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COMPOSITION, DIVERSITY AND SIZE OF DIATOMS CONSUMED BY THE ANDEAN FLAMINGO (*PHOENICOPARRUS ANDINUS*) IN SALAR DE PUNTA NEGRA, ANTOFAGASTA REGION, NORTHERN CHILE

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Resumen. – Composición, diversidad y tamaño de diatomeas consumidas por el flamenco andino (*Phoenicoparrus andinus*) en el Salar de Punta Negra, Región de Antofagasta, norte de Chile. – En abril de 2009 en la localidad del Salar de Punta Negra (24°35'S, 68°58'W) en la Región de Antofagasta, norte de Chile, hemos cuantificado la composición, la diversidad y el tamaño de las diatomeas, siendo esta la única categoría de presa consumida por los adultos y los polluelos del flamencos andinos (*Phoenicoparrus andinus*). Se identificaron un total de 39 especies, 34 en las heces de polluelos y 25 en las heces de adultos. Las especies más abundantes en ambos fueron *Surirella sella* y *Denticula thermalis*. Las diatomeas observadas en mayor frecuencia en las heces de los polluelos fueron *S. sella, D. thermalis*, *Pinnularia sp.* y *Haloroundia speciosa*, mientras que en las heces de adultos fueron *Denticula thermalis*, *Surirella sella*, *Pinnularia* sp. y *Haloroundia speciosa*. No hubo diferencias estadísticamente significativas en las diatomeas consumidas por los adultos y polluelos. La similitud de la dieta entre adultos y polluelos fue 0,644. Los polluelos consumieron una mayor diversidad de diatomeas que los adultos. La diatomea más consumida por los adultos (*S. sella*) tuvo un tamaño que varió entre 58 y 140 µm, con una mayor frecuencia para los organismos entre 70 y 100 µm. El tamaño de las diatomeas que consumieron los polluelos varió entre 40 y 120 µm, con una mayor frecuencia para los organismos entre 60 y 90 µm. Al comparar los tamaños de las diatomeas consumidas se encontró que los adultos prefirieron los individuos de mayor tamaño que los polluelos.

Abstract. – In April 2009, at the Salar de Punta Negra (24°35'S, 68°58'W) in the Antofagasta Region of northern Chile, we quantified the composition, diversity, and size of diatoms, the only consumed prey by both adults and nestlings of Andean Flamingos (*Phoenicoparrus andinus*). We identified a total of 39 species, 34 in the faeces of nestlings and 25 in adult faeces. The most abundant species in both was *Surirella sella* and *Denticula thermalis*. The most frequent diatoms observed in the nestlings' faeces were *S. sella*, *D. thermalis*, *Pinnularia* sp. and *Haloroundia speciosa,* whereas in the adult faeces they were *Denticula thermalis, Surirella sella, Pinnularia* sp. and *Haloroundia speciosa*. There was no statistically significant difference in diatoms consumed by adults and nestlings. The dietary similarity between adults and nestlings was 0.644. The nestlings consumed a greater diversity of diatoms than adults. The most consumed diatom by adults (*S. sella*) was sized between 58 and 140 µm, with a greater frequency for organisms between 70 and 100 µm. The size of the diatoms consumed by nestlings was between 40 and 120 µm with a greater frequency of organisms between 60 and 90 µm. Comparing the sizes of the consumed diatoms, we found that adults preferred individuals of greater size than nestlings. *Accepted 18 June 2012.*

Key words: Andean Flamingo, *Phoenicoparrus andinus, Denticula thermalis*, *Surirella sella*, diatoms, diet, high Andean wetland, northern Chile.

INTRODUCTION

The Andean Flamingo (*Phoenicoparrus andinus*) is endemic of the Andean puna. Its geographical distribution comprises mainly high Andean salt lagoons and pre-Andean areas in the puna of Argentina, Bolivia, Chile, and Peru (Goodall *et al.* 1951, Hurlbert & Keith 1979, Fjeldså & Krabbe 1990, Parada 1991, Araya & Millie 2005, Jaramillo 2005). During winter, Andean Flamingos extend their distribution towards low elevation wetlands in the central plains of Argentina (Caziani *et al.* 2007, Romano *et al.* 2009, Brandolin & Ávalos 2010). The species is considered vulnerable at the national and international level (Glade 1993, BirdLife 2008), mainly because of its low population size which is calculated at about 34,000 individuals (Caziani & Derlindatti 2000, Brandolin & Ávalos 2010).

Published data about the Andean Flamingo refers only to its reproduction (Valqui *et al.* 2000), geographic distribution (Johnson *et al.* 1958, Rocha 1997, Caziani *et al.* 2001, Marconi & Caziani 2002, Caziani *et al.* 2007), nesting, habitat use (Mascitti 2001, Mascitti & Bonaventura 2002, Mascitti & Castanera 2006), and conservation status (Bucher 1992). There is little agreement between the descriptions found in the literature of the Andean Flamingo diet (López 1991). According to Jenkin (1957), this species is mainly carnivorous, whereas other authors describe it as omnivorous, feeding mainly on diatoms, nematodes, and planktonic crustaceans (Hurlbert 1982, Hurlbert *et al.* 1986, Rodríguez 2005). The aim of this study, therefore, was to provide quantitative information about the composition, diversity and size of prey consumed by Andean Flamingo.

METHODS

Study area. During April 2009 (southern autumn), 96 *Phoenicoparrus andinus* faeces were collected (56 from adults and 40 from nestlings) in the Salar de Punta Negra (24°35'S, 68°58'W), Antofagasta Region, northern Chile (Fig. 1). This salt lagoon has an area of 250 km^2 and is located at 3000 m a.s.l., 80 km south of the Salar de Atacama. The climate of this region is dry and hot. Mean annual temperature is 15.5°C, with monthly means ranging between 5.0°C and 28.0°C, and is characterized by a high thermal oscillation that reaches 15°C. The relative humidity is about 50% and rainfall ranges between 0–10 mm annually (Díaz & Maidana 2005). The chemical composition of the Salar de Punta Negra corresponds to hyper saline waters

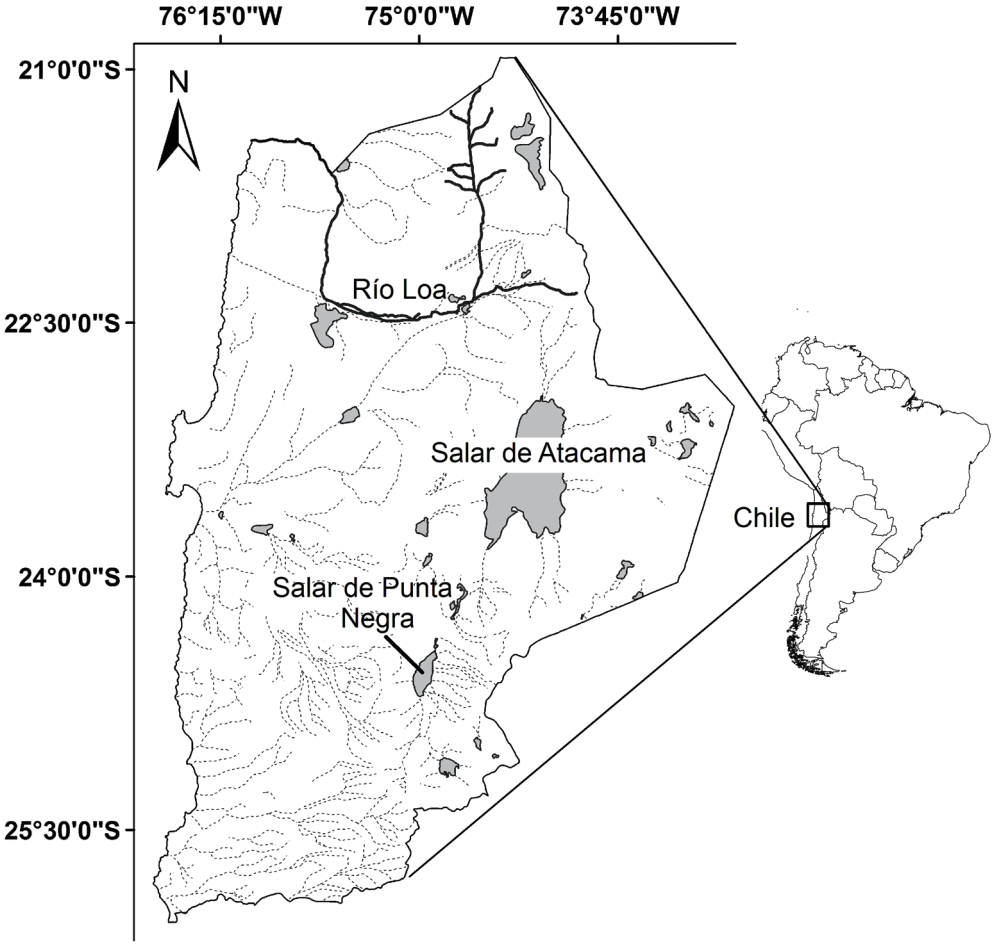

FIG. 1. Study area, Salar de Punta Negra, is located at 3.000 m a.s.l. at the Antofagasta Region, northern Chile.

(salinity above 10 g/l) with a pH ranging between 7.8–8.2 and dissolved oxygen about 6.7 ppm, fluctuating depending the season of the year. During the Austral summer, the Salar de Punta Negra is used exclusively as a reproductive site only by the Andean Flamingo, and is considered one of the three most important sites for the reproduction of this species. Each year, 2500 Andean Flamingos arrive to reproduce on these salt flats and lagoons (R. Villalobos pers. com.).

Sampling and processing. Each scat sample collected corresponded to one deposition of adult individual and its nestling, identified by observation of its plumage. The faeces were collected during the early morning (10:00 h and 12:00 h), (n = 9 days) in an area utilized by the birds for resting. The taxonomic analysis of faeces content was made under magnification (400x) using an optical microscope with phase contrast. For prey determination, we used taxonomic guides (Rivera *et al.* 1982,

TABLE 1. List of all the diatoms species found and frequency in the faeces of *Phoenicoparrus andinus* at the Salar de Punta Negra, Antofagasta Region, northern Chile.

Species	Frequency of occurrence (%)	
	adults	nestlings
Achnanthidium minutissimum	0.63	0.62
Amphora acutiuscula	0.63	2.47
Amphora atacamana	-	1.23
Amphora boliviana	1.89	0.93
Amphora carvajaliana	5.66	1.54
Amphora coffeaeformis	-	1.54
Amphora sp.	1.89	2.78
Amphora subrobusta	0.63	-
Amphora veneta	-	0.31
Anomoeoneis sphaerophora	-	0.93
Brachysira aponina	0.63	-
Brachysira atacamae	-	0.62
Denticula subtilis	-	0.93
Denticula thermalis	14.47	10.18
Diploneis smithii	5.03	0.31
Pinnicularia sp.	13.84	9.26
Planothidium sp.	-	1.85
Haloroundia speciosa	10.06	7.41
Mastogloia atacamae	3.77	2.47
Mastogloia braunii	0.63	0.62
Mastogloia smithii	10.06	4.63
Microcostatus andinus	-	0.62
Navicula kuripanensis	4.4	4.94
Navicula luisii	1.26	-
Navicula sp.	0.63	3.4
Nitzschia angustata	-	1.54
Nitzschia bacillum	-	0.62
Nitzschia chilensis	-	0.93
Nitzschia compressa	0.63	-
Nitzschia grunowii	0.63	-
Nitzschia lacunarum	-	0.31
Nitzschia latens	0.63	2.47
Nitzschia pusilla	1.26	3.7
Nitzschia sp.	-	1.23
Planothidium sp.	2.52	5.25
Proschkinia bulnheimii	1.26	4.32
Rhopalodia sp.	-	1.23
Sellaphora laevissima	3.14	7.41
Surirella sella	13.82	11.4
Total number of species	**25**	**34**

Díaz & Maidana 2005) and microphotography of different taxa, with a camera integrated in the microscope. These photos were subsequently loaded into a digital analysis procedure using the software SigmaScan Pro 5.0. Once classified, the prey items were analyzed for frequency of occurrence in each sample. In the case of diatoms, they were measured using a graduated ocular micrometer in addition to determining its longitudinal axis.

For the determination of composition and abundance of the most common prey items in the Andean Flamingo's diet, we counted prey items in transects according to the methodology proposed by Villafañe & Reid (1995). For this, we replaced the Sedgwick-Rafter camera for a microscope slide of 32x25 mm. On the microscope slide, an aliquot of 0.05 ml was precipitated, and we sampled systematically three horizontal transects, thus avoiding border effects (Fabricius *et al.* 2005).

Statistical analysis. The similarity of the diet composition between adults and nestlings of Andean flamingos was obtained using the Sorensen Similarity Index (Moreno 2001). Prey diversity was evaluated also between adults and nestlings with the Shannon-Wiener Index (H') using the software DIVERS (Krebs 1989). To verify both diversities and variances, we used a procedure proposed by Hutcheson (1970), which is analogous to a Student's *t*-test for independent samples (Moreno 2001). To compare the absolute frequencies of the sizes of the consumed diatoms by adult flamingos and nestlings, we used a chi-square test. All statistical analyses were made using an online statistical package (http://vassarstats.net/).

RESULTS

The autumn diet of the Andean Flamingo in the Salar de Punta Negra consisted of only diatoms. We identified a total of 39 species;

TABLE 2. List of the more abundant diatom species (ind/ml) found in the faeces of adults and nestlings of *Phoenicoparrus andinus*.

Species	Ind/ml	
	adults	nestlings
Surirella sella	3643	384
Denticula thermalis	160	64
Mastogloia sp.	42	32
Pinnicularia sp.	93	58
Haloroundia speciosa	21	9

34 in the faeces of nestlings and 25 in adult faeces (Table 1). There was no statistically significant difference (χ^2 = 0.61, gl = 2, P = 0.737) in diatoms consumed by adults and nestlings. The dietary similarity between adults and nestlings was 0.644. *Surirella sella* (11.4%), *Denticula thermalis* (10.2%), *Pinnularia* sp. (9.3%), and *Haloroundia speciosa* (7.4%) were the most common in the nestlings' faeces, whereas in the faeces of the adults *Denticula thermalis* (14.5%), *Surirella sella* (13.8%), *Pinnularia* sp. (13.8%), and *Haloroundia speciosa* (10.1%) were more frequent.

Surirella sella and *D. thermalis* were the most abundant species both in the adult and nestling faeces (Table 2), with adults consuming more diatoms than nestlings (χ^2 = 256.11, gl = 4, P = 0.0001).

Comparing the diversities of diatoms consumed by adult flamingos (H' = 0.37 ± $2.5x10^{-4}$) and nestlings (H' = 0.97 ± 1.76 x 10^{-3}), we found statistically significant differences, with the nestling's diet being more diverse (t = 13.41, P < 0.05). Adults consumed larger diatoms than did nestlings (χ^2 = 122.31, gl = 6, P = 0.0001), with the most consumed diatom, *S. sella*, ranging between 58 and 140 μm in length, with a greater frequency between 70 and 100 μm. Size range of the diatoms consumed by nestlings ranged between 40 and 120 μm, with a higher frequency between 60 and 90 μm (Fig. 2).

DISCUSSION

Our study shows that the autumn diet of the Andean Flamingo in the Salar de Punta Negra was mainly algaevorous, and that the trophic spectrum was made up of 39 different species of diatoms. This is in agreement with the observations made by López (1991) in the Salar de Carcote (21°15'S, 68°20'W), northern Chile, although they found only 16 species of diatoms, less than the half of the species found in this study. The similarity of the diet between adults and nestlings was near 50% of the consumed diatoms, although it showed important differences, mainly because the most abundant species consumed by adult flamingos individuals of the Andean Flamingo was *Surirella sella*.

Among the diatom species more frequently consumed, *Denticula thermalis* and *Surirella sella* stand out. The study by López (1991) showed a higher consumption of *Surirella sella*. Hurlbert & Chang (1983) registered a predominant consumption of *Surirella wetzeli* by flamingos in highland lagoons of Bolivia. We believe that the greater consumption of the diatoms of the genus *Surirella* was because mainly of their size, being larger than all the other species on this study.

Another factor that could influence in the abundance and the size of the consumed diatoms by adults and nestlings of the Andean Flamingo may be its bill morphology. This is constituted of lamellae that act like filters, excluding the entrance of higher size prey items and also the exit of lower size preys (Mascitti & Kravetz 2002). According to Servant-Vildary (1984), the inter-lamellae spaces in the Andean flamingo's bill could permit the consumption of preys with a size ranging only between 100 and 500 μm. Our findings would extend the minimum size of consumed organisms by this species, as we also found diatoms with longitudinal sizes of 40 μm.

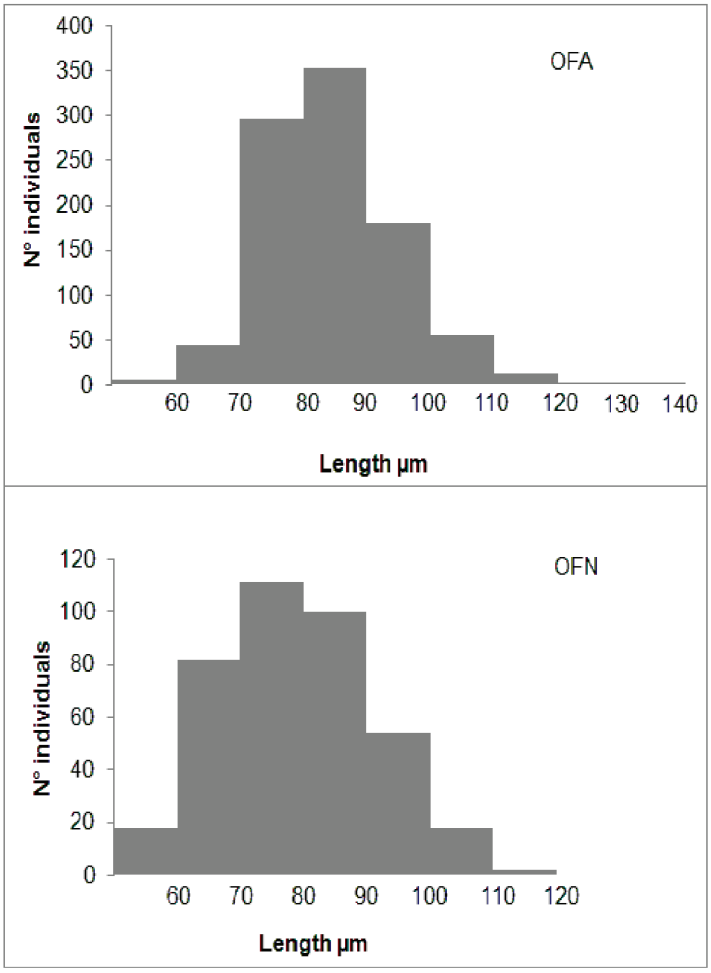

FIG. 2. Frequency distribution of sizes of *Surirella sella* in the faeces of adults (OFA) and nestlings (OFN) of *Phoenicoparrus andinus*.

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