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

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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 27,000km² 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 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. Conservating 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 nigercolis 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 km² between 32.317–34.583 °N and 77.750–79.300 °E at an average altitude of 4,000 m. 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 km²) in CWS: Pangong Tso, Puga, Rongo, Sato-Harong Marshes, Statapuk Tso, Tashi Chuling, Thasangkaru Tso, Tsigul Tso, Tsokar, Tsomorirri, and Yaya Tso (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 1 km. 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 06.30 h 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
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...
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 Ichthyaetus ichthyaetus, 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).

| Wetland      | Location      | Size (Km²) | 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             |
| Stapatuk 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            |
| Tsomoriri    | N 32.991°, E 78.258° | 22.19      | 9             |
| Yaya Tso     | N 33.323°, E 78.479° | 1.55       | 5             |

Table 1. Location, size and survey effort of the high altitude wetlands of Ladakh in Changthang Wildlife Sanctuary.
Table 2. List of waterbird species recorded at the high altitude wetlands of Changthang Wildlife Sanctuary, Ladakh.

| Family       | Common name         | Scientific name          | IUCN status | Recorded at wetlands | Abundance†  |
|--------------|---------------------|--------------------------|-------------|----------------------|-------------|
| Anatidae     | Bar-headed Goose    | Anser indicus            | LC          | 2,3,4,5,6,8,9,10,11  | 1298–1717   |
| Anatidae     | Common Merganser    | Mergus merganser         | LC          | 5,10,11              | 1573–1806   |
| Anatidae     | Common Pochard      | Aythya ferina           | LC          | 4                    | 44–61       |
| Anatidae     | Eurasian Wigeon     | Anas penelope            | LC          | 5,10                 | 20–48       |
| Anatidae     | Ferruginous Duck    | Aythya nyroca           | NT          | 1,5,10,11            | 40–56       |
| Anatidae     | Gadwall             | Aythya strepera         | LC          | 5                    | 29–56       |
| Anatidae     | Garganey            | Aythya querquedula      | LC          | 5,11                 | 58–105      |
| Anatidae     | Mallard             | Anas platyrynchos       | LC          | 5,8                  | 55–76       |
| Anatidae     | Northern Pintail    | Anas acuta              | LC          | 1,2,3,4,5,6,7,8,9,10,11 | 1341–1571  |
| Anatidae     | Northern Shoveler   | Anas clypeata           | LC          | 5,10,11              | 48–68       |
| Anatidae     | Red-crested Pochard | Netta rufina            | LC          | 5                    | 4           |
| Anatidae     | Ruddy Shelduck      | Tadorna ferruginea      | LC          | 2,3,4,5,6,7,8,9,10,11 | 943–1526   |
| Anatidae     | Tufted Duck         | Aythya fuligula         | LC          | 5,11                 | 31–48       |
| Ardeidae     | Grey Heron          | Ardea cinerea           | LC          | 4,5,11               | 7–8         |
| Charadriidae | Kentish Plover      | Charadrius alexandrinus | LC          | 5,9                  | 2–4         |
| Charadriidae | Lesser Sand Plover  | Charadrius mongolius    | LC          | 5,9                  | 146–210     |
| Charadriidae | Pacific Golden Plover | Pluvialis fulva      | LC          | 5                    | 2           |
| Gruidae      | Black-necked Crane  | Grus nigricolli         | LC          | 2,3,4,5,6,8,9,11     | 29–35       |
| Laridae      | Brown-headed Gull   | Chroicocephalus brunicephalus | LC   | 1,3,4,5,7,9,10     | 563–699     |
| Laridae      | Common Tern         | Sterna hirundo          | LC          | 2,5                  | 8–11        |
| Laridae      | Little Gull         | Hydrocoloeus minutus    | LC          | 5                    | 12–56       |
| Laridae      | Pallas's Gull       | Ichthyayetus ichthyayetus | LC    | 3                    | 2–4         |
| Motacillidae | Citrine Wagtail     | Motacilla citreola      | LC          | 5                    | 15–18       |
| Podicipedidae| Black-necked Grebe  | Podiceps nigricolli     | LC          | 5,9                  | 10–25       |
| Podicipedidae| Great Crested Grebe | Podiceps cristatus      | LC          | 1,5,7,9,10,11       | 520–860     |
| Rallidae     | Eurasian Coot       | Fulica atra             | LC          | 5                    | 7           |
| Rallidae     | Water Rail          | Rallus aquaticus        | LC          | 5                    | 2           |
| Recurvirostrida | Black-winged Stilt | Himantopus himantopus    | LC          | 5                    | 4           |
| Recurvirostrida | Pied Avocet   | Recurvirostra avosetta | LC          | 9                    | 21–23       |
| Scolopacidae | Common Redshank     | Tringa totanus          | LC          | 5,10                 | 71–101      |
| Scolopacidae | Common Sandpiper    | Actitis hypoleucos      | LC          | 2,3,4,5,6,7,8,9,10,11 | 1469–1854  |
| Scolopacidae | Common Snipe        | Gallinago gallinago     | LC          | 5                    | 73–90       |
| Scolopacidae | Eurasian Curlew     | Numenius arquata        | NT          | 5,9                  | 3–9         |
| Scolopacidae | Green Sandpiper     | Tringa ochropus         | LC          | 5,9                  | 104–131     |
| Scolopacidae | Little Stint        | Calidris minuta         | LC          | 5,9                  | 17–26       |
| Scolopacidae | Little Ringed Plover | Charadrius dubius       | LC          | 2,5,9                | 282–486     |
| Scolopacidae | Ruff                | Philomachus pugnax      | LC          | 5                    | 6           |
| Scolopacidae | Temminck's Stint    | Calidris temminckii     | 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—Tisgul Tso | 9—Tsokar | 10—Tsomorirri | 11—Yaya Tso | †—Range from minimum to maximum number of individuals counted.
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 = 93, 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$^2$) 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                            |
| Tsomoririri        | 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.
Waterbird diversity pattern of Changthang Wildlife Sanctuary

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Image 7. Common Redshank *Tringa totanus*

Image 8. Common Snipe *Gallinago gallinago*

Image 9. Common Tern *Sterna hirundo*

Image 10. Eurasian Coot *Fulica atra*

Image 11. Eurasian Curlew *Numenius arquata*

Image 12. Great-crested Grebe *Podiceps cristatus*
Image 13. Little Ringed Plover *Charadrius dubius* © Pushpinder Singh Jamwal

Image 14. Northern Shoveler *Anas clypeata* © Pushpinder Singh Jamwal

Image 15. Bar-headed Goose *Anser indicus* and Ruddy Shelduck *Tadorna ferruginea* © Pushpinder Singh Jamwal
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