

Demographics, diet and association with livestock of the Andean Goose *Oressochen melanopterus* in Lake Junín, Peru

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Abstract - The breeding distribution of the Andean Goose *Oressochen melanopterus* ranges roughly from the high Andes of central Peru to approximately the high Andes of central Argentina and Chile. Although its conservation status is of least concern, populations in the south of its distribution show signs of danger for its conservation. The aim of the present study was to assess several demographic aspects, its feeding ecology, and habitat use. To this end, we conducted observations on the population of the Andean Goose wintering in Lake Junín, Peru, between the 16th and 18th of September 2024, by surveying the approximately 112 km perimeter of the lake by vehicle. A total of 2391 Andean Geese were recorded: 1372 (57%) in the northeast zone of the lake, concentrated almost entirely (98.8%) in the northernmost region, and 1019 (43%) in the southwest zone of the lake, distributed mainly (69.5%) between the districts of Junín and Ondoës. The population of Andean Geese in Lake Junín was estimated to be approximately 3500 (± 2000) individuals. The diet of the Andean Goose consisted mainly of grasses (62.9%), graminoids (27.4%) and eudicots (6.2%). The most frequently consumed taxa were the grasses *Festuca* spp. (12.5%) and *Elymus* sp. (11.5%), along with Cyperaceae as *Carex* spp. (11.1%). Groups of Andean Geese were found in areas with water bodies 80% of the time, and a relatively high proportion (46%) were found using sites with livestock. All the above highlight the importance of proper management of wetland pastures to protect Andean Geese.

Key words: distance sampling, distribution, feeding ecology, livestock, population, wetlands.

Riassunto - Demografia, dieta e associazione con il bestiame dell'oca andina *Oressochen melanopterus* nel Lago Junín, Perù.

L'area di distribuzione durante la riproduzione dell'oca andina *Oressochen melanopterus* si estende dalle alte Ande del Perù centrale fino a quelle dell'Argentina centrale e del Cile. Sebbene la specie sia classificata come a rischio minimo, le popolazioni meridionali mostrano segnali di vulnerabilità. L'obiettivo di questo studio era valutare alcuni aspetti demografici, insieme all'ecologia alimentare e all'utilizzo dell'habitat. A tal fine, tra il 16 e il 18 settembre 2024 abbiamo condotto osservazioni sulla popolazione svernante nel lago Junín (Perù), percorrendo in veicolo l'intero perimetro del lago, lungo circa 112 km. Abbiamo registrato complessivamente 2391 individui: 1372 (57%) nella

zona nord-orientale, quasi tutti (98,8%) concentrati nella parte più settentrionale, e 1019 (43%) nella zona sud-occidentale, distribuiti soprattutto (69,5%) tra Junín e Ondoës. La popolazione complessiva del lago Junín è stata stimata in circa 3500 (± 2000) individui. La dieta risultava composta principalmente da poacee (62,9%), graminoidi (27,4%) ed eudicotiledoni (6,2%). Tra i taxa più frequentemente consumati figuravano le poacee *Festuca* spp. (12,5%) ed *Elymus* sp. (11,5%), insieme alle ciperacee *Carex* spp. (11,1%). I gruppi di oche erano presenti in aree con bacini idrici nell'80% dei casi e utilizzavano siti con bestiame in una percentuale relativamente alta (46%). Questi risultati sottolineano l'importanza di una gestione adeguata dei pascoli umidi per garantire la protezione dell'oca andina.

Parole chiave: bestiame, *distance sampling*, distribuzione, ecologia dell'alimentazione, pascoli umidi, popolazione.

INTRODUCTION

The Andean Goose *Oressochen melanopterus* is the highest altitude breeding species of all South American geese of the Tribe Tadornini (Madge & Burn, 1988; Fjeldså & Krabbe, 1990; Johnsgard, 2010). Its breeding distribution ranges roughly from the high Andes of central Peru (Department of Ancash) (Clements & Shany, 2001) to approximately the high Andes of central Argentina (Mendoza province) (Pearman & Areta, 2021) and Chile (Maule region) (Jaramillo, 2005), generally above 3000 m a.s.l. (Summers, 2005; Schulenberg *et al.*, 2010; de la Peña, 2015; Martínez Piña & González Cifuentes, 2021). Although at the international level its population status has been established as of "least concern" (del Hoyo *et al.*, 2014; del Hoyo, 2020; Sandvig *et al.*, 2024), in Argentina its status has been defined as "vulnerable" (Argentine Ministry of Environment and Sustainable Development & Argentine Birds, 2017), as there is evidence of negative interaction between extractive human activities and Andean Geese in some localities (López-Lanús *et al.*, 2008). Furthermore, in Chile, the southern limit of its reproductive distribution seems to have contracted considerably (Barros & Azócar, 2018), so its southernmost populations have been categorised as "endangered" (Chilean Ministry of the Environment, 2020).

Waterbirds are very sensitive to certain environmental changes and can therefore be used as bioindicators of ecosystem health (Kushland, 1993; Amat & Green, 2010; Rahman & Ismail, 2018). Thus, monitoring the distribution and abundance of the Andean Goose in different environments, such as the Lake Junín National Reserve, is of key importance to identify trends in its population and spatial arrangement of individuals. Population fluctuations could be reflecting alterations in habitat quality, the presence of introduced species or variations in climatic conditions, as oc-

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curs with several species of waterbirds around the world (Furness & Greenwood, 1993; Martínez Fernández *et al.*, 2005; Maron *et al.*, 2006). In addition, population monitoring can provide valuable data for the design of adaptive management measures (Baldassarre & Bolen, 1994; Kear *et al.*, 2005; Johnson *et al.*, 2023), such as restoration of degraded habitats or protection of areas preferentially used by geese for winter feeding.

The diets of different South American geese have been studied by several researchers (Martin *et al.*, 1981; Summers & Grieve, 1982; Punta *et al.*, 2019). South American geese feed mostly on grasses, usually grazing in pasture environments (del Hoyo *et al.*, 1992; Kear, 2005; Rodríguez Mata *et al.*, 2008), except for the Kelp Goose *Chloephaga hybrida*, which feeds mainly on algae in the marine intertidal zone (de la Peña, 1992; Valenzuela Rojas, 2002; Kovacs *et al.*, 2005). Despite this long-standing knowledge, the diet of the Andean Goose has been little studied (Orellana *et al.*, 2021; Punta *et al.*, 2021). Improving knowledge of the diet and association of Andean Geese with livestock in winter feeding sites, especially in areas such as wetlands, may be important to understand the overlap in forage resource use between Andean Geese and livestock in these fragile environments.

The present study aimed to assess the numbers and distribution of Andean Goose groups in the highlands surrounding Lake Junín, Peru, and provide an estimate of the total population in the wetlands near the lake during the non-breeding period. Moreover, we report on their diet in some of the environments surrounding the lake, as well as their association with the different types of livestock observed. Finally, we provide comparisons with observations made on the numbers and distribution of Andean Geese in the same lake, with dietary determinations of the Andean Goose in other localities, with the diet of other South American geese, and finally with associations of South American geese and livestock in different sites.

METHODS

Lake Junín (also called Chinchaycocha and formerly Los Reyes) is located in the central region of the Peruvian Andes (between 10°54.95'S and 11°5.13'S and between 76°2.39'W and 76°15.58'W), at an altitude of 4,080 m a.s.l., in the department of Junín (Fig. 1). It occupies the north-western end of the Junín or Bombón plains or “pampas”; its water body covers a surface area of up to 400 km², and its maximum depth is 12 m. The climate of the region corresponds to that of the “puna”, where the temperature generally oscillates between 3°C and 7°C, with the coldest period being that between May and September. Diurnal temperature can vary widely and can drop as low as -7°C at night. The average annual rainfall is 940 mm, with December to April (summer-autumn) being the rainiest months and June to September (winter) being the months with the lowest rainfall (Dourojeanni *et al.*, 1968; Asociación Ecosistemas Andinos, 2010). The level of ambient humidity perceived in the area is low throughout the year. The average hourly wind speed in Junín has slight seasonal variations during the year, with values ranging between 7.7 km/h and 9.7 km/h. The prevailing winds come from the east quadrant (Weather Spark, 2024).

Plant communities associated with this extensive high Andean wetland develop around the lake. The high Andean wetlands, known as “bofedales”, are generally made up of several plant communities, including: (i) *Distichia* peatlands, (ii) peatlands with mosses and shrubs, characterised by the abundance of mosses of the genus *Sphagnum*, (iii) peaty meadows, characterised by the presence of many species of Poaceae, Cyperaceae and Juncaceae, (iv) stream grasses or graminoid bogs, (v) floating communities, (vi) submerged communities in areas with shallow and slow currents, which form small lagoons, and (vii) amphibious communities, which are plants that develop in aquatic environments (Maldonado, 2014; Mendoza *et al.*, 2024).

We visited Lake Junín between September 16th and 18th 2024. For the purposes of demographic analysis, we divided the lake contour and its surroundings into two main zones: northeast and southwest (Fig. 1). On the 16th, we travelled the road from Vicco to Junín, passing through Shelby, recording only the number of livestock types observed (i.e., sheep, cattle, horses, pigs and auquenids (South American camelids)). On the 17th, we travelled around the entire perimeter of the lake in a clockwise direction, starting from Junín, initially passing through the southwest zone of the lake and returning to the starting point via the northeast zone. This route was divided into four sections: Junín-Ondores, Ondores-Pari, Pari-Vicco and Vicco-Junín. On the 18th, we travelled along the southwest part of the lake and collected faeces at two sites (Fig. 1). Along the entire route, systematic sampling points were established at regular intervals, where the same environmental variables were recorded regardless of Andean Goose presence.

During the tour on day 17, each time Andean Geese were observed, the vehicle was stopped to geo-reference their position and measure their distance from the observer. The counts were carried out by driving along the roads at a speed always <60 km/h and recording the positions using a GPS. The distances between our position and that of Andean Geese were measured using a 6×21 laser rangefinder with a range of 1500 m and an accuracy of ±1 m. During each count, the presence of livestock and water bodies (e.g., wetlands, streams, lake) within a radius of ≈200 m around Andean Geese was recorded. The radius was estimated by taking the approximate centre of the Andean Goose cluster as a reference point. To avoid disturbing the activity of Andean Geese, counts were always performed from inside the vehicle. In all cases, 12×42 binoculars and a 13-39×50 telescope were used. In addition, the number of groups of livestock observed in part of the route (between Junín and Vicco, passing through Ondores) was recorded.

The size of Andean Goose groups was differentiated between pairs of individuals and flocks (>2 individuals). The Andean Goose group sizes were then classified into three categories: i) pair of individuals; ii) 3-20 individuals (the maximum number that a few families could reach); iii) >20 individuals (which includes several families).

Andean Goose density was determined using the line transect method. Each section travelled was considered a transect. In each transect, the perpendicular distance between Andean Geese and the observer was measured (Bibby *et al.*, 1992; Henderson, 2003; Gibbons & Gregory, 2006). Andean Goose densities were calculated by using Distance Sampling, version 7.3, Release 2 (Thomas *et al.*, 2010).

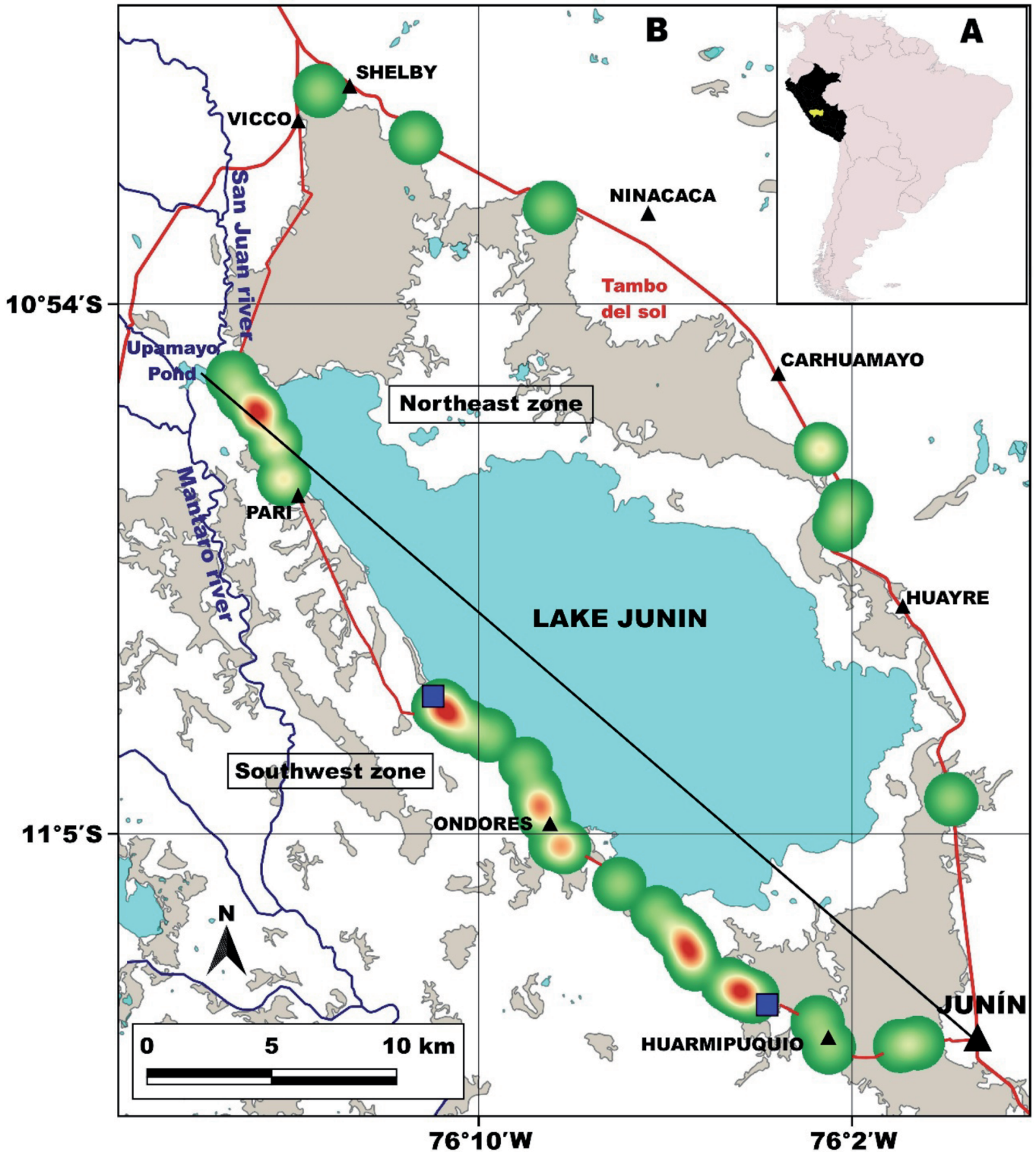


Fig. 1 – A) Location of the department of Junin in Peru, South America. B) Study area where some towns and places near the lake are indicated. The red colour indicates the road around the lake that we travelled to count Andean Geese and the grey colour indicates the high Andean wetlands (“bofedales”). The heatmap of the Andean Goose groups observed is shown with varying colours from green (lowest group density) to red (highest group density). The black line running from Junín to Upamayo pond indicates, for the purposes of this study, the boundary that we considered between the northeast and southwest zones of the lake and its surroundings. The two blue rectangles show the sites chosen for faecal collection for diet analysis. / A) Ubicazione del dipartimento di Junin in Perù, Sud America. B) Area di studio in cui sono indicate alcune città e località vicine al lago. Il colore rosso indica la strada intorno al lago che abbiamo percorso per contare le oche andine, mentre il colore grigio indica le zone umide dell’alta Anda (“bofedales”). La mappa dei gruppi di oche andine osservati è mostrata con colori che variano dal verde (densità di gruppo più bassa) al rosso (densità di gruppo più alta). La linea nera che va da Junin allo stagno di Upamayo indica, ai fini di questo studio, il confine che abbiamo considerato tra le zone nord-est e sud-ovest del lago e dei suoi dintorni. I due rettangoli blu mostrano i siti scelti per la raccolta delle feci per l’analisi della dieta.

This software allows data from transect counts (Buckland *et al.*, 2001) to be processed and modelled to fit a detection probability function. The detection probability function was estimated by selecting one of the possible models and one of the possible fitting terms offered by the Distance Sampling software (Southwood & Henderson, 2000), choosing the one with the lowest Akaike Information Criterion (AIC). The best-fitting model was the Half-Normal function with the cosine adjustment term (AIC: 655.65) (*Supplementary Fig. 1*). Alternative models had higher AIC values, ranging from 656.55 to 657.42 for the Hazard Rate, Negative Exponential, and Uniform functions with the cosine adjustment term, and from 656.70 to 682.48 for the half-normal, hazard rate, negative exponential, and uniform functions with the simple polynomial adjustment term. Finally, the surface of the high Andean wetlands surrounding Lake Junín (Fig. 1) was obtained from the vector file of the National Geographic Institute of Peru.

Areas of higher or lower density of Andean Goose clusters were identified by using the Kernel (kernel density) method. This is a non-parametric method that allows converting cluster position data into continuous surfaces, representing the intensity of space use in a heatmap (Netek *et al.*, 2018). A higher number of clustered points will result in higher densities. In simple terms, this procedure allows visualising the location of abundance and scarcity events (Nelson & Boots, 2008). The heatmap was created by using the QGIS software (version 3.34; QGIS Development Team, 2024).

The botanical composition of the Andean Goose diet was determined by microhistological analysis of feces (Williams, 1969; adapted from Latour & Pelliza Sbriller, 1981; Zarlavsky, 2014). Feces were collected at two sites in the southwest of the lake: between Huarmipuquio and Ondores and between Ondores and Pari (21 fecal samples at each site). Feces were collected by choosing from some of the areas with the highest concentration of Andean Geese observed the previous day. To analyse them, they were dried in an oven at 55°C for 96 hours and then ground separately, with an analytical grinder. The material from each faecal sample was placed in water and boiled, then washed with water in a strainer and placed in a container with water, where sodium hypochlorite was added. Then, the material was washed with water and allowed to dry. Finally, it was stained with safranin, and a portion of the material from each faecal sample was mounted on a slide with glycerine gelatine. Twenty microscopic fields per preparation, i.e., 840 fields for the total number of samples, were analysed. The analysis was performed with a microscope with magnifications of 100× and 400×, equipped with a digital camera.

The items were determined at the genus or species level by using catalogues (Pelliza Sbriller & Moraga, 1993) and by comparison with our own collection obtained in the study areas. The histological characteristics assessed were, among others, shape, border type, length–width ratio, and characteristics of interstomatic cells in epidermal cells, shape, size, location, and density of stomata, and shape, quantity, and location of papillae, microhairs, macrohairs, and roughness (Borgnia, 2009). Observations were recorded and the results expressed as frequency percentages of the items determined (Holechek & Vavra, 1981; Holechek & Gross, 1982). Floristic items that did not allow a confident identification were

classified as “unidentified”. For comparative purposes, the plant material determined was grouped into three food groups: Gramineae (Poaceae - Monocots), Eudicots and Graminoids (Juncaceae, Cyperaceae and Juncaginaceae - Monocots).

A sample of dried Andean Goose feces was measured and weighed. The measurements were taken with a Vernier calliper (precision 0.1 mm) and the weights with a digital balance (precision 0.01 g). The diet of the Andean Goose was also analyzed on the basis of three trophic variables: taxonomic richness, dietary diversity and diet evenness of the plants consumed. Taxonomic richness was calculated using Menhinick’s richness index ($D_{Mn} = S/\sqrt{n}$; Menhinick, 1964), where D_{Mn} is Menhinick’s species richness index, S is the total number of species and n is the total number of individuals of all species. Dietary diversity was calculated using the Shannon-Wiener diversity index ($H' = -\sum p_i \ln p_i$; Hurlubia, 1973; Pielou, 1975), where H' is the Shannon-Wiener diversity index and p_i is the proportion of each i th species identified. Diet evenness was estimated using Pielou’s evenness index ($E = H'/\ln S$), where H' is the Shannon-Wiener diversity index and S is the total number of species (Magurran, 2004).

We compared the proportions of plant-taxon groups in the Andean Goose diet between the samples obtained from the Huarmipuquio-Ondores and Ondores-Pari sectors using a G-test (Sokal & Rohlf, 2012), considering four diet categories (grasses, graminoids, eudicots and unidentified). We also compared the group sizes of Andean Geese recorded in our study with those reported by Summers & Castro (1988) using the Mann-Whitney test (Siegel & Castellan, 1995). Both analyses were conducted using InfoStat (Di Rienzo *et al.*, 2010). The association between the sites where Andean Geese were observed, and the presence of livestock and water bodies was assessed by calculating the proportion of co-occurrences between Andean Geese and the variables described. To complement the descriptive co-occurrence analysis, we also fitted a generalized linear model (GLM) with binomial error distribution and logit link to evaluate whether livestock presence and water presence explained the probability of detecting Andean Geese at each sampling point. Geese presence (1/0) was used as the dependent variable, while livestock presence (1/0) and water presence (1/0) were included as predictors (Gotelli & Ellison, 2013; Harrison *et al.*, 2018). This analysis was performed in R (R Core Team, 2024).

RESULTS

Abundance, distribution, density and population size of Andean Geese

We recorded a total of 2391 Andean Geese distributed around the lake. In the northeast zone of the lake, we counted 1372 (57%) individuals, concentrated almost entirely (98.8%) in the northernmost part of the lake. In the southwest zone of the lake, we counted 1019 (43%) individuals, distributed mostly (69.5%) between Junín and Ondores. The density of Andean Goose individuals around the lake was 14.4 ± 8.8 individuals/km². Based on this density, and considering that the wetlands around the lake occupy an area of ≈ 240 km², our estimate of the Andean Goose population was 3500 ± 2000 individuals.

Group distribution and high- and low-density areas

We recorded a total of 50 Andean Goose groups distributed around the lake. In the northeast zone of the lake, we counted 15 groups (30%), whereas in the southwest zone, we counted 35 groups (70%). The density of Andean Goose groups around the lake was 1.1 ± 0.53 groups/km². The heatmap shows the areas where the density of Andean Goose groups was high, although spatially discontinuous (Fig. 1). It also reveals that the highest concentrations of Andean Goose groups were observed in the southwest zone of the lake, mainly between Huarmipuquio and Ondores and, to a lesser extent, between Ondores and Pari (Fig. 1).

Size of groups

Most groups of Andean Geese consisted of pairs of

individuals. We observed 31 pairs of Andean Goose individuals (62% of observations) and 19 flocks of 3 or more individuals (38% of observations). Flock sizes of a few families (3-20 individuals) were the least frequent (14% of observations), followed by flocks of more than 20 individuals (24% of observations). Flock sizes ranged from 3 to 813 individuals. The mean size was 47.8 individuals (standard deviation=128.8, range=2-813, n=50).

Diet

Size and dry weight of feces

The size and dry weight of a set of Andean Goose feces obtained from the periphery of Lake Junín are shown in Tab. 1.

Tab. 1 – Size and dry weight of Andean Goose faeces from Lake Junín, Peru. / Dimensioni e peso secco delle feci dell'oca andina del lago Junín, Perù.

Parameter/variable	Length (mm)	Width (mm)	Weight (g)
Mean	66.4	13.1	1.5
Standard deviation	7.1	1.5	0.6
Range	57.0-79.0	10.8-14.9	0.83-2.52
n	12	12	12

Tab. 2 – Plant taxa identified in this study in the diet of the Andean Goose, along with their habit and status in the Junín highlands, Peru. / Taxa vegetali identificati in questo studio nella dieta dell'oca andina, insieme al loro habitat e al loro status negli altopiani di Junín, Perù.

Family Genus and species	Habit	Status
Poaceae		
<i>Festuca</i> spp. L.	Perennial herb	Native/adventitious
<i>Elymus</i> sp. L.	Perennial herb	Native
<i>Poa</i> spp. L.	Perennial/annual herb	Native/adventitious
<i>Agrostis</i> sp. L.	Perennial herb	Native/adventitious
<i>Deschampsia</i> sp. P. BEAUV.	Perennial herb	Native/adventitious
<i>Bromus</i> sp. L.	Perennial herb	Adventitious
<i>Stipa</i> sp. L.	Perennial herb	Native
<i>Hordeum</i> sp. L.	Perennial/annual herb	Native/adventitious
<i>Distichlis</i> sp. RAF.	Perennial herb	Native/adventitious
<i>Cinnagrostis</i> sp. ADANS.	Perennial herb	Native
<i>Dactylis glomerata</i> L.	Perennial herb	Adventitious
Fabaceae		
<i>Trifolium repens</i> L.	Perennial herb	Adventitious
Caryophyllaceae		
<i>Arenaria</i> sp. L.	Perennial herb	Native
Plantaginaceae		
<i>Plantago</i> sp. L.	Perennial/annual herb	Native/adventitious
Juncaceae		
<i>Juncus</i> sp. L.	Perennial herb	Native
<i>Luzula</i> sp. DC.	Perennial herb	Native
Cyperaceae		
<i>Carex</i> sp. L.	Perennial herb	Native
<i>Eleocharis</i> sp. R. Br.	Perennial herb	Native
<i>Uncinia</i> sp. Pers.	Perennial herb	Native
Juncaginaceae		
<i>Triglochin</i> sp. L.	Perennial herb	Native

Composition of the diet

The diet of the Andean Goose in the wintering area of Lake Junín consisted of plant taxa belonging to seven plant families. The habit of these taxa, identified to species or genus level, was entirely herbaceous, while their status corresponded mainly to native taxa (Tab. 2).

Proportions of the different plant groups and taxa in the diet

In the area near Lake Junín at the end of the wintering season, the Andean Goose's diet included a variety of

Tab. 3 – Taxa identified in the diet of the Andean Goose in the area near Lake Junín at the end of the wintering season, expressed as relative frequency according to microhistological analysis. / Taxa identificati nella dieta dell'oca andina nella zona vicina al lago Junín alla fine della stagione invernale, espressi come frequenza relativa secondo l'analisi microistologica.

Food item	Frequency (%)
Grasses	62.9
<i>Festuca spp.</i>	12.5
<i>Elymys sp.</i>	11.5
<i>Poa spp.</i>	10.4
<i>Agrostis sp.</i>	6.3
<i>Deschampsia sp.</i>	4.6
<i>Bromus sp.</i>	4.6
<i>Stipa sp.</i>	3.5
<i>Hordeum sp.</i>	2.7
<i>Distichlis sp.</i>	2.7
<i>Cinnagrostis sp.</i>	2.4
<i>Dactylis glomerata</i>	1.7
Eudicots	6.2
<i>Trifolium repens</i>	3.9
<i>Arenaria sp.</i>	1.3
<i>Plantago sp.</i>	1.0
Graminoids	27.4
<i>Carex spp.</i>	11.1
<i>Eleocharis sp.</i>	8.3
<i>Triglochin sp.</i>	3.8
<i>Uncinia sp.</i>	2.7
<i>Luzula sp.</i>	1.0
<i>Juncus sp.</i>	0.5
Unidentified	3.5

plants, with at least 20 plant taxa being ingested (Tab. 3). Grasses were the most frequently ingested plant group (62.9%), followed by graminoids (27.4%) and eudicots (6.2%) (Tab. 3). The frequency of grasses was twice that of graminoids, whereas that of graminoids was almost five times that of eudicots. Although a significant difference in the proportions of the three plant groups was detected between the two fecal collection sites ($G=10.1$, $df=3$, $p=0.018$), the comparative contribution of the groups remained stable across sites, with grasses always predominating, followed by graminoids and eudicots. The most frequently consumed taxa, considering all samples together, were the grasses *Festuca spp.* (12.5%) and *Elymus sp.* (11.5%), together with Cyperaceae, as *Carex spp.* (11.1%) (Tab. 3).

Species richness, trophic diversity and diet evenness

The Menhinick's species richness index in the Andean Goose diet was relatively low ($D_{Mn}=0.69$), while the dietary intake pattern observed showed moderate to high trophic diversity, reflected in a relatively high Shannon-Wiener index ($H^2=2.76$). The high Pielou's evenness index observed ($E=0.92$) suggested a highly even representation of the consumed taxa.

Habitat use

Andean Geese were recorded much more frequently at sites close to water bodies, occurring there 80% of the time ($n=50$). They also used sites with livestock in a relatively high proportion (46%). When geese co-occurred with livestock, cattle were the most frequent livestock type (52.2% of sites), followed by sheep (39.1%) (Supplementary Fig. 2). These proportions were almost exactly reversed when compared with the livestock composition around the lake, where sheep were more common than cattle (Tab. 4). Likewise, the proportions of livestock types were similar between the northeast and southwest zones of the lake. The logistic GLM further supported these patterns, indicating that water presence was a strong predictor of Andean Goose occurrence ($\beta=3.09$, $p<0.001$), with water-associated sites being about 22 times more likely to host geese than sites without water (odds ratio = 21.93, 95% confidence interval = 5.17-92.97). In contrast, livestock presence had no significant effect on goose occurrence ($\beta=0.43$, $p=0.579$). Overall, site use by Andean Geese appears to be strongly driven by proximity to water rather than by livestock presence.

Tab. 4 – Type of livestock recorded in the observations made during the tours. The proportion of the different types of livestock at sites with Andean Geese (co-occurrence) and the proportion of the different types of livestock observed around Lake Junín are shown. / Tipologia di bestiame registrata nelle osservazioni effettuate durante le osservazioni. Sono mostrate la proporzione delle diverse tipologie di bestiame nei siti con presenza di oche andine (co-occorrenza) e la proporzione delle diverse tipologie di bestiame osservate intorno al lago Junín.

Place of observation	Livestock types				
	Sheep % (n)	Cattle % (n)	Auquenid % (n)	Horses % (n)	Pigs % (n)
In places with Andean Geese	39.1 (9)	52.2 (12)	8.7 (2)	0 (0)	0 (0)
Around the lake	51.8 (44)	37.6 (32)	8.2 (7)	1.2 (1)	1.2 (1)

DISCUSSION AND CONCLUSIONS

Abundance, distribution, density and population size of Andean Geese

Records of Andean Goose counts around Lake Junín during the wintering season are few, and those that also indicate the distribution of groups of individuals in the field are even fewer. In addition, some studies, such as those of Fjeldså (1983) and Dinesen *et al.* (2019), have been made outside the winter season, yielding low values of <100 individuals and 149 individuals, respectively. Other studies, such as that of Harris (1981), who assessed the Andean Goose population in May and October 1979, only counted geese in part of the lake periphery (between 5% and 10% of the surface, including different habitats), extrapolating to present population numbers by using the total area occupied by Andean Geese estimated from maps available at the time. This author indicated totals of 500 and 1000 individuals in May and October, respectively.

In June 1967 (winter), Dourojeanni *et al.* (1968) counted 796 individuals and indicated that most individuals were found around Tambo del Sol and Huayre, in the northeast zone of the lake. In early September 1984, Summers & Castro (1988) counted 1887 Andean Geese, finding that the vast majority of these were in the northern region of the northeast zone of the lake (1496 individuals), with a smaller proportion around Ondores. In our study, we found only four groups of a pair of individuals each in the northeast region of the lake between Tambo del Sol and Huayre, despite having paid close attention to the stretch of the route where the road passes quite far from the lake. In addition, although most individuals continued to be found in the northern region of the northeast zone of the lake, the number of individuals between Junín and Pari, in the southwest zone of the lake, was similar (more than 1000).

The information analyzed here shows that the distribution of Andean Geese around the lake has undergone significant changes over time. It went from being concentrated between two localities in the northeast zone, to being almost entirely concentrated in the northern region of the northeast zone, and finally to being evenly distributed between the northeast and southwest zones of the lake. On the dates of the present study, we observed Andean Geese during the trips to and from Lima, the capital city of Peru. In lakes southwest of Lake Junín (e.g., Parionacocha and Huascacocha lakes), we observed five groups of Andean Geese, four of them composed of a pair of individuals each, and a flock of 13 individuals. Also, in wetlands formed by the Mantaro River (e.g., in the vicinity of La Oroya), we observed four groups, composed of a pair of individuals each. By early September, some pairs may already be trying to reoccupy territories to start the breeding cycle or may not have moved from these wetlands during the winter.

On the other hand, although it is difficult to judge changes in total numbers of Andean Geese, our study, carried out almost at the same time (early September) as that of Summers & Castro (1988), forty years apart, seems to indicate an increase in the population (27% more Andean Geese counted). However, this observation should be taken with caution. The Andean Geese wintering in Lake Junín come largely from smaller wetlands in the vicinity, where they nest, and their numbers may be determined by climatic conditions (mainly humidity) and breeding phe-

nology during the days prior to the count (Summers & Castro, 1988). Comparing our counts with those of Summers & Castro (1988) using the non-parametric Mann-Whitney U test to contrast the hypothesis of equality of distributions, a p-value of 0.0476 was obtained. Although the difference was statistically significant, its proximity to the significance threshold ($\alpha=0.05$) suggests that the result must be interpreted with extreme caution and is considered to be of borderline significance.

The density of Andean Goose groups was higher than that reported in Punta *et al.* (2021) for Andean Geese wintering in the Calingasta valley (Argentina), while the density of individuals was much lower. This may be because the proportion of Andean Goose pairs was much higher in Lake Junín than in the Calingasta valley (62% vs. 36%, respectively), where the environments are almost entirely intensively cultivated. Our estimate of the total population of Andean Geese in Lake Junín is the first to be presented based on a density obtained from a count of individuals around the entire lake during the winter season and fitted to a detection probability function. We thus showed that more than 3000 individuals of the Andean Goose were overwintering in the region around the lake, in the Junín highlands.

Diet

Fecal measurements and weights were similar to those reported by Summers & Castro (1988) and slightly lower than those previously reported in Punta *et al.* (2021). The present results show that the diet of the Andean Goose in Lake Junín is moderately varied, with at least 20 plant taxa identified. Although only four of them exceeded 10% of the intake, many other taxa were well represented, and only one of them had marginal values (<1%). A similar pattern, where only a few species exceed 10% occurrence in their diet, has been observed in studies on diets of other South American geese (Martin *et al.*, 1981; Summers & Grieve, 1982).

Our analysis revealed that the main component of the diet of Andean Geese in their wintering area in Lake Junín was grasses. This differs from that observed for wintering Andean Geese in the Calingasta valley (Punta *et al.*, 2021), where the most consumed group was eudicots, and from that reported for the diet of breeding Andean Geese in northern Chile (Orellana *et al.*, 2021), where graminoids had a higher percentage representation. However, this is consistent with the diet of other South American geese during both wintering and breeding (Martin *et al.*, 1982; Arriaga *et al.*, 2004; Gorosábel *et al.*, 2019; Punta, 2019). The differences observed for the diet of the Andean Goose in Junín Lake, with respect to the other sites mentioned for the species, may be due to the fact that, in our case, the samples came mostly from areas that could be classified as peaty meadows. In contrast, in the Calingasta valley, fecal samples were collected mainly from cultivated plots, while in the Coquimbo region (Chile), they seem to have been obtained in areas that could be classified as graminoid bogs.

In the present study, graminoid consumption was observed to be high (>27%) and corresponds to the characteristics of the sites where faeces were collected. In those sites, there were flooded areas relatively close to the collection points. In similar sites, graminoids have been found to constitute 28% and 30% of the plant components in the diet of

the Upland Goose *Chloephaga picta*, for both the wintering and breeding periods, respectively (Punta *et al.*, 2019).

The results of our dietary analysis suggest that the Andean Goose in Lake Junín, where no food item reached 15% of occurrence in the diet, consumes a large part of the plants that make up its diet opportunistically, perhaps taking advantage of them when they are most nutritious according to their vegetative state (e.g., shoots). Accordingly, the Shannon–Wiener index was higher than that in the diet of other South American geese (Punta *et al.*, 2024), showing that the species consumed are relatively equally represented in its diet.

Habitat use

In the wetlands surrounding Lake Junín, we found Andean Geese near water bodies on a very high proportion of occasions. Furthermore, on almost half of the occasions on which we observed Andean Geese, they co-occurred with livestock, particularly cattle. Dourojeanni *et al.* (1968) also noted that Andean Geese in Lake Junín were associated with livestock, observing them alongside cattle and indicating that they avoided sheep herds. In contrast, Summers & Castro (1988) found no association between Andean Geese and livestock in Lake Junín. In southern South America, different studies have also shown relatively high co-occurrences of geese with livestock, being predominantly with sheep in the far south (Petracci *et al.*, 2014; Punta, 2021) and with cattle slightly further north (Punta, 2024).

In Junín, Andean Geese are probably not more frequently associated with sheep, as shepherds often manage their small sheep herds with the help of dogs, which

can scare Andean Geese away. It is possible that the relatively high co-occurrence between livestock and Andean Geese is due to the fact that Andean Geese preferentially use sites with young and constantly renewing pastures due to livestock grazing, as already observed for *C. picta* (Punta, 2019).

Conservation

The results of our study revealed unpublished aspects about the abundance and diet of the Andean Goose in Lake Junín, important for its conservation. We provide for the first time an estimate of the total population of the species around the lake by using a methodology that takes into account the omissions of individuals in the counts. In addition, we provide a description of its diet, indicating taxa consumed and their proportions, information that was completely lacking.

Around Lake Junín, family-type livestock farming has been practised since pre-Columbian times. The pastures on which livestock feed have been improved by the introduction of species of high forage value (Shoobridge, 2006; Agraria.pe, 2018), some of which we have determined to be part of the Andean Goose diet. Taking advantage of the intake of more nutritious cultivated species during the wintering season is common to most geese in South America and other parts of the world (Ogilvie, 1978; Van Eerden *et al.*, 1996; Fox & Madsen, 2017; Fox *et al.*, 2017; Punta, 2019). However, in the case of the area adjacent to Lake Junín, the construction of new wire fences that delimit the planted areas and further fragment the environments, especially in the southwest zone of the lake, should be carefully analyzed (Fig. 2).



Fig. 2 – View of a pasture environment in the southwest area of Lake Junín used by Andean Geese and sheep where several wire fences can be seen. / Vista di un ambiente di pascolo nella zona sud-occidentale del lago Junín, utilizzato da oche andine e pecore, dove si possono vedere diverse recinzioni di filo spinato.

Although the abundance of the Andean Goose seems to be increasing in the area, perhaps due to the effectiveness of the protection measures implemented since the declaration of the area as a national reserve, some actions could reinforce its conservation, as well as that of the rest of the birds in the lake. An action that can be taken is the placement of flight or roosting deterrents, at least in the critical areas of the power lines that run close to the lake, where we observed several birds killed by collision or electrocution. All the above highlights the importance of proper management of the environment around Lake Junín, especially wetland grasslands, to protect Andean Geese.

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SUPPORTING INFORMATION

Supplementary Fig. 1 – Half-Normal detection probability function with cosine adjustment term (red curve) fitted to the histogram of perpendicular distances between the observer and Andean Goose groups. / Funzione di probabilità di rilevamento semi-normale con termine di aggiustamento del coseno (curva rossa) adattata all'istogramma delle distanze perpendicolari tra l'osservatore e i gruppi di oca andina.

Supplementary Fig. 2 – Boxplot of Andean Goose group size by livestock type. Group sizes varied across livestock categories, with the largest aggregations generally recorded in areas where cattle or equids were present. Sites without livestock typically showed small group sizes, but with high variability and occasional large aggregations. Although larger groups frequently co-occurred with certain livestock types, this pattern does not imply a causal association and is consistent with the GLM results indicating that livestock presence does not significantly predict goose occurrence. / Boxplot delle dimensioni dei gruppi di oche andine per tipo di bestiame. Le dimensioni dei gruppi variavano a seconda delle categorie di bestiame, con le aggregazioni più grandi generalmente registrate in aree in cui erano presenti bovini o equidi. I siti senza bestiame mostravano in genere gruppi di piccole dimensioni, ma con elevata variabilità e occasionalmente grandi aggregazioni. Sebbene gruppi più grandi si presentassero frequentemente contemporaneamente a determinati tipi di bestiame, questo schema non implica un'associazione causale ed è coerente con i risultati del GLM, che indicano che la presenza di bestiame non predice in modo significativo la presenza di oche.