).

In community II, *Gentiana capitata* Buch. -Ham. ex D. Don, *Viola biflora* L., and *Pedicularis gracilis* Wall. ex Benth. were influenced by elevation. These species usually occur at high altitude, according to Tendar and Sridith (2020). Nitrogen and Potassium are crucial for the growth and development of plants (Wu and Zhao 2010). So, plant species such as *Saxifraga harry-smithii* Wadhwa, *Lepisorus* sp., *Aconogonom molle* (D. Don) H. Hara, *Utrica doida* L., *Delphinium cooperi* Munz, *Ajuga lobata* D. Don, *Thalictrum foetidum* L. and *Parochetus communis* Buch. -Ham. ex D. Don formed the distinct zonation from other communities, and their presence was influenced by available Nitrogen and available Potassium. Therefore, this research can infer the possible reasons affecting plant species in community II were available Nitrogen and available Potassium. However, species such as *Allium wallichii* Kunth and *Aster albescens* (DC.) Wall. ex Hand. -Mazz. in community II was influenced by soil pH. Scientific studies also observed that soil pH influence makes distinct separation of vegetation from other community, and hence plays the role of determinant in productivity of a site (Dong et al. 2014). Presence of *Persicaria hydropiper* (L.) Delarbre in this community indicates a seasonally flooded

TABLE 2. Site description of each wetland of Wangchuck Centennial National Park of Bumthang, Bhutan

Study site	Code	Elevation(m)	Latitude(N)	Longitude(E)	Slope	Soil pH
Kotogaithang	KT	3215	N27°29.541’	E090°57.793’	10.4	5.2
Tarshingthang	TT	3320	N27°29.548’	E090°57.796’	16.8	4.9
Tangzurung	TZ	3350	N27°29.328’	E090°57.768’	13.8	4.1
Shamzor	SZ	3405	N27°29.549’	E090°57.707’	16.6	4.5
Nangkaipong	NP	3520	N27°29.546'	E090°57.786’	17.7	4.2
Rethangtokor	RT	3600	N27°29.550’	E090°57.789’	20.2	5.8

area that forms the large water bodies underneath the basin due to inadequate drainage to serve as a place for foraging animals (Tendar et al. 2020) leading to the high acidic formation of soil. Acid-loving ericaceous shrubs such as *Rhododendron thomsonii* Hook. f., and *Rhododendron anthopogon* D. Don were found in this habitat. If the foraging on the wetland continuous, the endemic plant (*Saxifraga harry-smithii* Wadhwa) in this community will be affected.

In community III, *Pseudognaphalium hypoleucum* (D.C.) Hilliard and B. L. Burtt, *Melanoseris bracteata* (Hook. f. and Thomson ex C.B. Clarke) N. Kilian, and *Parnassia chinensis* Franch. were co-dominant species. This community was diverse, and it is located near the stream due to the high dispersal of seed along the stream's corridor (Johansson et al. 1999). It is also located close to the periphery of the farmland because of plant species such as *Rumex nepalensis* Spreng. was found in the community as it was introduced as fodder to animals. The plot closest to the human settlement was observed to have the highest impact of grazing as reported by Lodge and Tyler (2020). Plant species were under threat due to pressure from both grazing animal and anthropogenic activities (Mayer et al. 2009). Due to the anthropogenic activities, the local species were found degrading (Sax and Gaines 2003). Anthropogenic disruption influences vegetation coverage and species composition in wetlands therefore, control in all anthropogenic activities should be seriously considered.

Community IV was composed of *Athyrium spinulosum* (Maxim.) Milde, *Athyrium filix-femina* (L) Roth and *Athyrium niponicum* (Mett.) Hence, such plants species are primarily associated with dry habitats and thrive in low nutrient soil. Other plant species that grows in such stress condition is *Phalaris arundinacea* L. in community IV. Green and Galatowitsch (2001) reported that *Phalaris arundinacea* L. performs well in poor nutrient soil. Nevertheless, numerous works have supported that *Phalaris arundinacea* L. grows well in a stressed-out environment with low water condition and gets a survival strategy to adapt to a wide range of harsh environmental circumstances (Morrison and Molofsky, 1999; Westlake and Kvet, 2009; Chen et al., 2015). Furthermore, in a similar study observed by Tilman (1988) also indicated that plant species thriving in arid habitats promote their growth with one another for nutrient cycling mechanism for minimum interspecific and intraspecific competition in such community.

CONCLUSION

Shingkhar wetland is one of the crucial high-altitude wetlands found in Bumthang, Bhutan, containing different highland wetland plant communities. Those plant communities are very characteristic and might seldom occur in other places in the country. They are composed of many rare plant species due to the particular environmental factors of the high-altitude wetlands. Environmental factors such as soil pH, available Nitrogen and available Potassium are the possible main factors determining the plant communities and species composition. The present work provides information on wetland plants to safeguard the highland plant diversity of Shingkhar. Furthermore, to maintain the diversity of species in the wetland, the local people and National park must have a memorandum of understanding aimed towards future academic inquiries and mitigations of probable threats to such diverse vegetations.

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LITERATURE CITED

Abila, R., Salzburger, W., Ndonga, M.F., Owiti, D.O., Barluenga, M. and Meyer, A. 2008. The role of Yala swamp lakes in the conservation of Lake Victoria region haplochromine cichlids: Evidence from genetic and Tropical ecology studies. Lakes and Reservoirs: Research and Management, 13: 95–104.

Allen, M.L., Narain, U., Gupta, S. and Veld, K. 2005. Poverty and environment: Exploring the relationship between household incomes, Private assets, and natural assets. World Resources Institute, Washington, D.C, 13: 95–104.

Ayalew, W. 2010. Current land-use practices and possible management strategies in shore area wetland ecosystem of lake Tana: Towards improving livelihoods, productivity, and biodiversity conservation. In: Seyoum M, Brook L (Eds) Management of shallow water bodies for improved productivity and peoples' livelihood in Ethiopia. EFASA, Addis Ababa University Printing Press, Addis Ababa, 9–16 pp.

Brand, R.F., Du Preez, P.J. and Brown, L.R. 2013. High altitude montane wetland vegetation classification of the Eastern Free State, South Africa. South African Journal of Botany, 88: 223–236.

Chawla, A., Rajkumar, S., Singh, K.N., Lal, B., Singh, R.D. and Thukral, A.K. 2008. Plant species diversity along an altitudinal gradient of Bhaba Valley in Western Himalaya. Journal of Mountain Science, 5:157–177.

Chen, X., Li, X., Xie, Y., Li, F., Hou, Z. and Zeng, J. 2015. Combined influence of hydrological gradient and edaphic factors on the distribution of macrophyte communities in Dongting Lake wetlands, China. Wetlands ecology and management, 23: 481–490.

Costanza, R., De Groot, R., Sutton, P., Van Der Ploeg, S., Anderson S.J., Kubiszewski, I., Faber, S. and Turner, R.K. 2014. Changes in the global value of ecosystem services. Global Environmental Change, 26: 152–158.

Davis, J. and Brock, M. 2008. Detecting unacceptable change in the ecological character of Ramsar Wetlands. Ecological Management and Restoration, 9: 26–32.

Dong, L., Xu, L., Xu, J., Xu, J., Wang, X. and Zang, Q. 2014. Effects of soil environmental Factors on Vegetation Distribution in Shoaly Wetlands Typical to Poyang Lake. Aca Pedologica Sinica, 51: 618–626.

Dufrễne, M. and Legendre, P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monograph, 67: 345–366.

Dwire, K.A., Kauffman, J.B. and Baham, J.E. 2006. Plant species distribution in relation to water-table depth and soil redox potential in montane riparian meadows. Wetlands, 26: 131–146.

Ewart-Smith, J.L., Ollis, D.J., Day, J.A. and Malan, H.L. 2006. National wetland inventory: development of a wetland classification system for South Africa. Water Research Commission [Report KV 174/06], Pretoria, 108 pp.

Fan, H., Xu, L., Wang, X., Jiang, J., Feng, W. and You, H. 2017. Relationship between vegetation community distribution patterns and environmental factors in typical wetlands of Poyang lake, China. Wetlands, 39: 75–87.

Franklin, J. and Bergman, E. 2011. Patterns of pine regeneration following a large, severe wildfire in the mountains of southern California. Canadian Journal of Forest Research, 41: 810–821.

Gichuki, J., Guebas, F.D., Mugo, J., Rabuor, C.O., Triest, L. and Dehairs, F. 2001. Species inventory and the local uses of the plant species and fishes of lower Sondu Miriu wetland of Lake Victoria, Kenya. Hydrobiologia, 458: 99–106.

Green, E.K. and Galatowitsch, S.M. 2001. Differences in wetland plant community establishment with additions of nitrate-N and invasive species (Phalaris arundinacea and Typha xglauca). Canadian Journal of Botany, 79: 170–178.

Grierson, A.J.C. and Long, D.C. 1983. Flora of Bhutan: Including a record of plants from Sikkim, Vol 1 (1). Royal Botanic Garden, Edinburgh, 186 pp.

Grierson, A.J.C. and Long, D, C. 1984. Flora of Bhutan: Including a record of plants from Sikkim, Vol 1 (2). Royal Botanic Garden, Edinburgh, 462 pp.

Grierson, A.J.C. and Long, D,C. 1987. Flora of Bhutan: Including a record of plants from Sikkim, Vol 1 (3). Royal Botanic Garden, Edinburgh, 834 pp.

Grierson, A.J.C. and Long, D.C. 1991. Flora of Bhutan: Including a record of plants from Sikkim, Vol 2 (1). Royal Botanic Garden, Edinburgh, 426 pp.

Grierson, A.J.C. and Long, D.C. 1999. Flora of Bhutan: Including a record of plants from Sikkim and Darjeeling, Vol 2 (2). Royal Botanic Garden, Edinburgh, 1033 pp.

Grierson, A.J.C. and Long, D.C. 2001. Flora of Bhutan: Including a record of plants from Sikkim and Darjeeling, Vol 2 (3). Royal Botanic Garden, Edinburgh, 1675 pp.

Jamtsho, K. and Sridith, K. 2015. Exploring the pattern of alpine vegetation of Eastern Bhutan: a case study from the Merak Himalaya. SpringersPlus, 4: 304.

Johansson, M.E., Nilsson, C. and Nilsson, E. 1996. Do rivers function as corridors for plant dispersal? Journal of Vegetation Science, 7: 593–598.

Junk, W.J., An, S., Finlayson, C.M., Gopal, B., Květ, J., Mitchell, S.A., Mitsch, W.J. and Robarts, R.D. 2013. Current state of knowledge regarding the world's wetlands and their feature under global climate change: a synthesis. Aquatic Sciences, 75: 151–167.

Kadlec, R.H. and Knight, R.L. 1996. Treatment Wetlands, First Edition. Boca Raton, Florida: CRC press, 893 pp.

Kent, M. 2012. Vegetation description and analysis: a practical approach, 2nd ed. Wiley-Blackwell, Chichester, 402 pp.

Lhamo, P., Kabir, A. and Uddin, S.M.N. 2020. Assessing the influence of human settlements on the plant diversity in wetlands of Phobji and Gangtey, Bhutan. Natural Science and Technology, 12: 11–14.

Li, X., Xue, Z. and Goa, J. 2016. Environmental influence on vegetation properties of frigid wetlands on the Qinghai-Tibet plateau, western China. Wetlands, 36: 807–819.

Lodge, K.A. and Tyler, A.C. 2020. Divergent impact of grazing on plant communities of created wetlands with varying hydrology and antecedent land use. Wetlands Ecology and Management, 28: 797–813.

Mayer, R., Kaufmann, R., Vorhauser, K. and Erschbamer, B. 2009. Effects of grazing exclusion on species composition in high-altitude grasslands of the Central Alps. Basic and Applied Ecology, 10: 447–445.

McCartney, M., Rebelo, L.M., Senaratna Sellamutta, S. and Silva, S. 2010. Wetlands, Agriculture and Poverty Reduction. Colombo, Sri Lanka: International Water Management Institute. IWMI Research Report, 39 pp.

McCune, B., Grace, J.B. and Urban, D.L. 2002. Analysis of ecological communities (Vol.28). Gleneden

Beach, OR MjM Software design, Oregon, US, 300 pp.

Mitsch, W.J. and Gosselink, J.G. 2000. 'The value of wetlands: Importance of scale and landscapes setting.' Ecological Economics, 35: 25–33.

Morrison, S.L. and Molofsky, J. 1999. Environmental and genetic effects on the early survival of the invasive grass Phalaris arundinacea. Canadian Journal of Botany, 77: 1447–1453.

Mulatu, K., Hunde, D. and Kissi, E. 2014. Impacts of wetland cultivation on plant diversity and soil fertility in South-Bench District, Southwest Ethiopia. African Journal of Agricultural Research, 9: 2936–2947.

Ramsar Convention Secretariat, 2011. The Ramser Convention Manual: a guide to the Convention on wetlands (Ramsar, Iran, 1971), 5th ed. Ramsar Convention Secretariat, Gland, Switzerland, 112 pp.

Ramsar Convention Secretariat, 2013. The Ramser Convention Manual: a guide to the Convention on wetlands (Ramsar, Iran, 1971), 5th ed. Ramsar Convention Secretariat, Gland, Switzerland, 161 pp.

Rebelo, L.M., McCartney, M.P. and Finlayson, C.M. 2010. Wetlands of Sub-Saharan Africa: distribution and contribution of agriculture to livelihoods. Wetlands Ecology and Management, 18: 557–572.

Ruto, W.K.S., Kinyamario, J.I., Ng'etich, N.K., Akunda, E. and Mworia, J.K. 2012. Plant species diversity and composition of two wetlands in the Nairobi National Park, Kenya. Journal of Wetlands Ecology, 6: 7–15.

Sax, D.F. and Gaines, S.D. 2003. Species diversity: From global decreases to local increases. Trends in ecology and evolution, 18: 561–566.

Sherub, Wangdi, N. and Norbu, N. 2011. Saving wetland sky high: Inventory of high-altitude wetlands in Bhutan. Ugyen Wangchuk Institute for Conservation and Environment, 26 pp.

Tendar, P., Cooper, D.J. and Sridith, K. 2020. Wetland plant communities of the Eastern Himalayan highlands in Northern Bhutan. Wetlands, 40: 2477–2488.

Tendar, P. and Sridith, K. 2021. Vegetation structure of wetlands in Eastern Himalayan highlands of Gasa, Bhutan. ScienceAsia, 47: 78–85.

Tilman, D. 1988. Plant Strategies and the Dynamic and Structure of plant communities Princeton. New Jersey: Princeton University Press, 26–28.

Vymazal, J., Brix, H., Cooper, P., Green, M. and Haberl, R. 1998. Constructed wetlands for wastewater treatment in Europe: Backhuys Leiden. Water Environ. Res, 67: 855–862.

Wassens, S., Ning, N., Hardwick, L., Bino, G. and Maguire, J. 2017. Long-term changes in freshwater aquatic plant communities following extreme drought. Hydrobiologia, 799: 233–247.

Westlake, D.F., Kvet, J. and Szczepanski, A. (Eds.). 2009. The production ecology of wetlands: the IBP synthesis. Cambridge University Press, Cambridge, 78–139 pp.

Wu, W. and Zhao, J. 2010. Advanced on plants' nitrogen assimilation and utilization, Chinese Agriculture. Science Bulletin, 26: 75–78.

Zhou, D., Luan, Z., Guo, X. and Lou, Y. 2012. Spatial distribution patterns of wetland plants in relation toenvironmental gradient in the Honghe National Nature Reserve, Northeast China. Journal of Geographical Sciences, 22: 57–70.