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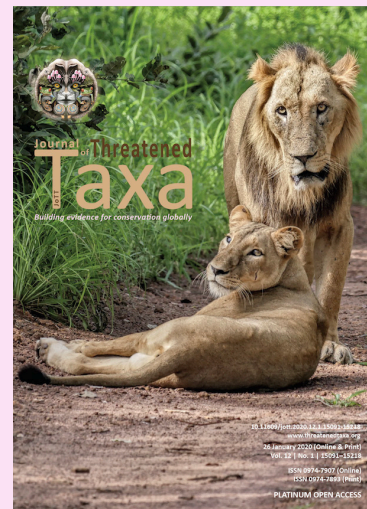
## COMMUNICATION

### THE PATTERN OF WATERBIRD DIVERSITY OF THE TRANS-HIMALAYAN WETLANDS IN CHANGTHANG WILDLIFE SANCTUARY, LADAKH, INDIA

Pushpinder Singh Jamwal, Shivam Shrotriya & Jigmet Takpa

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## The pattern of waterbird diversity of the trans-Himalayan wetlands in Changthang Wildlife Sanctuary, Ladakh, India

Pushpinder Singh Jamwal<sup>1</sup> , Shivam Shrotriya<sup>2</sup> & Jigmet Takpa<sup>3</sup>

<sup>1</sup> University of Molise, Department of Biosciences and Territory, Pesche 86090, Italy.

<sup>2</sup> Wildlife Institute of India, P.O. Box 18, Chandrabani, Dehradun, Uttarakhand 248001, India.

<sup>3</sup> Ministry of Environment, Forest and Climate Change, Government of India, New Delhi 110003, India.

<sup>1</sup> pushpindersjamwal@gmail.com (corresponding author), <sup>2</sup> shivam@wii.gov.in, <sup>3</sup> jiksmet@gmail.com

**Abstract:** Ladakh lies on an important bird migratory route between the Palearctic and the Indian sub-continent, and the high altitude migratory species utilise Ladakh frequently as a stopover site. The trans-Himalayan landscape in Ladakh also serves as a breeding site for many water birds species including the globally threatened Black-necked Crane *Grus nigricollis*. Yet, only sporadic information is available on the status and diversity of waterbirds here. In a landscape-level assessment study spanning over 27,000km<sup>2</sup> area, we surveyed 11 major high-altitude wetlands of Changthang Wildlife Sanctuary, Ladakh during the pre-winter season of the year 2013. We recorded a total of 38 waterbird species belonging to 10 families, including one species in Vulnerable and two species in Near Threatened categories of IUCN Red List. We calculated species diversity and richness indices to compare the wetlands. Statapuk Tso and Tsokar were the most diverse wetlands of the sanctuary (Shannon diversity 2.38 and 2.08, respectively). We used principal component analysis to find out the wetlands with unique species assemblage and identify the sites with high conservation value. We also observed a directional pattern of diversity among the wetlands of Ladakh. We provide a reminder that wildlife even in protected areas should be surveyed regularly with the sources of threats to their conservation documented carefully.

**Keywords:** Black-necked Crane, conservation management, migratory birds, point count survey, species assemblage, tourism.

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**Author details:** PUSHPINDER SINGH JAMWAL is working on the ecology of otters along Indus River and its tributaries in Ladakh region of India. SHIVAM SHROTRIYA's research focuses on Himalayan Wolf along with other large mammals in the Trans-Himalayan landscape of Ladakh. JIGMET TAKPA undertook several initiatives on biodiversity conservation, rural development and renewable energy in Ladakh.

**Author contribution:** PSJ and JT conceptualised and designed the study. PSJ and SS collected the data, analysed and wrote the manuscript. All the authors reviewed the final manuscript.

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## INTRODUCTION

Waterbirds are an essential component of wetland ecosystems and serve as bio-indicators and models to monitor the health of wetlands (Urfi et al. 2005). Aquatic birds function at multiple trophic levels in the wetland food webs, thus reflecting the changes in different ecosystem components (Custer & Osborne 1977; Grimmett et al. 2011). The Convention on wetlands or the Ramsar Convention stresses the importance of waterfowl habitats. Conserving and managing wetlands over vast landscapes, however, requires extensive resources, is cumbersome and often difficult to achieve. For practical reasons, it is important that wetlands supporting important species assemblages are identified and protected (Young et al. 2014). Avifauna diversity parameters such as species richness, diversity and density of the birds frequently provide information on habitat quality and are crucial to wetland management (Nilsson & Nilsson 1978; Sampath & Krishnamurthy 1990; Colwell & Taft 2000).

India harbours more than 4,000 high altitude lakes, and most of those are situated in the trans-Himalayan Ladakh region (Space Applications Centre 2011). Ladakh is the westward extension of the Tibetan Plateau. The Indus Valley in Ladakh is a crucial bird migratory route between the Palearctic and the Indian sub-continent (Williams & Delany 1986; Ali & Ripley 1988). As many as 319 bird species, making about 26% of Indian avifauna, are reported from Ladakh; and out of these 44 species are waterbirds (Pfister 2004; Chandan et al. 2008; Hussain et al. 2008). Ladakh is the only known breeding ground of Black-necked Crane *Grus nigricollis* in India (Chandan et al. 2006). Other waterbird species that breed in Ladakh are Bar-headed Goose *Anser indicus*, Brown-headed Gull *Chroicocephalus brunnicephalus*, Common Merganser *Mergus merganser*, Common Redshank *Tringa totanus*, Common Tern *Sterna hirundo*, Great Crested Grebe *Podiceps cristatus*, Ruddy Shelduck *Tadorna ferruginea*, and Lesser Sand Plover *Charadrius mongolus* (Prins & Wieren 2004; Chandan et al. 2008; Hussain et al. 2008; Humbert-Droz 2011).

Only a few sporadic scientific studies on waterbirds in the Indian trans-Himalaya have been conducted so far, leaving a significant information gap. Except for a few studies on waterbirds at specific high altitude wetlands (Mishra & Humbert-Droz 1998; Hussain & Pandav 2008; Namgail et al. 2009; Chandan 2015), there has been no attempt made to study waterbirds of Ladakh at the landscape level. We surveyed 11 major high-altitude wetlands of Ladakh during the pre-winter

season from 15 September to 15 November 2013, when bird migration towards India takes place. Here, we provide an inventory of migratory waterbirds of Ladakh and report on the species richness and diversity of the wetlands. We also highlight the critical wetlands that support a high diversity and threatened bird species.

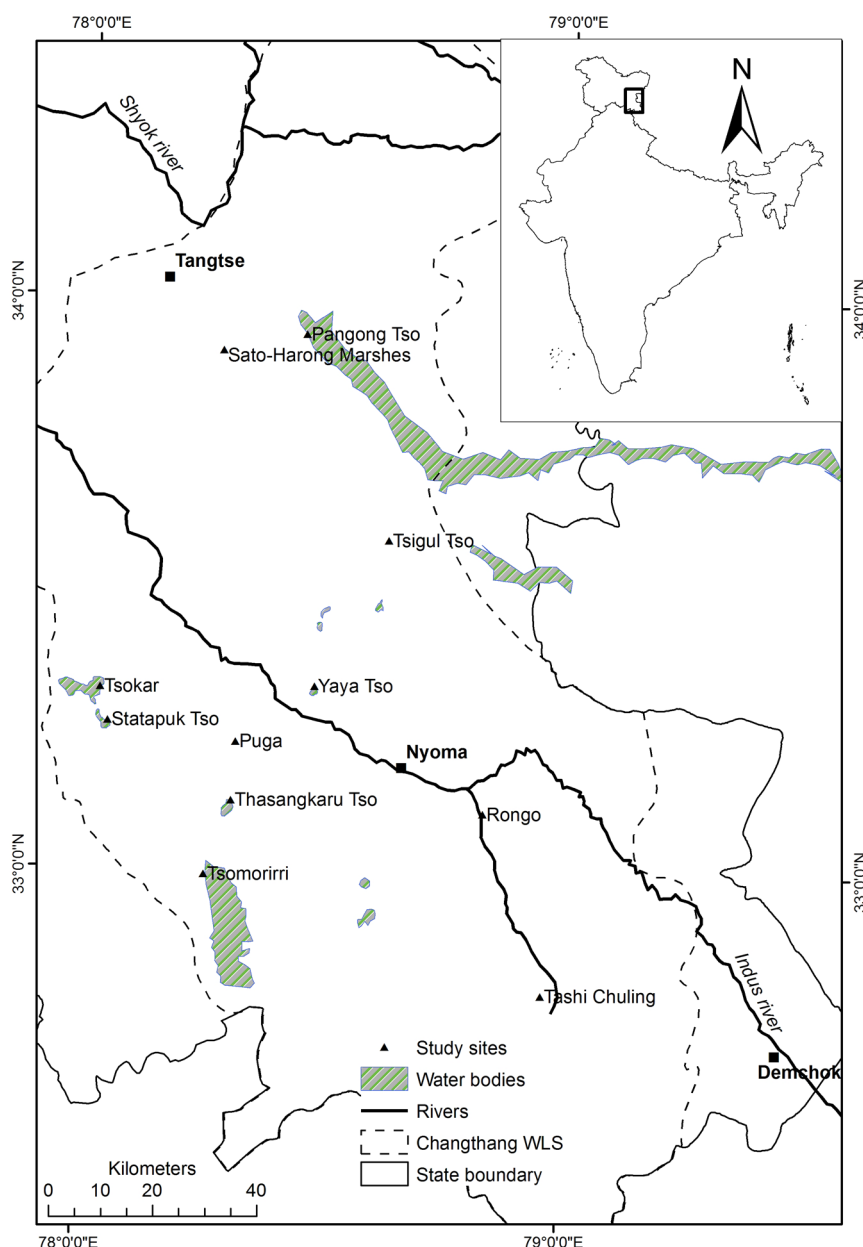
## MATERIAL AND METHODS

### Study area

Ladakh constitutes the trans-Himalayan landscape bordering Tibet (China). A high number of wetlands including 22 lakes and Indus river catchment are located in Changthang Wildlife Sanctuary (CWS) in eastern Ladakh (Chandan et al. 2006). CWS spans about 27,000 km<sup>2</sup> between 32.317–34.583 °N and 77.750–79.300 °E at an average altitude of 4,000m. CWS is an important highland grazing system in the cold desert biotope with a short summer and Arctic-like winter. Powerful and unpredictable winds make the area highly inhospitable; temperature ranges from 0°C to 30°C during summer and from -10°C to -40°C during winter (Mishra & Humbert-Droz 1998; Chandan 2015). Most of the wetlands in Ladakh are of glacial origin and remain frozen from December to March. Several brackish and freshwater wetlands here are home to a wide variety of flora and fauna. We surveyed 11 major wetlands (>0.4 km<sup>2</sup>) in CWS: Pangong Tso, Puga, Rongo, Sato-Harong Marshes, Statapuk Tso, Tashi Chuling, Thasangkaru Tso, Tsigul Tso, Tsokar, Tsomorirri, and YayaTso (Figure 1, Table 1).

### Data collection

We conducted field surveys from 15 September to 15 November 2013 following point count survey method (Bibby et al. 1992). The points were placed on the shores of the wetlands keeping the inter-point distance of at least 1km. A total of 59 points were surveyed and repeated fortnightly four times each (Table 1). Observations were aided by binoculars and carried out early in the morning during the first three hours after sunrise at 06.30h when the bird activity is at its peak. Each survey consisted of three 10-minute scans with a break of one hour in between. All the corresponding points for a wetland were surveyed simultaneously at the same time. Each of the wetlands was surveyed by a different team of authors, wildlife department guards and volunteers ranging 6–22 members. The checklist of species was prepared following (Grimmett et al. 2011). The conservation status of species was assigned using



**Figure 1. Location of the study area and surveyed high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.**

the Red List classification of IUCN (IUCN 2019).

### Data analysis

We calculated Shannon-Weiner diversity index SDI (Hutchison 1970), Margalef's richness index MRI (Margalef 1958), Pielou's evenness index PEI (Pielou 1966), and McNaughton's community dominance index CDI (McNaughton 1968) to compare the species richness and diversity across the sites. We performed principal component analysis with Bray-Curtis distances on the species assemblage to develop a minimum spanning tree of the surveyed wetlands (Bray & Curtis 1957; Gower 1966). Minimum spanning tree is closely

related to single linkage clustering. All the analyses were performed in statistical program R, version 3.4.4 (R Core Team 2018) using the package "vegan", version 2.4-6 (Oksanen et al. 2018).

### RESULTS

We recorded 38 water-bird species belonging to 10 families in 11 high altitude wetlands of Ladakh, India (Images 1–15). Anatidae accounted for 34% species followed by Scolopacidae (21%), Charadriidae and Laridae (11% each), Podicipedidae, Rallidae, and

**Table 1. Location, size and survey effort of the high altitude wetlands of Ladakh in Changthang Wildlife Sanctuary.**

Wetland	Location	Size (Km <sup>2</sup> )	Survey Points
Pangong Tso	N 33.936°, E 78.447°	26.99	4
Puga	N 33.223°, E 78.318°	0.84	4
Rongo	N 33.105°, E 78.835°	1.66	3
Sato-Harong Marshes	N 33.905°, E 78.274°	6.34	4
Statapuk Tso	N 33.256°, E 78.052°	6.09	8
TashiChuling	N 32.789°, E 78.962°	0.44	4
Thasangkaru Tso	N 33.121°, E 78.311°	5.48	4
Tsigul Tso	N 33.579°, E 78.627°	0.89	3
Tsokar	N 33.314°, E 78.035°	21.53	11
Tsomorirri	N 32.991°, E 78.258°	22.19	9
Yaya Tso	N 33.323°, E 78.479°	1.55	5

Recurvirostridae (5% each), and Ardeidae, Gruidae and Motacillidae (2.6% each). Bar-headed Goose, Common Merganser, Common Sandpiper *Actitis hypoleucos*, Northern Pintail *Anas acuta*, and Ruddy Shelduck *Tadorna ferruginea* were the most abundant species, while less than five individuals were recorded for Black-winged Stilt *Himantopus himantopus*, Kentish Plover *Charadrius alexandrinus*, Pacific Golden Plover *Pluvialis fulva*, Pallas's Gull *Ichthyaeetus ichthyaeetus*, Red-crested Pochard *Netta rufina*, and Water Rail *Rallus aquaticus*. Bar-headed Goose, Black-necked Crane *Grus nigricollis*, Brown-headed Gull *Chroicocephalus brunicephalus*, Common Sandpiper *Actitis hypoleucos*, Great Crested Grebe, Northern Pintail *Anas acuta* and Ruddy Shelduck were the most well distributed species, recorded at more than five wetlands (Table 2).

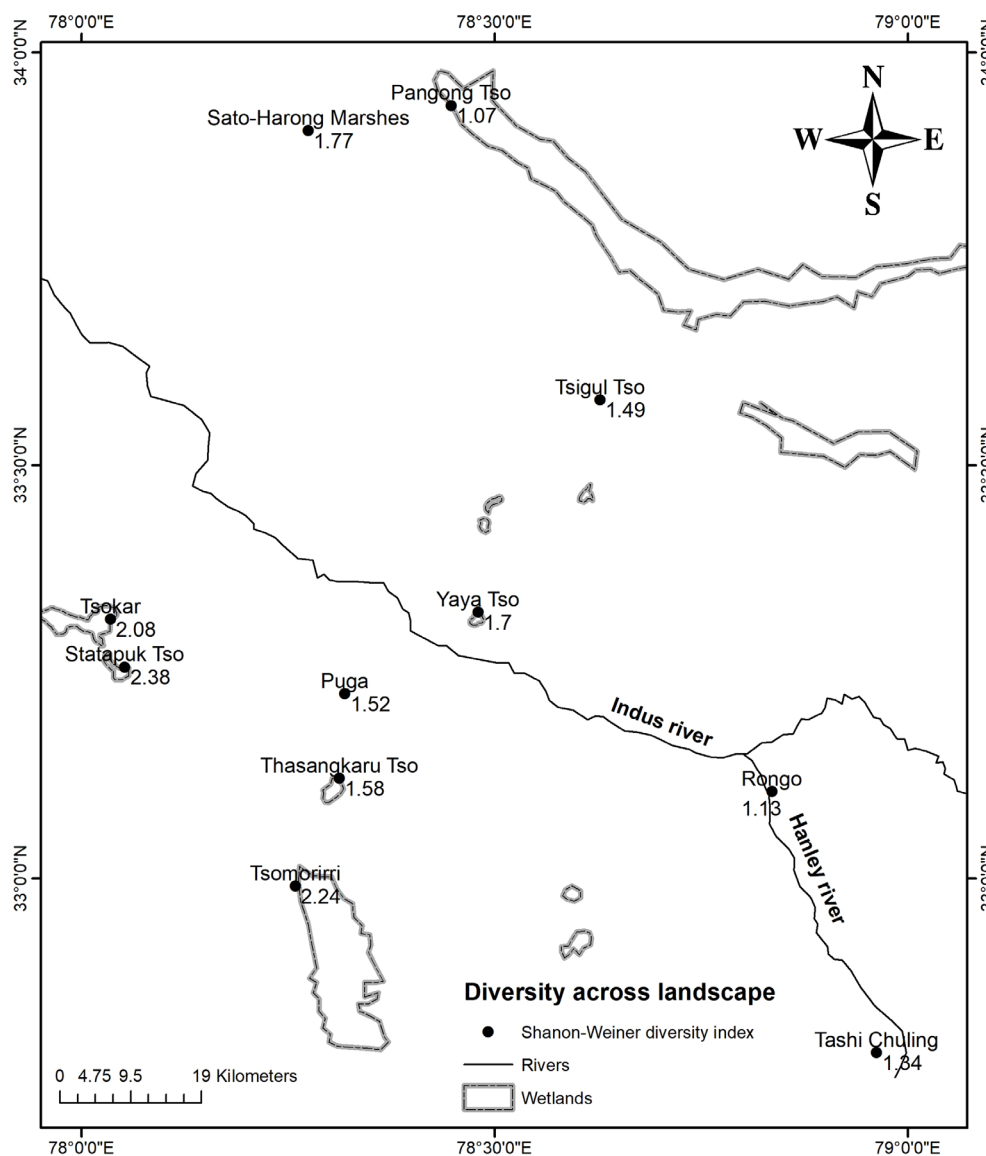
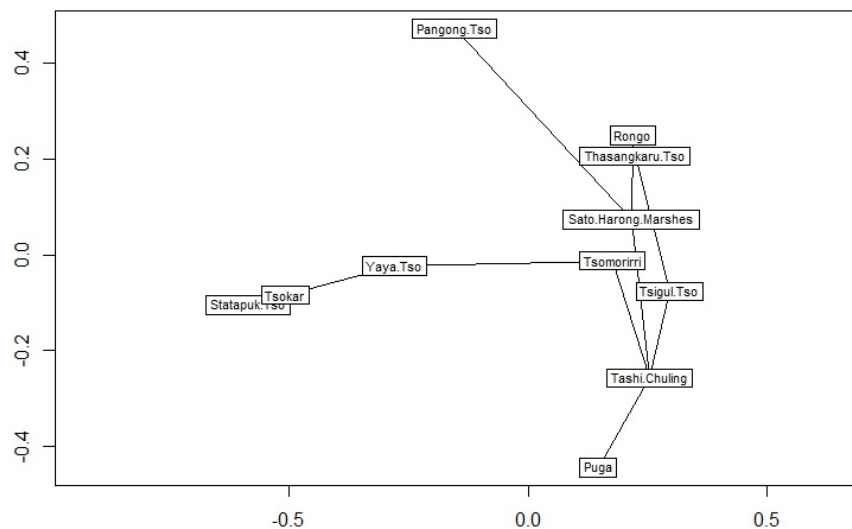
**Figure 2. Pattern of Shannon-Weiner diversity across the high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.**



Table 2. List of waterbird species recorded at the high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.

Family	Common name	Scientific name	IUCN status <sup>†</sup>	Recorded at wetlands <sup>#</sup>	Abundance <sup>†</sup>
Anatidae	Bar-headed Goose	<i>Anser indicus</i>	LC	2,3,4,5,6,8,9,10,11	1298–1717
Anatidae	Common Merganser	<i>Mergus merganser</i>	LC	5,10,11	1573–1806
Anatidae	Common Pochard	<i>Aythya ferina</i>	LC	4	44–61
Anatidae	Eurasian Wigeon	<i>Anas penelope</i>	LC	5,10	20–48
Anatidae	Ferruginous Duck	<i>Aythya nyroca</i>	NT	1,5,10,11	40–56
Anatidae	Gadwall	<i>Anas strepera</i>	LC	5	29–56
Anatidae	Garganey	<i>Anas querquedula</i>	LC	5,11	58–105
Anatidae	Mallard	<i>Anas platyrhynchos</i>	LC	5,8	55–76
Anatidae	Northern Pintail	<i>Anas acuta</i>	LC	1,2,3,4,5,6,7,8,9,10,11	1341–1571
Anatidae	Northern Shoveler	<i>Anas clypeata</i>	LC	5,10,11	48–68
Anatidae	Red-crested Pochard	<i>Netta rufina</i>	LC	5	4
Anatidae	Ruddy Shelduck	<i>Tadorna ferruginea</i>	LC	2,3,4,5,6,7,8,9,10,11	943–1526
Anatidae	Tufted Duck	<i>Aythya fuligula</i>	LC	5,11	31–48
Ardeidae	Grey Heron	<i>Ardea cinerea</i>	LC	4,5,11	7–8
Charadriidae	Kentish Plover	<i>Charadrius alexandrinus</i>	LC	5,9	2–4
Charadriidae	Lesser Sand Plover	<i>Charadrius mongolus</i>	LC	5,9	146–210
Charadriidae	Pacific Golden Plover	<i>Pluvialis fulva</i>	LC	5	2
Gruidae	Black-necked Crane	<i>Grus nigricollis</i>	VU	2,3,4,5,6,8,9,11	29–35
Laridae	Brown-headed Gull	<i>Chroicocephalus brunnicephalus</i>	LC	1,3,4,5,7,9,10	563–699
Laridae	Common Tern	<i>Sterna hirundo</i>	LC	2,5	8–11
Laridae	Little Gull	<i>Hydrocoloeus minutus</i>	LC	5	12–56
Laridae	Pallas's Gull	<i>Ichthyophaga ichthyophaga</i>	LC	3	2–4
Motacillidae	Citrine Wagtail	<i>Motacilla citreola</i>	LC	5	15–18
Podicipedidae	Black-necked Grebe	<i>Podiceps nigricollis</i>	LC	5,9	10–25
Podicipedidae	Great Crested Grebe	<i>Podiceps cristatus</i>	LC	1,5,7,9,10,11	520–860
Rallidae	Eurasian Coot	<i>Fulica atra</i>	LC	5	7
Rallidae	Water Rail	<i>Rallus aquaticus</i>	LC	5	2
Recurvirostridae	Black-winged Stilt	<i>Himantopus himantopus</i>	LC	5	4
Recurvirostridae	Pied Avocet	<i>Recurvirostra avosetta</i>	LC	9	21–23
Scolopacidae	Common Redshank	<i>Tringa totanus</i>	LC	5,10	71–101
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	LC	2,3,4,5,6,7,8,9,10,11	1469–1854
Scolopacidae	Common Snipe	<i>Gallinago gallinago</i>	LC	5	73–90
Scolopacidae	Eurasian Curlew	<i>Numenius arquata</i>	NT	5,9	3–9
Scolopacidae	Green Sandpiper	<i>Tringa ochropus</i>	LC	5,9	104–131
Scolopacidae	Little Stint	<i>Calidris minuta</i>	LC	5,9	17–26
Scolopacidae	Little Ringed Plover	<i>Charadrius dubius</i>	LC	2,5,9	282–486
Scolopacidae	Ruff	<i>Philomachus pugnax</i>	LC	5	6
Scolopacidae	Temminck's Stint	<i>Calidris temminckii</i>	LC	5,9	453–566

LC—Least Concern | NT—Near Threatened | VU—Vulnerable | 1—Pangong Tso | 2—Puga | 3—Rongo | 4—Sato-Harong Marshes | 5—Statapuk Tso | 6—TashiChuling | 7—Thasangkaru Tso | 8—Tsigul Tso | 9—Tsokar | 10—Tsomorirri | 11—Yaya Tso | '—Range from minimum to maximum number of individuals counted.



**Figure 3.** Minimum spanning tree based on principal coordinate analysis of the bird assemblage at the high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.

Statapuk Tso was the most diverse and species-rich wetland (SDI 2.38, MRI 3.91) with 35 species recorded there. Diversity and richness were higher at Tsokar ( $n=16$ , SDI 2.08, MRI 1.93), Yaya Tso ( $n=12$ , SDI 1.7, MRI 1.58) and Tsomoriri ( $n=11$ , SDI 2.24, MRI 1.79) as well. Pangong Tso had the lowest number of species ( $n=4$ , SDI 1.07, MRI 0.54). PEI was the highest at Thasangkaru Tso (0.98) and the lowest at Rongo (0.58), while CDI was the highest at Pangong Tso, Rongo and Tashi Chuling (0.8) and the lowest at Statapuk Tso and Tsomoriri (0.4) (Table 3). We also observed that the western wetlands held comparatively higher waterbird diversity than the eastern wetlands, revealing a directional pattern (Figure 2). We tested the hypothesis if the species diversity was affected by the size of the wetlands using paired Mann-Whitney-Wilcoxon test; and we found that wetland size does not relate with Shannon diversity ( $V=53$ ,  $p=0.083$ ). Following the species assemblage, studied sites aligned into two main groups. Statapuk Tso, Tsokar, and Yaya Tso formed one group and Rongo, Thasangkaru Tso, Sato Harong Marshes, Tsomoriri, Tsigul Tso, and Tashi Chuling formed another group. Species assemblage at Pangong Tso and Puga were distinct from each other and all other wetlands as well (Figure 3).

## DISCUSSION

Measures of diversity are frequently seen as indicators of the wellbeing of ecological systems (Magurran 1988). The presence of an endangered species, however, can add to the conservation importance of a site. For effective conservation, wetlands supporting important

species, diversity and unique assemblages should be identified and protected (Young et al. 2014). Black-necked Crane was the most threatened waterbird species in our checklist, categorised as Vulnerable in the IUCN Red List (Rahmani 2012; Rahmani et al. 2015; IUCN 2019). Ladakh is the only known breeding ground of Black-necked Crane in India (Chandan et al. 2006). The species was present at all wetlands but Thasangkaru Tso, Tsomoriri and Pangong Tso. Although widespread among the surveyed wetlands, its abundance was very low (Table 2). Seasonality might have affected its sighting as the species is reported to begin migrating at the beginning of the winter season (Chandan 2015). Eurasian Curlew *Numenius arquata* and Ferruginous Duck *Aythya nyroca*, categorised as Near Threatened in the IUCN Red List (IUCN 2019), were also sighted infrequently (Table 2). Eurasian Curlew was present at Statapuk Tso and Tsokar, whereas Ferruginous Duck was present at Statapuk Tso, Tsomoriri, Yaya Tso and Pangong Tso. We did not sample a large number of the smaller wetlands ( $<0.4$  km<sup>2</sup>) during the present study, where a few species and individuals of threatened species might find refuge. Principal coordinates analysis of the wetlands based on their species composition indicated that Statapuk Tso, Puga and Pangong Tso are unique, falling on the farthest edges of the minimum spanning tree (Figure 3). Statapuk Tso and Tsokar hold most of the waterbird diversity and are situated together forming a complex (Chandan et al. 2014). Tsomoriri and Tsigul Tso are located at the centre of the minimum spanning tree (Figure 3), suggesting that the water-bird communities of these wetlands share common species with other wetlands as well. Tsomoriri is a high altitude Ramsar



**Table 3. Measurements of waterbird diversity and richness at the high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.**

Wetland	Total Species	Shannon-Weiner diversity index (SDI)	Margalef's richness index (MRI)	Pielou's evenness index (PEI)	Community dominance index (CDI)
Pangong Tso	4	1.07	0.54	0.77	0.8
Puga	7	1.52	1.06	0.78	0.6
Rongo	7	1.13	1.25	0.58	0.8
Sato-Harong Marshes	8	1.77	1.26	0.85	0.5
Statapuk Tso	35	2.38	3.91	0.67	0.4
Tashi Chuling	5	1.34	0.76	0.83	0.8
Thasangkaru Tso	5	1.58	1.07	0.98	0.5
Tsigul Tso	6	1.49	1.03	0.83	0.6
Tsokar	16	2.08	1.93	0.75	0.5
Tsomorirri	11	2.24	1.79	0.93	0.4
YayaTso	12	1.7	1.58	0.68	0.7

site, while Tsokar and Tsomoriri are also identified as 'Important bird areas' in India (Rahmani et al. 2013).

The wetlands with the highest Shannon diversity and Margalef's richness, namely, Statapuk Tso, Tsokar, and Tsomoriri, were all situated in the southwestern region of CWS (Figure 2, Table 3). Other wetlands in this region, such as Yaya Tso, Puga, and Thasangkaru Tso, also hold comparatively higher diversity than that of the wetlands situated in the eastern part of the sanctuary, e.g., Tashi Chuling and Rongo (Figure 2, Table 3). Our results show that wetland size did not affect waterbird diversity. We, however, observed a directional pattern in the species diversity of wetlands of the eastern Ladakh landscape (Figure 2). In general, wetlands on the western part were comparatively more diverse than the eastern wetlands. Wetlands in the south-west seem to offer suitable habitat for the majority of waterbird species. The landscape in Ladakh opens towards Tibetan Plateau in the east, which is comparatively much drier and colder habitat. Moreover, the wetlands in the north such as Pangong Tso have steep shores, providing less area for waterbirds to establish. Therefore, geo-climatic factors might be the reason for a directional pattern of species diversity.

Worldwide more than 50% of natural wetland areas have been lost due to human activities. This has adversely affected the hydro system, plant growth and avian communities that depend on wetland habitats directly and indirectly for various activities (Fraser & Keddy 2005; Coleman et al. 2008; Zakaria & Rajpar 2014). Ladakh is facing similar threats owing to growing tourism close to many of the wetlands (Chandan et al. 2006). Pangong Tso, Tsokar and Tsomoriri, three

crucial wetlands for waterbirds, are also among the prime tourist places during the summer season. Global population trend of the waterbird species recorded in Ladakh shows that 20 species (53%) are declining in number, three species (8%) have a stable population, three species (8%) are increasing, and the status of 13 species (34%) is unknown (Wetlands International 2012; Gopi et al. 2014). As much as nine waterbird species are known to breed in the area (Prins & Wieren 2004; Hussain et al. 2008; Humbert-Droz 2011). Therefore, wetlands of Ladakh hold a high conservation value. We recommend that critical areas around the wetlands need to be mapped where tourist routes and waterfowl habitats overlap, and protective measures such as restriction of access to key waterfowl habitats especially during their breeding time could be applied.

Knowledge of the spatiotemporal distribution of biodiversity is still quite incomplete in several parts of the world. It is one of the major problems preventing the assessment and effectiveness of conservation actions (de Carvalho et al. 2017). Our study provides an assessment of the water-bird diversity of the eastern Ladakh during the pre-winter season. We also highlighted the critical wetlands that support a high diversity and threatened bird species. Future assessment surveys can use this study as a baseline and expand the survey effort to include smaller wetlands. We provide a reminder that wildlife even in protected areas should be studied regularly, with the sources of threats to their conservation documented carefully.



Image 1. Bar-headed Goose *Anser indicus*



Image 2. Ruddy shelduck *Tadorna ferruginea*



Image 3. Black-necked Crane *Grus nigricollis*



Image 4. Black-winged Stilt *Himantopus himantopus*



Image 5. Brown-headed Gull *Chroicocephalus brunnicephalus*



Image 6. Common Pochard *Aythya ferina*





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Image 7. Common Redshank *Tringa totanus*

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Image 8. Common Snipe *Gallinago gallinago*

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Image 9. Common Tern *Sterna hirundo*

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Image 10. Eurasian Coot *Fulica atra*

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Image 11. Eurasian Curlew *Numenius arquata*

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Image 12. Great-crested Grebe *Podiceps cristatus*





Image 13. Little Ringed Plover *Charadrius dubius*



Image 14. Northern Shoveler *Anas clypeata*



Image 15. Bar-headed Goose *Anser indicus* and Ruddy Shelduck *Tadorna ferruginea*

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## Article

**A citizen science approach to monitoring of the Lion *Panthera leo* (Carnivora: Felidae) population in Niokolo-Koba National Park, Senegal**

– Dimitri Dagorne, Abdoulaye Kanté & John B. Rose, Pp. 15091–15105

## Communications

**Status, distribution, threats, and conservation of the Ganges River Dolphin *Platanista gangetica* (Mammalia: Artiodactyla: Cetacea) in Nepal**

– Deep Narayan Shah, Amit Poudyal, Gopal Sharma, Sarah Levine, Naresh Subedi & Maheshwar Dhakal, Pp. 15106–15113

**Bat (Mammalia: Chiroptera) diversity, dominance, and richness in the southwestern region of Bhutan with three new records for the country**

– Sangay Tshering, Dhan Bahadur Gurung, Karma Sherub, Sumit Dookia, Kuenzang Dorji & Pema Choephyl, Pp. 15114–15128

**The pattern of waterbird diversity of the trans-Himalayan wetlands in Changthang Wildlife Sanctuary, Ladakh, India**

– Pushpinder Singh Jamwal, Shivam Shrotriya & Jigmet Takpa, Pp. 15129–15139

**Composition, diversity and foraging guilds of avifauna in agricultural landscapes in Panipat, Haryana, India**

– Parmesh Kumar & Sharmila Sahu, Pp. 15140–15153

**An overview of fishes of the Sundarbans, Bangladesh and their present conservation status**

– Kazi Ahsan Habib, Amit Kumer Neogi, Najmun Nahar, Jina Oh, Youn-Ho Lee & Choong-Gon Kim, Pp. 15154–15172

**Digital image post processing techniques for taxonomic publications with reference to insects**

– Nikhil Joshi, Hemant Ghate & Sameer Padhye, Pp. 15173–15180

## Short Communications

**Description of a new species of the genus *Lamprosephus* Fleutiaux, 1928 (Coleoptera: Elateridae: Elaterinae: Dicrepidiini) from Konkan, Maharashtra, India**

– Amol Patwardhan & Rahul Khot, Pp. 15181–15185

**Spiders (Arachnida: Araneae) from the vicinity of Araabath Lake, Chennai, India**

– John T.D. Caleb, Pp. 15186–15193

**Two new records of gilled mushrooms of the genus *Amanita* (Agaricales: Amanitaceae) from India**

– R.K. Verma, V. Pandro & G.R. Rao, Pp. 15194–15200

## Notes

**A first record of oviposition of Common Onyx *Horaga onyx* Moore, 1857 (Insecta: Lepidoptera: Lycaenidae) in Sri Lanka and its importance in conserving a highly threatened butterfly**

– Chathura Udayanga Herath, Pavan Bopitiya Gamage, Iroshan Rupasinghe & Moditha Hiranya Kodikara Arachchi, Pp. 15201–15204

**Additions to known larval host plants of butterflies of the Western Ghats, India**

– Deepak Naik & Mohammed S. Mustak, Pp. 15205–15207

***Rhynchochlamys parviflorum* Blume (Gesneriaceae): a new record to mainland India**

– Momang Taram, Puranjay Mipun & Dipankar Borah, Pp. 15208–15211

**Re-collection of the Luminous Lantern Flower *Ceropegia lucida* Wall. (Apocynaceae) from Assam, India**

– Debolina Dey, Manash Baruah, Nilakshee Devi & Jitendra Nath Borah, Pp. 15212–15215

***Tetrasporidium javanicum* Möbius (Chlorophyta), a rare species recorded from Arpa River in Bilaspur, Chhattisgarh, India**

– Rakesh Kumar Dwivedi, Pp. 15216–15218

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