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Short Communication

The Potential Food Supply of Relict Gulls and the Preliminary Prediction of its Population Size after the Lake Restoration in Ordos Relict Gull National Reserve, Inner Mongolia, China

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CD and WL conceived the idea. LL and LG analyzed the data. CD, YR, and SW collected samples. CD and WL wrote the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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ABSTRACT

The Ordos Relict Gull National Nature Reserve (Taolimiao-Alashan Nur, TAN) was once the most important breeding place for the Ordos sub-population of relict gulls *Ichthyaetus relictus*, but there were no more gulls breeding here since the lake dried up in the early 21st century. Since the water diversion started in 2018, five and 35 nests have been recorded breeding here in 2020 and 2021, but the arthropod community in the wetland has not been completely rebuilt. Whether its diversity and biomass can provide sufficient food during the breeding period is the key to the recovery of the relict gull. Here we investigated aquatic arthropods in the TAN and Hotong Qagan Nur (HQN) to compare the food supply and predict the capacity of the reserve after the lake water was restored. The results showed that the arthropod communities are low abundant in two lakes with a total of 16 taxa, but their biomass in TAN was significantly lower than HQN. According to the breeding records of relict gulls in HQN, we roughly estimate that up to 400 relict gulls pairs may be able to breed in TAN. The low availability of food supply during the brooding period might still be a limiting factor for the restoration of the TAN relict gull population in the following years.

The relict gull (*Ichthyaetus relictus*) is the latest recognized species in the family Laridae and one of the least known birds (He *et al*., 2002). It was listed in the First Class State Protected Wildlife in China and as a vulnerable species on the Red List of the International Union for Conservation of Nature (He *et al*., 2002; Bird Life International, 2021).

Since the relict gull was designated as a full species in 1971, several breeding colonies of relict gulls have been studied around the world (Auezov, 1971; He *et al*., 2002). In 1990, the first breeding colony of relict gulls in China was discovered in the Taolimiao-Alashan Nur (TAN) in Ordos, Inner Mongolia (Zhang *et al*., 1991). This finding has changed the global distribution of relict gull populations, and the subsequent investigations have shown that the Ordos population was the world's largest independent breeding subgroup (3,594 pairs in 1998), exceeding the sum of the other three subgroups of the Central Asian population, the Gobi population, and the Far East population (Duff *et al*., 1991; He *et al*., 1994, 2002). The Ordos relict gull National Nature Reserve was established in TAN in 2001 and was listed as the No. 1148 Internationally Important Wetland in the next year (He *et al*., 2010). However, the water area in this wetland declined year after year and completely dried up in 2008, the protected area has lost its ecological function although the lake water had slightly recovered in the following 10 years (He *et al*., 2015). During the decade, the Ordos subgroup of relict gulls moved to Hongjian nur for breeding, and then some of them emigrated to HQN in 2015 (Wang *et al*., 2021), so that no relict gull was recorded breeding in the national reserve since 2004. In 2018, TAN began to divert

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water from the Yellow River, and the lake was restored and reached an area of 7-8 km^2 in 2019. Five and 35 nests of relict gulls were recorded breeding here in 2020 and 2021, respectively. Although TAN has restored most of its water area by now, the aquatic habitat has changed from a semi-desert saltwater lake to a semi-arid freshwater-brackish lake (He *et al*., 2020), and the aquatic arthropod community in the area must have changed as well.

Since 2018, the TAN ecosystem Wetland has not been stabilized yet, and the arthropod community is still in the process of reconstruction. Therefore, whether the diversity of arthropods in the wetland and their biomass could provide sufficient food for relict gulls during the breeding period is the key to the recovery of relict gulls in this wetland in the future. In this study, the aquatic arthropods in TAN were investigated and compared with those found in HQN to assess the potential food supply of aquatic arthropods in the reserve for relict gulls. The results can provide important references and guidance for the restoration of relict gulls in the reserve.

Materials and methods

Ordos Relict Gull National Reserve (39°46'–39°48'N, 109°17'–109°21'E) is located in TAN, south of Bojianghaizi Town, Ordos, Inner Mongolia, China, at an elevation of 1,365 m. The lake area is about 7.5 km^2, and the pH is 8.64. HQN (39°11'–39°14'N, 108°57'–109°02'E) is located in the south of Wushenzhao Town, Ordos, Inner Mongolia, at an elevation of 1,260 m. The alkali lake has an area of 22 km^2 with a pH of 9.89. The brooding period of relict gulls is from late May to mid-June. Field work was conducted three times during the brooding period, dividing it into early, middle, and late stages at an interval of 7-10 days. 27 and 44 sampling sites were selected on the shores around TAN and HQN, respectively, to investigate aquatic arthropods in both lakes in 2021 (Fig. 1).

The aquatic arthropods of each 1 m^2 sample site were collected using the standard sweeper for 20 times sweeping and counted. A 40 cm diameter sample sieve (60 mesh) was used to collect the aquatic arthropods in upper layer water at a depth of 20 cm. Additionally, a 20 cm^2 with 5 cm in depth mud was dug, washed, and filtered to collect animals in the mud. All collected arthropods were microscopically inspected, sorted, and weighed.

The data were analyzed and plotted using the R statistical software 3.6.3. The data sets were checked for normality tests using the Shapiro-Wilk test before performing analyses of variance. The population parameters were analyzed using one-way ANOVA and Tukey's post-hoc tests to statistically identify differences among groups. All comparisons were two-tailed, and statistical differences were considered significant at $p < 0.05$.

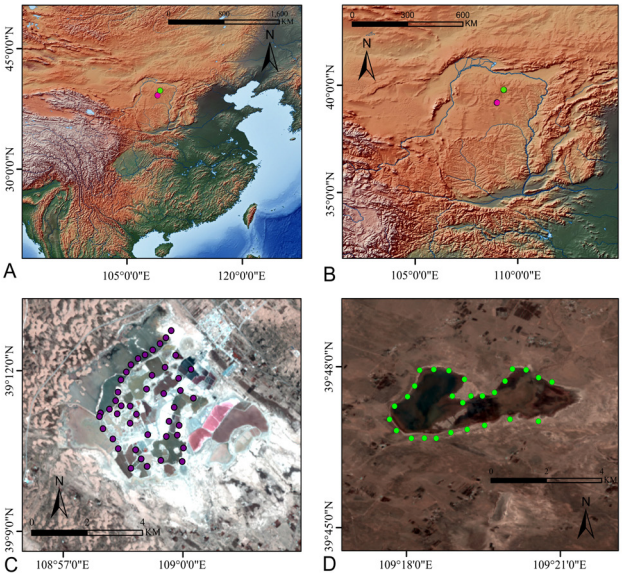

Fig. 1. Maps of Taolimiao-Alashan Nur (TAN) and Hotong Qagan Nur (HQN) in Ordos, China (A and B), and the sampling sites in TAN (C) and HQN (D).

Results and discussion

A total of 16 species of aquatic arthropods were collected from two wetlands. Of these, Diptera was the most diverse arthropods including three species of Chironomids (*Chironomus* sp., *Procladius* sp., and *Psectrocladius* sp.), one species of biting midge (*Ceratopogonidae* sp.), and three species of flies belonging to the infraorder Muscomorpha within suborder Brachycera (*Lispe neimongola*, *Ephydra* sp., and *Philophylla* sp.). Besides, other insects, including one species of damselfly (Coenagrionidae sp.), *Sigara lateralis*, *Ylodes reuteri*, and two species of ants (*Cataglyphis* sp. and *Camponotus* sp. within Formicidae), and a species of mole cricket (*Gryllotalpidae* sp.), were also abundant in the wetlands. In addition, two species of water fleas (*Daphnia magna* and *Calanidae* sp.) and brine shrimps (*Artemia* sp.) were also observed. The amount and biomass of the main arthropods in the two lakes were investigated three times during the brooding period of the relict gulls (Table I), the remaining species are scattered because their number were very low. The sampled taxa of arthropods in the wetlands were more abundant than in the previous study before the lake dried up (Liu *et al*., 2008).

The benthic animal communities in both studied wetlands are dominated by aquatic arthropods, with a lower abundance of taxa than in the wintering sites in Bohai Bay and Laizhou Bay (Liu *et al*., 2006; Bo *et al*., 2020). A notable difference in species composition between them is that brine shrimps were very abundant in HQN but absent

in TAN. This may be due to the input of freshwater that hindered the population of the halophilic shrimps.

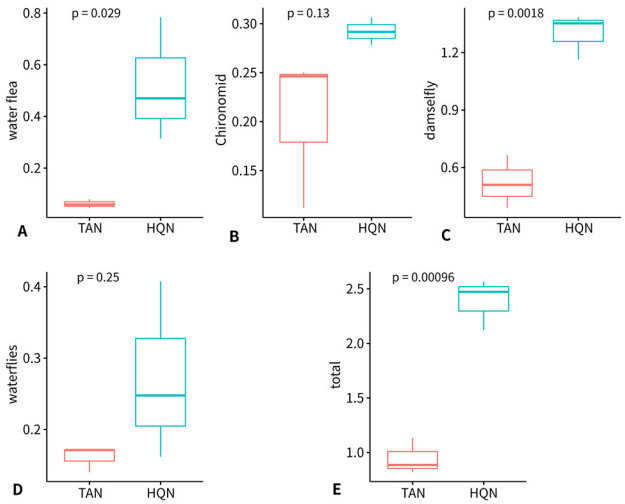

Fig. 2. The biomass of dominant taxa in Taolimiao-Alashan Nur (TAN) and Hotong Qagan Nur (HQN), including water flea (A), Chironomid (B), damselfly (C), waterflies (D), and the total (E).

We divided the main arthropods into 4 categories to compare their biomass (Fig. 2). The biomass densities of water fleas and damselflies in HQN were significantly higher than that of TAN ($p < 0.05$), but there was no significant difference in the biomass density of Chironomids and water flies between the two wetlands. It is worth noting that the total biomass density of arthropods in HQN is about 2.52 times that in TAN. Such a large difference may be closely related to the ecosystem reconstruction of the TAN wetland. Because the lake had dried up for more than ten years until being restored in 2019, its ecosystem is still reconstructing and the arthropod community had not been fully established yet. The current lake area of HQN is about 2.93 times that of TAN, so the amount of food supply for relict gulls in TAN is about 13.52% of that in HQN. If only the food supply was taken into account, knowing that the average number of relict gulls breeding in HQN in recent years is about 3000 pairs (Wang *et al*., 2021), we roughly estimate that the food supply in TAN could potentially afford about 400 nests of relict gulls for breeding. This population size estimate based on the potential availability in the food supply is just a crude approximation because data on the diet and food requirements of the gulls at both breeding sites are currently lacking. Even so, the present work provides a first crude estimation of the number of pairs that may settle in TAN in the following years and thus helps to assess the potential of this historically important site for the restoration of relict gulls' populations in China. Clearly, additional studies on the feeding ecology of the relict gull in TAN are urgently needed to conveniently address this question knowing its poor conservation status. Additionally, our estimate is far away from the historic number of more than 3,000 nests. As the water volume of TAN and the arthropod community continue to recover, it is believed that the wetland could potentially carry more breeding relict gulls. However, ours results suggest that the total biomass of arthropods in TAN decreased in the middle and late brooding periods. Knowing that as chicks grow up their food intake increases, the food supply available during the brooding period might become an important factor restricting chicks' survival and limiting the colony size. Again additional ecological studies are needed to soundly address this question.

Table I. The density and biomass of arthropods during the brooding period of relict gulls in TAN and HQN.

	TAN (individuals/m², mg/m² dry weight)						HQN (individuals/m², mg/m² dry weight)					
	Early		Middle		Late		Early		Middle		Late	
	1	2	1	2	1	2	1	2	1	2	1	2
Daphnia magna	652	25.5	170	8.2	840	36.3	2888	216.1	1060	75.1	1700	107.9
Calanidae sp.	1730	20.3	2270	51.2	2400	43.6	3094	98.3	41830	708.2	14420	362.1
Chironomid larvae	235	55.0	143	27.1	124	35.5	225	55.9	127	23.6	145	29.3
Chironomid adults	28	22.3	9	11.1	40	37.5	196	113.3	180	100.2	184	98.5
Chironomid pupae	171	50.4	154	46.1	140	49.3	124	50.6	194	68.1	247	86.7
Chironomid puparium	1416	122.5	206	27.5	1024	123.9	652	71.9	750	86.3	1014	92.0
Damselfly	48	503.6	36	304.3	25	220.5	73	966.9	62	702.8	83	872.8
Damselfly puparium	310	161.0	380	205.2	240	168.4	950	385.6	1150	460.8	1430	510.8
Sigara lateralis	67	23.3	84	31.8	76	32.7						
Ephydrid	137	171.7	170	140.4	162	171.2	149	162.0	200	247.7	379	407.4
Artemia							5436	598.3	5790	426.0	1530	21.5

In conclusion, the wetland ecosystem will be gradually rebuilt with the restoration of lake water, but it will take a long way to restore the historic number of relict gulls breeding here. At present, food supply might still be a limiting factor for the relict gulls in the wetland. In the near future, we will pay attention to the recovery of the arthropod community and the relict gull population in this potentially important wetland.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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