Surveys of waterbirds in the Darkhad Depression, Mongolia, during summer and autumn

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Abstract

The Darkhad Depression provides one of the most extensive concentrations of waterbird breeding, moulting, and migration stopover site habitat in Mongolia. To our knowledge, this is the first large-spatial scale survey completed for waterbirds in the region. Surveys were conducted at 60 wetlands and a portion of a river (total area = 5,873 ha) in summer (15−19 July), and at 36 wetlands (5,285 ha, including 27 wetlands from the summer) in autumn 2018 (6−10 October). Thirty-seven species were detected (13 with juveniles) during the summer and 23 species in autumn. The frequency of occurrence of species among wetlands and densities of waterbirds among occupied wetlands (birds/ha) were calculated for summer. These estimates were scaled to the total wetland area in the region, for estimating the proportion of the flyway population occurring in the Darkhad Depression for each species. Six species were on the IUCN Red List (IUCN 2018) or in the Mongolian Red Book (Shiirevdamba *et al.* 2016): Falcated Duck *Anas falcata*, Common Pochard *Aythya ferina*, Common Crane *Grus grus*, Northern Lapwing *Vanellus vanellus*, Eurasian Curlew *Numenius arquata,* and Horned Grebe *Podiceps auritus*. In summer, Common Goldeneye *Bucephala clangula* used the greatest percentage of wetlands included in the survey (57.4%) and Tufted Duck *Aythya fuligula* had the greatest mean density among occupied wetlands (6.66 ± 5.69 s.e. birds/ha). Most individuals appeared to be moulting adults. Greatest juvenile:adult ratios were for Eared Grebes *Podiceps nigricollis* (1.3), Ruddy Shelduck *Tadorna ferruginea* (1.4), and Whooper Swans *Cygnus cygnus* (1.1).

In autumn, Common Goldeneye (n = 1,375), dabbling ducks (*Anas* sp.; n = 2,206), and Whooper Swans (n = 1,065) were the most common waterbirds observed, and 88% of all waterbirds counted occurred on just three wetlands. The Darkhad Depression appears to be important for waterbirds from the Central and East Asian Flyways, and our surveys suggest it likely supports > 1% of Common Goldeneye, Tufted Duck, Bar-headed Goose *Anser indicus*, and Ruddy Shelduck populations of these Flyways. To develop a greater understanding of waterbird reproduction and seasonal use, as well as threats to waterbirds in the region, we suggest that standardised surveys should be undertaken during spring through to autumn in future years.

Key words: breeding, Central Asia, migration, moulting, waterfowl.

The Darkhad Depression (alternatively tranliterated as Darhad Depression) in northern Mongolia has approximately 300 wetlands with dynamic hydrology (*c.* 12,312 ha of open water in 2018, determined from LandSat imagery) within a 150 × 40 km steppe basin that is surrounded by the Khövsgöl (alternately transliterated as Huvsgul) Mountains (Gombobaatar *et al.* 2012; BirdLife International 2018a). Montane rivers, including the Tengis and Shishged Rivers, flow into the depression, feeding the wetlands and creating this dynamic wetland system. Wetlands often connect to each other by shallow channels and rivers and, during periods of intense rain, multiple smaller wetlands may connect to form larger wetlands (T. Jal, pers. obs.). Mongolia's wetlands are important breeding and migratory sites for eastern Palearctic birds (Ganbold *et al.* 2018), and the Darkhad Depression provides critical habitat for breeding, moulting and migrating birds from the Central and East Asian Flyways (Scott & Rose 1996; del Hoyo *et al.* 2018; Ganbold *et al.* 2018).

The Darkhad Depression is classified as an Important Bird Area (IBA) by BirdLife International, meeting three of the four global criteria for IBAs (BirdLife International 2018a). Several globally threatened bird species are reported as occurring regularly in the region (criteria A1; BirdLife International 2018a; Ganbold *et al.* 2018), so vulnerable species which may use the Darkhad Depression could include Common Pochard *Aythya ferina*, Relict Gull *Larus relictus* and Horned Grebe *Podiceps auratus*, while near-threatened species could include the Northern Lapwing *Vanellus vanellus*, Eurasian Curlew *Numenius arquata*, Black-tailed Godwit *Limosa limosa*, Asian Dowitcher *Limnodromus semipalmatus*, and Falcated Duck *Aanas falcata* (BirdLife International 2018b; IUCN 2018). The Mongolian Red Book (Shiirevdamba *et al.* 2016) lists five near-threatened or threatened waterbird species in the Darkhad Depression, with some overlap: Relict Gull (endangered in Mongolia), Asian Dowitcher (vulnerable), Eurasian Bittern *Botaurus stellaris* (near threatened), Falcated Duck (near-threatened), and Common Crane *Grus grus* (near-threatened; Shiirevdamba *et al.* 2016). The

East Asian population of the Demoiselle Crane *Anthropoides virgo*, classed as of "least concern" by IUCN but a biome-constricted species (criteria A3; BirdLife International 2018a), is thought to occur in the Darkhad Depression during the breeding season. Additionally, the site was estimated to hold > 1% of the flyway populations of Bar-headed Geese *Anser indicus*, Ruddy Shelduck *Tadorna ferruginea*, Gadwall *Mareca strepera* and Common Goldeneye *Bucephala clangula* at the time that it was classified as an IBA (criteria A4; BirdLife International 2018a). As many as 66 waterbird species may use the Darkhad Depression as a breeding area (del Hoyo *et al.* 2018).

Surveys of the Darkhad Depression and most other IBA sites in Mongolia are incomplete (Ganbold *et al.* 2018). To our knowledge, the only other avifaunal survey conducted in the Darkhad Depression was conducted at a single wetland, as part of a larger study to assess avifaunal diversity on identified IBA wetland sites in Mongolia. That study identified 70 avian species (including waterbird species) during three survey periods (see Ganbold *et al.* 2018). More extensive waterbird surveys in the Darkhad Depression would provide additional information on the distribution, abundance and reproductive success for these species, enhancing the development of conservation strategies for the region and knowledge on whether an increased level of protection for wetlands and associated habitats are necessary (Shiirevdamba *et al.* 2016). The importance of the Darkhad Depression for waterbirds can be determined by obtaining estimates of species abundance for the site, for comparison with estimates of total numbers in the biogeographic population of each species, on the basis that Ramsar Criterion 6 states that a site can be considered of international importance if it regularly supports 1% of the individuals in the population of one waterbird species or subspecies (Ramsar Convention Secretariat 2013). The objective of this study therefore was to conduct a field survey of waterbirds in the Darkhad Depression during summer when breeding adults with juveniles and moulting adults would be present, and also during autumn to record species staging in the region during migration, in order to provide initial baseline data on the use of the site by breeding and migratory waterbirds. As far as we are aware, this is the first large-spatial scale survey of waterbirds throughout the Darkhad Depression (see Ganbold *et al.* 2018).

Methods

Study area

The Darkhad Depression (51.02°N, 99.45°E) is part of Khövsgöl aimag (*i.e.* province) in north-central Mongolia (Fig. 1). The region is at the southern edge of the Siberian Taiga ecosystem and has high alpine, talus, larch forest, taiga, dry steppe and wetland habitats. Most of the Darkhad Depression is already under the protection of the Ulaan Taiga Protected Areas Administration, which oversees the Ulaan Taiga Strictly Protected Area, the Horidol Saridag Strictly Protected Area, and the Tengis-Shishged National Park. The border of Tengis-Shishged National Park (created in 2012) gives some protection to the western half of the wetland system and valley bottom, with many nomadic

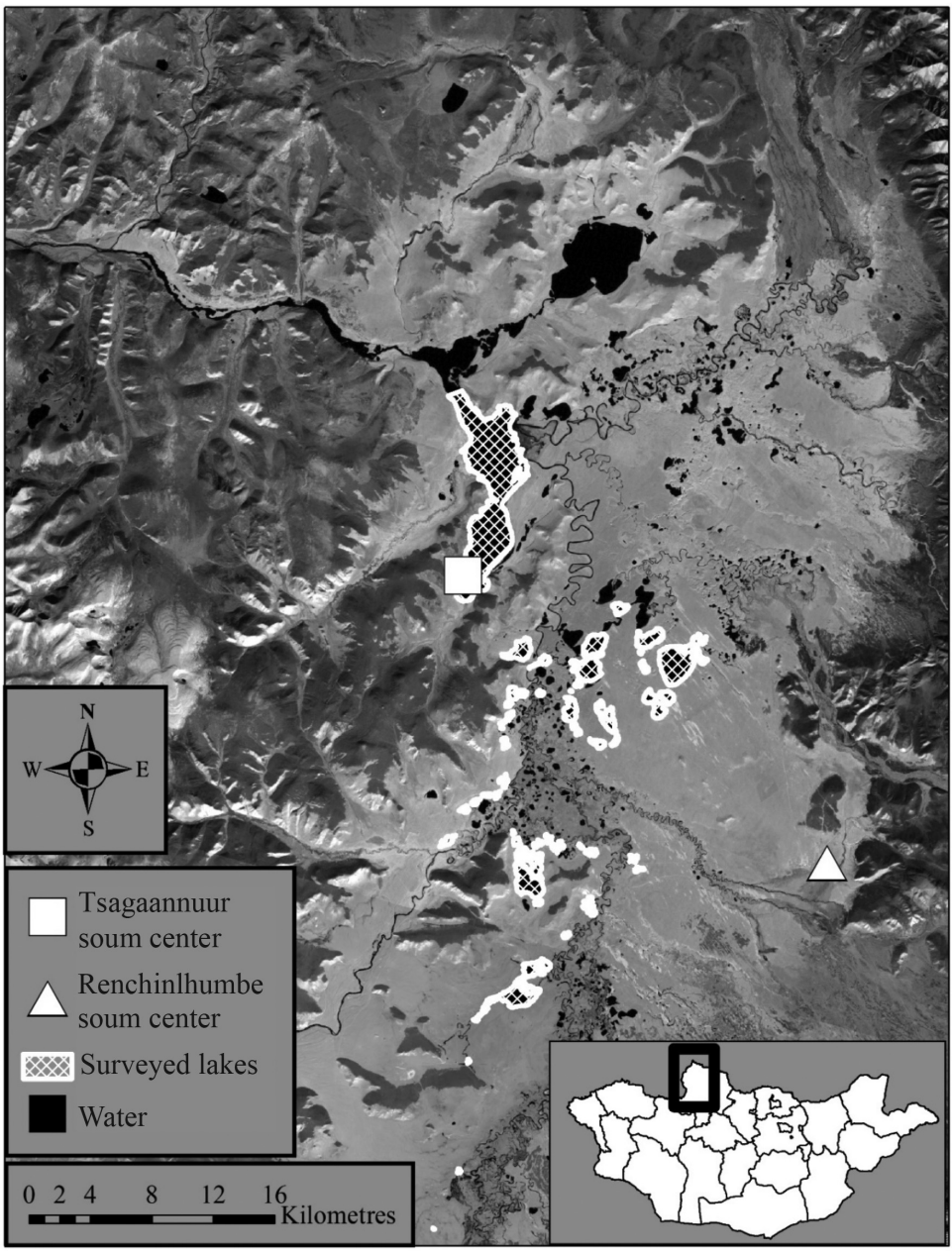

Figure 1. Sixty wetlands surveyed 15–19 July 2018 and the relative location of the Darkhad Depression within Mongolia.

herders and the soum (*i.e.* town) centre of Tsagaan Nuur within its buffer zone. Strictly Protected Areas (SPAs) provide the greatest degree of protection to land in Mongolia, limiting human use to rangers and permitted research (IUCN Protected Areas Management Category 1a), whilst national parks in Mongolia permit restricted tourism and human use (IUCN Protected Areas Management Category 2; Reading *et al.* 2015). Buffer zones limit development around Mongolia's national parks and SPAs, but allow greater human use of natural resources in these zones than in the protected areas (Reading *et al.* 2006, 2015).

In Mongolia, birds receive protection from hunting under the Mongolian Law on Hunting, which provides wetland birds with a designated permitted hunting season (Wingard & Odgerel 2001). However, birds and their eggs are not traditionally used as food by Mongolians (B. Dovchin, pers. obs.). Grazing herds of livestock is the most common use of land in the Darkhad Depression, with fishing also important in the area historically; periods of intense fishing occurred on wetlands such as Lower Tsagaan Nuur (alternatively, Dood Tsagaan Nuur) during Mongolia's communist period (from 1924–1990; B. Dovchin, unpubl. data). Small-scale subsistence fishing currently continues on several smaller wetlands (B. Tumur, pers. obs.).

Survey methods

Field surveys for waterbirds were conducted in the Darkhad Depression in the Tsagaan Nuur and Renchinlhumbe soums (*i.e.* districts), 15–19 July and 6–10 October 2018. Most waterbirds that breed in the Darkhad Depression were expected to be present during the summer survey because southward migration does not begin until late summer and early autumn (del Hoyo *et al.* 2018). Additionally, most waterbirds of the region have young that do not fledge until late July (del Hoyo *et al.* 2018). For these reasons, the timing of our summer survey was considered most appropriate for a one-time survey for detecting breeding adults with young to estimate productivity, as well as waterbirds that migrated to the region to moult during summer (*i.e.* moult migrants). During our autumn survey, waterbirds were immigrating and emigrating in the region and, as such, the numbers observed only provide an initial estimate of the importance of the region as a migratory stopover because it was not possible to measure the total number of individuals using the region during this period of high turnover.

The wetland sites included in the surveys were chosen on the basis of their accessibility. The Darkhad Depression wetlands are dynamic, with periods of flooding and drought, so it was logistically infeasible to access some areas. All sites in the summer and autumn were approached by vehicle and by walking to observation points. Our sampling scheme limited bias as much as was logistically possible because nearly 50% of open water areas were surveyed and the full range of wetland sizes available to the birds at this time were covered.

Waterbirds in the orders Anseriformes, Podicipediformes, Gruiformes, Charadriiformes, Gaviiformes, Ciconiiformes, Suliformes and Pelecaniformes were

counted. For wetlands that were small enough for us to see across the entire width, the census was completed from one point on the shoreline. For larger wetlands, where we could see the middle but not the entire length, we stopped at multiple points around the wetland. Coverage of each surveyed wetland site was complete, so that all waterbirds on each wetland were counted. To avoid double-counting birds, GPS points were placed at landmarks along the shoreline to determine where counting ended at previous observation points. The total number of adults and juveniles per species per wetland were recorded. Both summer and autumn surveys were conducted over four consecutive days to minimize double-counting of birds due to movement between wetlands. Movement of birds within wetlands was possible, but summer surveys were conducted during the breeding and brood-rearing period which is generally a period of limited movements. One hundred percent detectability was assumed during the surveys because the Darkhad Depression wetlands have sparse low-growing to no vegetation on the shoreline, although potential biases may still exist in counts of cryptic species hidden within vegetation, such as shorebirds.

For species with juveniles, densities were calculated using totals of adults and unfledged hatch-year juveniles (hereafter juveniles), and an estimate of the ratio of juveniles to adults was used as an index of productivity for each species across the study area (juveniles per adults; Serie *et al.* 2002). Waterfowl are flightless in summer, when they undergo a simultaneous wing and body moult, and some individuals may conduct a migration to areas with adequate resources and protection from predators prior to moulting (*i.e.* moult migration; Salomonson 1968). As a result, some adults using the study area prior to our survey may have migrated elsewhere to moult. Additionally, adults in non-breeding plumage observed in large flocks without juveniles were assumed to be primarily birds that had undertaken a moult migration into the Darkhad Depression, but some may have been local failed and non-breeders. It also is likely that some moult migrants had completed the moult and left the region prior to our surveys. Flocks of non-breeding adults that were assumed to be moult migrants adults due to their non-breeding plumage and lack of accompanying juveniles were removed from estimates of juveniles:adults. For these reasons, the juvenile:adult ratio should be considered a coarse estimate, comprised mainly of successful breeding adults and their young.

Data analysis

ArcGIS was used to calculate the total area of surveyed wetlands from Landsat08, Band 7 imagery of the Darkhad Depression (30 m pixel size, image captured on 28 May 2018). Rasters were reclassified to three values using the Isocluster Unsupervised Classification tool, then converted to polygons to measure the area of each wetland. For larger wetlands or rivers, polygons were edited to include only the area surveyed. The area of each polygon was then calculated and summed to determine the total area of wetlands covered by the surveys. Frequency of occurrence among wetlands and the mean density of

Table 1. Species inventory for the Darkhad Depression, Mongolia, in July 2018. Estimated numbers of waterbirds in the entire Darkhad Depression were extrapolated from observations made across 47.7% of its total estimated water surface area (12,348 ha) in 2018. Birds that use habitats besides wetlands (*i.e.* Common and Demoiselle Cranes) likely are more abundant than estimated. Flyway population estimates are derived from the Waterbird Population Estimates data available from Wetlands International and estimates may not be based on quality assessments (Wetlands International 2019). * = listed by the IUCN or Mongolian Red Book as a threatened or near-threatened species; NA = not available.

Species	No. adults	No. juveniles	Percentage of wetlands used	Mean density (birds/ha) on used wetlands (± s.e.) (range)	Mean size (ha) of wetland(s) used (± s.e.) (range)	Estimated no. birds in the Darkhad Depression, (birds/ha)	Estimated flyway population (population name)	Percentage range of flyway population estimated to be in Darkhad Depression in summer
Bean Goose	1	0	1.6	0.01 ± 0.0 (NA)	113.7 ± 0.0 (NA)	2 (0.0002)	1,000–5,000 (W/C Siberia)	0.04–0.2
Bar-headed Goose	424	64	9.8	2.5 ± 1.4 (0.05–9.9)	601.9 ± 449.5 (17.0–3055)	1,023 (0.083)	52,000–60,000 (C, S, SE Asia)	1.7–2.0
Whooper Swan	153	70	39.3	3.7 ± 3.3 (0.005–2.0)	215.0 ± 123.9 (0.06–3055)	467 (0.038)	60,000 (E Asia)	0.8
Ruddy Shelduck	180	209	49.2	0.8 ± 0.2 (0.002–3.9)	167.5 ± 100.2 (2.6–3055)	815 (0.066)	50,000–100,000 (E Asia)	0.8–1.6
Northern Shoveler	7	0	3.3	0.07 ± 0.04 (0.01–0.1)	68.2 ± 15.8 (45.9–90.5)	14 (0.001)	500,000 (S, SE Asia)	0.003
Gadwall	19	0	4.9	0.8 ± 0.6 (0.04–2.3)	38.4 ± 21.8 (2.6–90.5)	39 (0.003)	500,000–1,000,000 (E Asia)	0.004–0.008

Falcated Duck*	4	0	3.3	0.03 ± 0.008 (0.02–0.04)	68.2 ±15.8 (45.9–90.5)	8 (0.001)	78,000–89,000 (C, E Asia)	0.009–0.01
Eurasian Wigeon	67	0	11.5	0.2 ± 0.1 (0.003–0.5)	107.1 ± 43.0 (22.2–372.1)	140 (0.011)	500,000–1,000,000 (E Asia)	0.01–0.03
Mallard	33	15	3.3	6.4 ± 4.5 (0.02–12.8)	57.1 ± 37.9 (3.6–110.7)	100 (0.008)	1,500,000 (E Asia)	0.007
Northern Pintail	14	0	3.3	0.06 ± 0.04 (0.01–0.1)	112.2 ± 1.08 (110.7–113.7)	29 (0.002)	200,000–300,000 (E, SE Asia)	0.009–0.01
Common Teal	14	0	4.9	0.4 ± 0.3 (0.04–1.1)	68.3 ± 26.8 (3.6–110.7)	29 (0.002)	600,000–1,000,000 (E, SE Asia)	0.003–0.005
Common Pochard*	236	0	18.0	0.5 ± 0.1 (0.08–1.1)	55.8 ± 12.7 (8.6–131.4)	494 (0.040)	300,000 (E Asia)	0.2
Tufted Duck	1,496	0	41.0	6.7 ± 5.7 (0.001–146.1)	211.5 ± 118.9 (3.4–3,055.0)	3,136 (0.255)	200,000–300,000 (E, SE Asia)	1.05–1.6
White-winged Scoter[a]	81	10	14.8	0.3 ± 0.1 (0.02–1.2)	94.8 ± 50.2 (2.6–511.6)	190 (0.015)	600,000–1,000,000 (E Asia)	0.02–0.03
Common Goldeneye	1,475	47	57.4	0.9 ± 0.1 (0.03–4.2)	154.5 ± 86.3 (2.6–3,055.0)	3,190 (0.259)	100,000–1,00,000 (E Asia)	0.3–3.2
Smew	2	0	1.6	0.04 ± 0.0 (NA)	55.9 ± 0.0 (NA)	4 (0.0003)	25,000 (E Asia)	0.02
Red-breasted Merganser	3	0	1.6	< 0.0001 (NA)	3055.0 ± 0.0 (NA)	6 (0.0005)	25,000–100,000 (E Asia)	0.01–0.02
Eared Grebe	29	39	6.6	0.2 ± 0.1 (0.01–0.6)	76.6 ± 19.1 (12.0–110.7)	142 (0.012)	10,000–100,000 (E Asia)	0.1–1.4
Great Crested Grebe	123	0	9.8	0.07 ± 0.03 (0.02–0.2)	667.4 ± 438.2 (45.9–3,055)	257 (0.021)	25,000–50,000 (E Asia)	0.5–1.02

Table 1 (*continued*).

Species	No. adults	No. juveniles	Percentage of wetlands used	Mean density (birds/ha) on used wetlands (± s.e.) (range)	Mean size (ha) of wetland(s) used (± s.e.) (range)	Estimated no. birds in the Darkhad Depression, (birds/ha)	Estimated flyway population (population name)	Percentage range of flyway population estimated to be in Darkhad Depression in summer
Eurasian Coot	6	3	3.3	0.2 ± 0.07 (0.07–0.3)	57.1 ± 37.9 (3.6–110.7)	18 (0.002)	100,000–1,000,001 (E, SE Asia)	0.002–0.02
Common Crane*	4	1	1.6	0.2 ± 0.0 (NA)	29.6 ± 0.0 (NA)	10 (0.001)	70,000 (W Siberia, SE Asia)	0.01
Demoiselle Crane	33	0	6.6	3.7 ± 3.1 (0.1–14.3)	29.7 ± 17.8 (0.7–90.5)	69 (0.006)	70,000–100,000 (E Asia)	0.07–0.1
Pied Avocet	20	2	1.6	1.6 ± 0.0 (NA)	13.7 ± 0.0 (NA)	46 (0.004)	100,000 (E Asia)	0.05
Northern Lapwing*	57	0	9.8	0.2 ± 0.1 (0.01–0.4)	93.7 ± 38.3 (12.0–286.1)	119 (0.010)	100,000–1,000,000 (E, SE Asia)	0.02–0.2
Eurasian Curlew*	2	0	1.6	0.02 ± 0.0 (NA)	90.5 ± 0.0	4 (0.0003)	100,000 (E, SE Asia)	0.004
Spotted Redshank	8	0	1.6	0.1 ± 0.0 (NA)	90.5 ± 0.0 (NA)	16 (0.001)	25,000 (E, SE Asia)	0.06
Common Redshank	3	0	1.6	0.03 ± 0.0 (NA)	90.5 ± 0.0 (NA)	6 (0.0005)	25,000–100,000 (E, SE Asia)	0.006–0.02

Common Greenshank	1	0	1.6	0.01 ± 0.0 (NA)	90.5 ± 0.0 (NA)	2 (0.0002)	100,000 (S, SE Asia, Australasia)	0.002
Wood Sandpiper	3	0	1.6	0.03 ± 0.0 (NA)	90.5 ± 0.0 (NA)	6 (0.0005)	100,000 (S, SE Asia, Australasia)	0.006
Black-headed Gull	28	3	8.2	0.2 ± 0.09 (0.009–0.6)	104.0 ± 62.5 (8.5–372.1)	64 (0.005)	100,000–1,000,001 (E, SE Asia)	0.006–0.06
Mongolian Gull[b]	359	65	18.0	0.3 ± 0.3 (0.005–2.9)	382.0 ± 259.4 (7.0–3055.0)	888 (0.072)	100,000–1,000,001 (Black Sea, W/SW Asia, NE Africa)	0.09–0.9
White-winged Tern	97	0	4.9	2.5 ± 1.0 (0.04–4.3)	38.8 ± 21.1 (12.0–90.5)	203 (0.017)	100,000–1,000,001 (Asia, Australasia)	0.02–0.2
Common Tern	141	0	19.7	0.2 ± 0.06 (0.01–0.4)	352.6 ± 238.1 (9.8–3055)	295 (0.024)	25,000–1,000,000 (W Asia)	0.03–1.2
Arctic Loon	13	1	14.8	0.05 ± 0.02 (6.5×10^{-4}–0.19)	501.4 ± 306.9 (10.4–3055.0)	29 (0.002)	250,000–500,000 (C Asia, Caspian)	0.006–0.1
Black Stork	1	0	1.6	< 0.0001 (NA)	3055 ± 0.0 (NA)	2 (0.0002)	1–500 (E Asia)	0.4–200
Great Cormorant	442	0	29.5	0.2 ± 0.1 (0.002–1.1)	297.8 ± 161.3 (5.4–3055)	926 (0.075)	25,000–100,000 (E, SE Asia)	0.9–3.7
Grey Heron	210	0	11.5	0.4 ± 0.2 (0.003–1.5)	450.5 ±349.5 (2.6–3055.0)	440 (0.036)	25,000–1,000,000 (W, SW Asia)	0.04–1.8

[a]Based on population estimates for Siberian Scoter *Melanitta stejnegeri*
[b]Based on population estimates for Caspian Gull *Larus cachinnans*

birds among occupied wetlands were determined for each species.

The same Landsat imagery was used to estimate total area of open water in the Darkhad Depression (U.S. Geological Survey 2018). Rasters were reclassified to two values: water and non-water. The areas of water recorded for each wetland were summed to obtain an estimate of the total area of open water in the Darkhad Depression (12,312 ha). This total area of water may vary annually, however, depending on the amount of snow melt and rainfall in each year (T. Jal, pers. obs.). The relative abundance of each species in the Darkhad Depression was extrapolated by multiplying the observed bird densities by total area of open water. This method is simplistic and could introduce bias if the sampling scheme was not representative of wetlands in the Darkhad Depression. However, nearly 50% of the open water area in 2018 was surveyed and included a broad range of wetlands sizes, which likely reduced the potential for such bias.

Results

During summer, 60 wetlands and a 5.4 ha portion of the Shishged River were surveyed in the Darkhad Depression (5,872.69 ha of aquatic habitat; 47.7% of the total open water habitat). A total of 6,318 waterbirds were counted from 37 different species (Table 1). During autumn, 35 wetlands (5,285 ha) were surveyed, and a total of 6,180 waterbirds from 23 species were counted (Table 2). In summer, we detected one species in the threatened category of the IUCN Red List of Threatened Species (IUCN 2018), the Common Pochard. Four species seen were listed in the near-threatened category on the IUCN Red List of Threatened Species (IUCN 2018) or the Mongolian Red Book (Shiirevdamba *et al.* 2016): Falcated Duck (IUCN and Mongolia), Common Crane (Mongolia), Northern Lapwing (IUCN), and Eurasian Curlew (IUCN) (Table 1). In autumn, three species on these lists were detected: Horned Grebe, Common Pochard, and Northern Lapwing. During summer, the most common species were Common Goldeneye (n = 1,522 birds, 57.4% of wetlands occupied), Ruddy Shelduck (n = 389, 49.2%), Tufted Duck *Aythya fuligula* (n = 1,496, 41.0%), and Whooper Swans *Cygnus cygnus* (n = 223, 39.3%). Greatest densities (± s.e.) among occupied wetlands were for Tufted Duck (6.66 ± 5.69 birds/ha), Mallard *Anas platyrhynchos* (6.39 ± 4.51 birds/ha), Demoiselle Cranes (3.70 ± 3.06 birds/ha), and Whooper Swans (3.69 ± 3.30 birds/ha). Most Great Cormorants *Phalacrocorax carbo* observed (62.9%) were on a sand island across from Tsagaan Nuur soum center, but the density and distance made it difficult to observe if juveniles were present. For other species, bird density and distance were generally not problematic, but reduced detection of juveniles could have occurred because of their behaviour of hiding during summer, especially when vegetation was present. Additionally, birds that use habitats outside wetlands, such as Demoiselle Cranes, likely are more abundant within the Darkhad Depression than our estimates suggest.

Juveniles of 13 species were observed (Table 1). Ruddy Shelduck and Eared Grebe *Podiceps nigricollis* had juvenile:adult ratios of > 1, whereas other species observed

with juveniles had ratios of < 1 (Table 1). For Whooper Swans, there were 1.08 juveniles:adults once large groups of adult moult-migrants were excluded (n = 88). Bar-headed Geese occurred in four flocks with goslings and had a ratio of 0.22 juveniles:adults (range = 0.04–1.65) once two flocks of moulting adults (n = 131) were excluded. Other waterfowl detected in relatively large moulting flocks without young included Common Pochard, Tufted Duck and Common Goldeneye. For these species, no adult males were observed in breeding plumage, suggesting they were moulting. Mongolian Gulls *Larus mongolicus* were detected in a large breeding colony (0.25 juveniles:adults at this location), but no other juvenile Mongolian Gulls were observed during the survey.

Twenty-two species observed during summer were not present in autumn, likely indicating that they had migrated prior to our survey. A neck-collared Whooper Swan tagged in December 2016 at the Whooper Swan National Wetland Park of Sanmenxia Prefecture of Henan Province, China, was observed, suggesting that some of the swans wintering in China migrate through or breed in the Darkhad Depression. Four species were observed in autumn, but not in summer: Bewick's Swan *Cygnus c. bewickii*, Greater Scaup *Aythya marila*, Grey Plover *Pluvialis squatarola*, and Red-necked Phalarope *Phalaropus lobatus*. Of 16 wetlands with > 100 waterbirds in summer, 12 had < 100 waterbirds in autumn. In autumn, Lower Tsagaan Nuur contained 4,221 individuals, or 68% of all waterbirds counted (56% of all swans, 80% of dabbling ducks, 76% of diving ducks; 5-times greater than summer). Two other lakes, Upper Tsagaan Nuur (at 51.032°N, 99.399°E) and an unnamed lake (at 51.202°N, 99.541°E) also contained 20% of waterbirds counted in autumn. Eleven of the 36 lakes surveyed in autumn had measurable ice cover in early October. Only two of these lakes had birds on them (both < 7 individuals). Smaller lakes were more likely to freeze: 91% (10 out of 11) of iced lakes were < 12 ha in area.

Discussion

This survey is likely to be the first to document and estimate densities of waterbirds throughout the Darkhad Depression during breeding, moulting and autumn migration (but see Ganbold *et al.* 2018 for a survey of a single wetland in the region). Over 10 days in the summer and autumn, 12,498 waterbirds were counted, representing 41 species. Our summer surveys covered 47.7% of the open water in the Darkhad Depression, though the extent of wetland may vary annually because the region's hydrology is dynamic and varies between years.

Of the species detected, five are listed on the threatened or near-threatened categories of the IUCN Red List (IUCN 2018) or in the Mongolian Red Book (Shiirevdamba *et al.* 2016). Of these, only the vulnerable Common Pochard and near threatened Northern Lapwing had relatively substantial abundance estimates ($\hat{n}$ = 494 and 119, respectively), but they were not observed in abundances > 1% of their flyway populations. BirdLife International lists the Darkhad Depression as an Important Bird Area, in part because it receives four waterbirds species which have > 1% of their

Table 2. Counts of birds detected during autumn migration, 6–10 October 2018 at the Darkhad Depression wetlands. Estimated flyway populations are based on the Waterbird Population Estimates; many estimates are not based on a quality assessment (Wetlands International 2019).

Species	No. individuals	Autumn density (per ha)	Percentage of wetlands used	Estimated flyway population (population name)	Percentage of flyway population estimated to be in Darkhad Depression in autumn
Bewick's Swan	13	0.002	6.0	1,000 (North Siberian/Caspian)	2.5
Whooper Swan (adult)	892	0.169	36.0	–	–
Whooper Swan (juvenile)	173	0.033	28.0	–	–
Whooper Swan (total)	1,065	0.205	36.0	60,000 (E Asia)	4.1
Ruddy Shelduck	588	0.111	25.0	50,000–100,000 (E Asia)	1.4–2.7
Northern Shoveler	15	0.003	3.0	500,000 (S, SE Asia)	0.007
Eurasian Wigeon	772	0.146	11.0	500,000–1,000,000 (E Asia)	0.2–0.4
Mallard	520	0.098	17.0	1,500,000 (E Asia)	0.08
Northern Pintail	899	0.170	8.0	200,000–300,000 (E, SE Asia)	0.7–1.05
Common Pochard	17	0.003	8.0	300,000 (E Asia)	0.01
Tufted Duck	391	0.074	33.0	200,000–300,000 (E, SE Asia)	0.3–0.5

Greater Scaup	22	0.004	11.0	200,000–300,000 (E Asia)	0.01–0.02
White-winged Scoter	116	0.022	8.0	600,000–1,000,000 (E Asia)	0.02–0.05
Common Goldeneye	1,375	0.260	50.0	100,000–1,00,000 (E Asia)	0.3–3.2
Smew	6	0.001	11.0	25,000 (E Asia)	0.05
Common Merganser	117	0.023	31.0	50,000–100,000 (E Asia)	0.3–0.6
Red-breasted Merganser	5	0.001	6.0	25,000–100,000 (E Asia)	0.01–0.05
Great Crested Grebe	32	0.006	14.0	25,000–50,000 (E Asia)	0.1–0.3
Horned Grebe	20	0.004	11.0	10,000–25,000 (E Asia)	0.2–0.5
Northern Lapwing	20	0.004	3.0	100,000–1,000,000 (E, SE Asia)	0.005–0.05
Grey Plover	1	0.0001	3.0	104,000 (E, SE Asia, Australasia)	0.001
Red-necked Phalarope	1	0.0001	3.0	100,000–1,000,000 (NE Asia)	0.0001–0.001
Black-headed Gull	28	0.005	8.0	100,000–1,000,001 (E, SE Asia)	0.006–0.06
Mongolian Gull	140	0.026	3.0	100,000–1,000,001 (Black Sea, W/SW Asia, NE Africa)	0.03–0.3
Great Cormorant	17	0.003	14.0	25,000–100,000 (E, SE Asia)	0.04–0.1

flyway population at the site (BirdLife International 2018a). These species, their flyway population estimates, the number observed in the Darkhad Depression during summer survey, and the percentage of their flyway population estimated in the Darkhad Depression are: 52,000−60,000 Bar-headed Geese ($\hat{n}$ = 1,023, 1.7–2% of the flyway population), 50,000–100,000 Ruddy Shelduck ($\hat{n}$ = 815, 0.8–1.6%), 300,000 Gadwall ($\hat{n}$ = 39, 0.004–0.008%) and 100,000−1 million Common Goldeneye ($\hat{n}$ = 3,190, 0.3–3.2%) (Wetlands International 2019). Extrapolated estimates suggest that the total number of birds in the region likely surpasses the 1% threshold for Bar-headed Geese, Ruddy Shelduck, and Common Goldeneye, but not for Gadwall. Additionally, our estimate of the number of Tufted Duck ($\hat{n}$ = 3,136) is above the 1% threshold (2,000–3,000 birds) of the East/South East Asian population (200,000–300,000 birds; Table 1).

The region also appears important for breeding populations of several species (Table 1), including the Ruddy Shelduck (present at 49% of wetlands surveyed) and Eared Grebe (7% of wetlands surveyed). All wetlands with breeding Whooper Swans (39% of wetlands) had cygnets. Bar-headed Geese occurred as flocks with goslings on 6.6% of wetlands surveyed, but 31% of all Bar-headed Geese were in moulting flocks of only adults at two wetlands. Moulting adults could have accompanied flocks with goslings, but additional counts of breeding pairs earlier in the season or juvenile:adult ratios measured in autumn are needed to provide a better assessment of Bar-headed Goose productivity at the site. Common Goldeneye were abundant in our survey (n = 1,522), were widespread (present at 57% of wetlands), and juveniles were detected (n = 47), but most Common Goldeneye appeared to be moulting adults (n = 1,364). All other species were detected at ≤ 18% of surveyed wetlands, suggesting they may have specific breeding territory needs which could make them more sensitive to environmental change. The dynamic hydrology of the Darkhad Depression leads to annual variation in the availability of wetlands and safe islands for nesting, and this should be monitored and modelled because it may greatly influence waterbird nest and juvenile survival in the region, especially as Mongolia is increasingly impacted by climate change (Batbayar 2013).

For several waterbird species, the Darkhad Depression appears to be an important area for moulting by post-breeding or non-breeding adults. Waterfowl and many cranes (excluding the Demoiselle Crane) undergo a flightless period during a single wing moult in summer (Johnsgard 1983; Baldassare & Bolen 1994; Pyle 2005). Many species detected in our survey are known to migrate to summer moulting areas (*i.e.* to make a moult migration; Jehl 1990), including the Bar-headed Goose, Tufted Duck, Common Goldeneye and Common Pochard (van der Wal & Zomerdijk 1979; del Hoyo *et al.* 2018). We observed the latter three ducks almost exclusively in basic plumage, with only a few Common Goldeneye juveniles detected, suggesting they were failed breeders from the Darkhad Depression that were moulting, or moult migrants from regions outside of the Darkhad Depression (Johnsgard 1983). Dabbling ducks including Eurasian Wigeon

Mereca penelope, Northern Pintail *Anas acuta*, Northern Shoveler *Spatula clypeata*, Gadwall, Common Teal *Anas crecca* and Falcated Duck were less common, but also appeared to be using the region mainly for moulting because they were in basic plumage with no juveniles. As such, the Darkhad Depression appears to be an important moulting area for waterfowl.

Juvenile Demoiselle Cranes (unfledged or fledged) were not recorded during our surveys despite observing 33 adults, and only 4 adults and 1 juvenile Common Crane were detected. Similarly, researchers catching cranes in Eastern Mongolia also observed few juveniles during spring and summer 2018, which were abnormally dry, whereas juveniles were common during the wetter summer of 2017 (A. Gungaa & H. Purev-Ochir, Mongolian Bird Conservation Centre, pers. comm.). Based on these observations, monitoring and modelling crane reproduction may be important for understanding how crane populations in Mongolia may be impacted in the future by predicted climate variability in Mongolia (Dagvadorj *et al.* 2014).

Common Tern *Sterna hirundo*, White-winged tern *Chlidonias leucopterus* and Grey Heron *Ardea cinerea* are colony nesters and were common during the survey, but juveniles were not detected. It is possible that the foraging adults detected were returning to breeding colonies elsewhere in the Darkhad Depression. Additionally, grebes were seen building or sitting on nests, and it is unclear whether our lack of juveniles was due to failed or late breeding. For shorebirds, including Common Redshank *Tringa totanus*, Northern Lapwing, Eurasian Curlew, and Wood Sandpiper *Tringa glareola*, lack of juveniles could be of concern, as all these species are supposed to breed in the Darkhad Depression (del Hoyo *et al.* 2018). However, all species but the Wood Sandpiper are often known to nest on the ground, and all these species rear their young in dense cover (del Hoyo *et al.* 2018). It is likely that the lack of juveniles observed could therefore result from a variety of factors, including early migration and the inability to detect juveniles or adults concealed in the vegetation, although vegetation was limited on the study area. Spotted Redshank *Tringa erythropus* were also detected, but they breed farther north than our survey area and were likely starting migration.

The Darkhad Depression appears important to breeding and moulting waterbirds of the East and Central Asian Flyways. Local factors that may explain why the Darkhad Depression is such an important region for breeding waterbirds were not measured during the survey; however, the region's importance may be explained by its extensive system of small-scale wetlands and by Mongolia's location on the migration routes for many of the waterbird populations in east Asia. Threats to these wetlands may include wetland degradation due to overgrazing and disturbance from herds of livestock, unnatural seasonal hydrology if waters were ever dammed, and wetland loss due to climate change (Batbayar 2013; Ganbold *et al.* 2017; Ganbold *et al.* 2018).

Further study is needed to determine breeding status and to monitor the population trends and reproductive success of all waterbird species in the Dakhard

Depression. Taxon-specific studies focused on counting breeding pairs in the spring to estimate breeder densities and determine the importance of the region for breeding waterbirds would be of high value. We recommend conducting surveys early spring through late autumn. Based on a literature review of fledging times and current observations, surveying in mid-July for waterbird juveniles seems to be an ideal time to determine annual productivity for many species in this region (van der Wal and Zomerdijk 1979; Batbayar 2013; Cui *et al.* 2010; del Hoyo *et al.* 2018). These include cranes, Bar-headed Geese, Whooper Swans and many of the diving duck species, such as Common Goldeneye, Tufted Duck and Common Pochard. However, due to variation in breeding, hatching and fledging periods for other species, more extensive surveying over a longer period (*e.g.* June–late July) would ensure that productivity is adequately monitored. A survey in early June could help establish the number of breeding pairs across many areas and locate breeding colonies of important species, such as Bar-headed Geese. Similarly, several surveys spanning early to late migration (late July–early November) would aid in our understanding of autumn migration chronology through the region. However, intensive surveying in the region may be difficult to implement due to limited funding and resources.

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