Waterbird Richness in Altiplano Wetlands of Northwestern Argentina

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Abstract.—We measured waterbird richness and abundance, and characterized wetland features (altitude, size, and presence of submergent vegetation) of 50 altiplano wetlands, during summer and winter, 1998. We estimated 36,700 individuals of 24 avian species during the summer census. James' Flamingo (*Phoenicoparrus jamesi*) and Andean Flamingo (*P. andinus*) were the most abundant species, followed by Horned Coot (*Fulica cornuta*), Chilean Flamingo (*Phoenicopterus chilensis*), and Crested Duck (*Anas specularioides*). These species comprised 78% of total individuals. In winter, we counted 7,421 individuals of 16 species, and the three flamingo species were the most abundant. In summer, we found Chilean and Andean Flamingos primarily in intermediate-altitude wetlands (3,500-4,000 m a.s.l.), whereas James' Flamingos and other waterbirds were above 4,000 m. In winter, the three flamingo species moved to lower-altitude wetlands (below 3,500 m). Waterbird abundance was positively correlated with wetland size in wetlands with aquatic vegetation, with waterbird richness in wetlands without macrophytes. During summer, total abundance and richness were significantly higher in wetlands with macrophytes, where Chilean Flamingo and ten other waterbird species (e.g., ducks, grebes, gulls, and coots) were more common. James' Flamingo was the only species more abundant in hypersaline wetlands. In summer, four wetlands (Grande, La Alumbrera, Vilama, and Pozuelos) contained 68% of the total individuals, with more than 3,000 waterbirds each. In winter, wetlands Pozuelos and Guayatayoc included 50% of waterbirds counted, with more than 5,000 birds each. Thirty four percent of the wetlands surveyed are within protected areas, but only in Laguna de los Pozuelos Natural Monument is it actually implemented. In 42% of the wetlands we detected land uses that could represent threats to these environments. Here we propose some criteria to detect and prioritize relevant sites for conservation of altiplano waterbirds: a) large aggregations of individuals, either seasonal or permanent, b) vulnerable and/or endemic species and presence of nesting sites, c) ecological uniqueness, d) proximity to other complementary wetlands, e) high heterogeneity between and within sites. The complementary use of these environments by waterbirds, both seasonally and spatially, suggests considering conservation action from a landscape perspective. *Received 2 September 2000, accepted 9 December 2000.*

Key words.—Altiplano, Andean Flamingo, Chilean Flamingo, *Fulica cornuta*, High Andes, Horned Coot, James' Flamingo, *Phoenicoparrus andinus, Phoenicoparrus jamesi, Phoenicopterus chilensis*, Puna, waterbirds, wetlands.

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The altiplano of the central Andes extends through parts of Argentina, Bolivia, Chile and Peru, between 3,500 and 4,500 m above sea level. It is a cold and arid region, exposed to intense solar radiation, strong winds, and high daily temperature fluctuations of up to 30 Centigrade degrees. Temperature averages 8.5° to 9.5°. The scarce rainfall occurs in summer, from November to February, decreasing westwards and southwards from 700 to <50 mm per year (Cabrera and Willink 1973). The dominant vegetation types are grasses and shrubs, and soils are poorly developed. Numerous endorheic basins form lakes and saltpans (called "salares"), and thus constitute patches of aquatic habitat within a desert matrix. Many of them are surrounded by bogs (called "vegas") with cushion plants (*Juncaceae*) and grasses. In this paper we give the general denomination of "wetlands" to lakes, salares and bogs.

Two types of wetland can be distinguished, based on biogeographical provinces: (1) High Andes wetlands are those found over 4,400 m above sea level, which freeze in winter, and (2) Puna wetlands between 3,200 and 4,400 m above sea level (Cabrera and

Willink 1973). Within both wetland types, some wetlands are hypersaline (>60,000 (s.cm^{-1}) and shallow (<1 m), while other wetlands are deeper (1-12 m) and saline (<60,000 (s.cm^{-1}) (Cowardin *et al.* 1979). The hypersaline shallow wetlands have abundant diatoms but no macrophytes, and attract great numbers of flamingos. The deeper wetlands are rich in plankton and macrophytes, with higher waterbird diversity (Fjeldså and Krabbe 1990; Caziani and Derlindati 2000). Thus at a landscape scale, the wetland complex provides waterbird communities with alternative habitats and resources, both seasonally and spatially.

These wetlands are characterized by avifauna communities of high abundance and richness (Hurlbert and Keith 1979; Almonacid 1990; Fjeldså and Krabbe 1990; Hurlbert and Chang 1983; Sarmiento *et al.* 1998). Many of these waterbirds are endemic, rare or vulnerable, and/or specialist (e.g., filter-feeders in hypersaline aquatic environments). The James' (*Phoenicoparrus jamesi*) and Andean Flamingos (*P. andinus*) and the Horned Coot (*Fulica cornuta*) are classified as vulnerable species (Collar *et al.* 1992).

One threat to the altiplano wetlands is soil profile alteration caused by drainage and sedimentation. Overgrazing, firewood extraction, and the use of land for pastures and housing construction have decreased the vegetation cover and increased erosion of soils that are naturally undeveloped and fragile (Moscatelli 1990). Mining activities in the basins and mineral extraction from saltpans (sulfates, borates and others) affect waterbird communities due to surface water pollution and intense groundwater use that alters natural hydrological regimes. Taking of waterbird eggs for personal consumption seems to be a common practice in communities adjacent to the wetlands.

Despite hosting rich and unique waterbird communities, these wetlands have been scarcely studied, because of the extreme conditions in which they are found and the difficult access. Moreover, very few are included in current protected areas.

The objectives of our study were: (1) estimate waterbird richness and abundance in altiplano wetlands, (2) relate the community composition to wetland characteristics, such as altitude, size and the presence of submergent vegetation, and (3) analyze the conservation value of the sites.

METHODS

We surveyed 50 different altiplano wetlands during two sampling periods in 1998 (Fig. 1). We surveyed 41 wetlands during the austral summer (22 to 31 January), and 32 wetlands during the winter (7 to 14 August). Thirty-five wetlands had not been surveyed prior to our study. For each wetland we recorded altitude using an altimeter, geographic localization with a Global Position System and the presence/absence of macrophytes.

We estimated wetland size by using a polar planimeter on LANDSAT TM satellite images from 1986. The scale of the images (1:400,000) did not allow us to measure wetland surfaces less than 70 ha.

We estimated waterbird richness and abundance by censuses from one or more points on the shoreline, depending on the size and shape of the wetland, using binoculars or spotting scopes. For groups of birds (4,000, we counted individuals of each species, and for groups >4,000 we counted estimated blocks (10, 100, etc.) (Bibby *et al.* 1992). We calculated constancy as the percentage of total wetlands occupied by the species. Wetlands with no avifauna present (mainly dry wetlands) were discarded from further analysis.

Partial correlations (Zar 1999) were used to analyze the relationship between waterbird abundance and richness, and wetland altitude and size. Macrophyte pres-

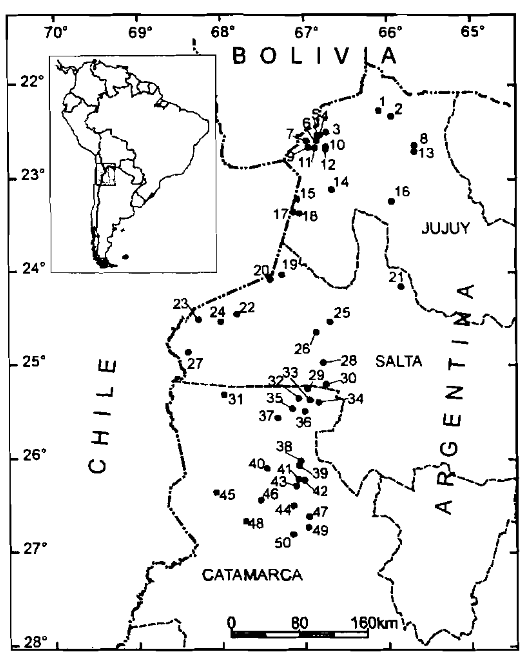

Figure 1. Altiplano wetlands in northwestern Argentina: location of the 50 wetlands surveyed in two sample periods January 1998 (summer) and August 1998 (winter). References to wetland numbers are provided in Table 1.

Table 1. Location, size, macrophyte presence, threats and protection status of Altiplano wetlands in Argentina.

Province	Wetlands	Altitude (m)	Area (ha)	Macrophytes	Threats
Jujuy	1. Larga	3,850	<70	no	—
	2. Pozuelos[a,b,c]	3,504	16,470	yes	E, S
	3. Cerro Negro[d,e]	4,400	361	yes	—
	4. Caití[d,e]	4,573	72	yes	—
	5. Pululos[d,e]	4,413	433	yes	T
	6. Isla Grande[d,e]	4,400	433	yes	—
	7. Vilama[d,e]	4,400	3,177	no	P, T, E
	8. Runtuyoc	3,482	<70	yes	—
	9. Colpayoc[d,e]	4,389	72	yes	—
	10. Arenal[d,e]	4,631	578	yes	E
	11. Palar[d,e]	4,309	1,516	no	—
	12. Catal[d,e]	4,320	433	yes	—
	13. Los Enamorados	3,482	<70	yes	—
	14. Turilari	3,900	<70	no	—
	15. Vega Jama	4,100	<70	yes	—
	16. Guayatayoc	3,660	<70	no	—
	17. Mucar	4,154	<70	no	—
	18. Vega Cantera	4,100	<70	no	—
Salta	19. Salar Rincón[f]	4,050	<70	no	—
	20. Santa María[f]	4,200	<70	yes	R
	21. Vega y Laguna Toro	3,750	<70	yes	T
	22. Taca taca	3,500	<70	no	—
	23. Socompa[f]	3,900	<70	no	R
	24. Vega Arizaro[f]	4,100	<70	no	G
	25. Pastos Grandes[f]	3,900	<70	no	D, E
	26. Salar Pocitos	3,900	<70	no	—
	27. Salar Llullaillaco	3,929	<70	no	—
	28. Centenario	3,900	<70	no	M
	29. Diablillos	3,900	<70	no	R
Catamarca	30. Tincalayu	4,000	<70	no	M
	31. Archibarca	4,100	<70	no	—
	32. Mina FMC	4,000	<70	no	M
	33. Vega los Patos[i]	3,947	<70	yes	G, S
	34. Verde[i]	4,212	<70	no	—
	35. Sin nombre	3,850	<70	no	—
	36. Hombre Muerto[i]	4,100	<70	no	—
	37. Caro	3,818	361	no	—
	38. Diamante[i]	4,388	1,372	no	P
	39. Pabellón[i]	4,399	72	yes	P
	40. La Alumbrera[i]	3,250	217	yes	T
	41. Grande[i]	4,101	433	no	E, P, T
	42. Baya[g,h,i]	4,200	72	no	—
	43. Cabi[i]	4,050	<70	no	P
	44. Rincón[i]	4,050	<70	yes	—
	45. Aguas Dulces[i]	3,286	289	no	E
	46. Carachipampa[i]	2,915	361	no	T
	47. Blanca[g,h]	3,147	1,372	no	—
	48. Purulla[i]	3,664	144	no	P
	49. Pasto Ventura	3,750	<70	no	—
	50. Colorada	3,850	<70	no	—

[a]National Monument Laguna de los Pozuelos.
[b]Biosphere Reserve Laguna de los Pozuelos.
[c]Ramsar Site.
[d]Provincial Reserve Altoandina de la Chinchilla.
[e]Proposed Reserve and Ramsar Site Lagunas de Vilama.
[f]Provincial Reserve Los Andes.
[g]Biosphere Reserve Laguna Blanca.
[h]Natural Provincial Reserve of Wildlife Laguna Blanca.
[i]Proposal National Reserve and Natural Monuments Las Parinas. T: Unregulated Tourism, P: Prospecting for minerals, M: Mining, E: Egg consumption, R: Garbage, G: Goat grazing, S: Sheep grazing, D: Damming.

ence or absence and basin morphology allowed us to distinguish saline wetlands from hypersaline wetlands (Caziani and Derlindati 2000). We separated *a priori* two wetland types based on presence or absence of macrophytes, and compared total abundances by species and richness using the Mann-Whitney test (Siegel and Castellan 1995). The waterbird species-wetland matrix was analyzed by Detrended Correspondence Analysis (DCA), using the PC-ORD version 3.0 software, which performs data arrangement after reciprocal averaging (Gauch 1982; McCune and Mefford 1997). DCA arranges species and samples (wetlands) simultaneously, so wetlands close to certain species show higher abundances of the species in these wetlands. Partial correlations, Mann-Whitney and DCA were applied only to the summer survey, because it included more wetlands and species.

For each wetland, human activities that represent actual or potential threats to the wetlands and waterbirds were recorded, such as unregulated tourism, mining and mine prospecting, garbage, damming, goat or sheep grazing, and egg consumption.

The winter data were used only for the descriptive analysis of the spatial and seasonal variations in richness and species abundance.

RESULTS

We surveyed 18 wetlands in Jujuy Province, 11 in Salta Province, and 21 in Catamarca Province, of which 48% were above 4,000 m, 40% between 3,500 and 4,000 m, and 12% below 3,500 m (for exact geographical location of the wetlands contact the first author) (Fig. 1). Sixteen wetlands had submergent macrophytes, and three of these wetlands also had emergent macrophytes (Los Enamorados, Runtuyoc, and La Alumbrera), (Table 1).

Seventeen percent (N = 41) of the sites surveyed in summer had no aquatic avifauna: Salar Taca Taca, Salar de Pocitos, Pista Tincalayu, Salar Diablillos, Salar Centenario, Rincón, and Pasto Ventura. Eight of the 32 wetlands visited in winter lacked waterbirds: Mucar, Socompa, Diablillos, Verde, Vega Los Patos, Blanca, Rincón, and Pasto Ventura.

In the summer census, we estimated 36,700 individuals from 24 avian species (Appendix A). The James' and Andean Flamingos were the most abundant species, (17,512 and 4,567 individuals respectively) followed by Horned Coot, Chilean Flamingo (*Phoenicopterus chilensis*) and Crested Duck (*Anas specularioides*). These five species represented 78% of total individuals. Flamingos were present in more than three quarters of the wetlands. Andean Goose (*Chloephaga melanoptera*) and Crested Duck showed constancy values of 45%. Finally, the Horned Coot, Andean Avocet (*Recurvirostra andina*), Silvery Grebe (*Podiceps occipitalis*), Speckled Teal (*Anas flavirostris*), Puna Teal (*Anas puna*), and Andean Gull (*Larus serranus*) reached a constancy value close to 30%.

In winter, we counted 7,421 individuals of 16 species (Appendix B). Eight of the species observed in summer were absent in winter: Yellowlegs (*Tringa* sp.) and Wilson's Phalarope (*Phalaropus tricolor*), both nearctic migrants; Red Shoveler (*Anas platalea*), Cinnamon Teal (*Anas cyanoptera*), Red-gartered Coot (*Fulica armillata*), Common Gallinule (Moorhen; *Gallinula chloropus*), (the latter four species observed in La Alumbrera), and finally Andean Lapwing (*Vanellus resplendens*) and Puna Plover (*Charadrius alticola*). Flamingos were the most abundant waterbirds and constituted 78% of the total individuals. Four species were present in at least 30% of the wetlands: the three flamingo species and the Crested Duck.

In summer, we found Chilean and Andean Flamingos mainly in intermediate-altitude wetlands (3,500-4,000 m above sea level), whereas we found James' Flamingos and other waterbirds almost exclusively above 4,000 m. In winter, the flamingos moved to lower-altitude wetlands (Fig. 2). Average species richness was seven during the summer, and La Alumbrera was the richest wetland, with 23 bird species. In winter, average richness was four, ranging from 1-11 species per wetland (Fig. 3).

In the summer, we observed 18 active flamingo nests and five Horned Coot's nests in Pabellón. In Santa María we found 122 abandoned nests (probably Chilean Flamingo) and evidence of predation on eggs.

We calculated the partial correlation between altitude, area (always >70ha), abundance and richness. Waterbird abundance was positively correlated with wetland area in wetlands with aquatic vegetation ($r_5 = 0.80$, $P < 0.04$) (Fig. 4). In wetlands with no macrophytes a possible association was observed between abundance and waterbirds richness ($r_6 = 0.70$, $P < 0.055$) (Fig. 4).

In summer, total abundance and richness were significantly higher in wetlands with

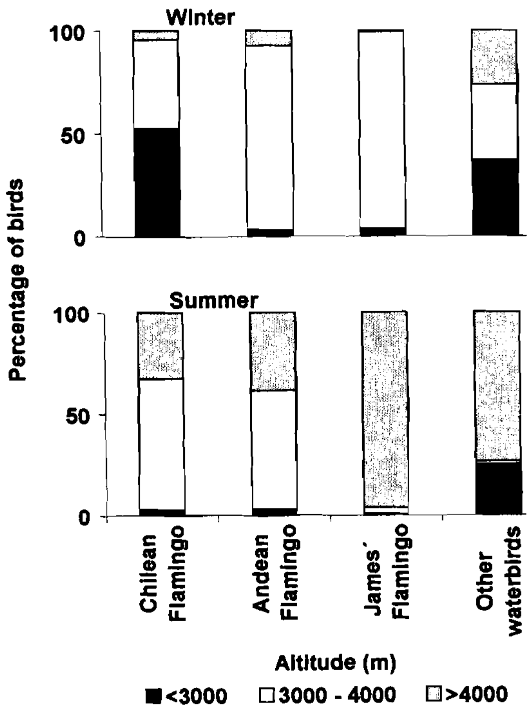

Figure 2. Proportion of the flamingo species and other waterbirds along altitude ranges of the altiplano wetlands in northwestern Argentina in summer and winter, 1998.

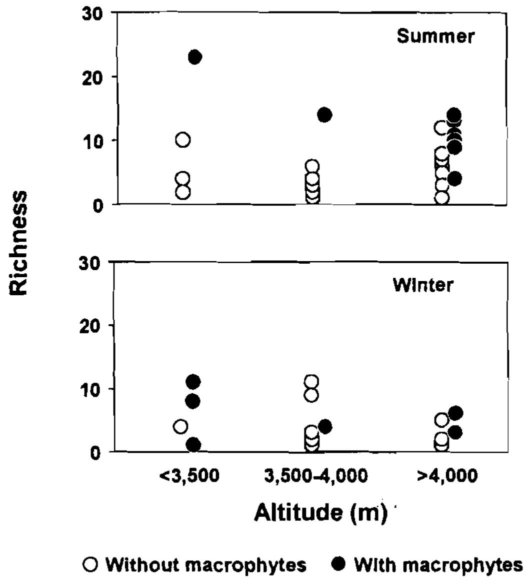

Figure 3. Altiplano waterbird richness in wetlands with and without macrophytes, within different altitude ranges. Summer and winter 1998.

macrophytes ($_m$), than in wetlands without macrophytes ($_{wm}$) (Mann-Whitney, $U = 30$, $N_m = 12$, $N_{wm} = 21$, $P < 0.001$, and $U = 14$, $N_m = 11$, $N_{wm} = 20$, $P < 0.001$, respectively). When comparing species abundance among wetlands with and without macrophytes, we found twelve species were significantly more frequent when macrophytes were present (Chilean Flamingo $U = 16.5$, $P < 0.001$; Silvery Grebe $U = 20$, $P < 0.001$; Andean Goose $U = 14.5$, $P < 0.001$; Crested Duck $U = 12.5$, $P < 0.001$, Yellow-billed Pintail (*Anas georgica*) $U = 60$, $P < 0.01$; Speckled Teal $U = 55$, $P < 0.01$; Puna Teal $U = 22$, $P < 0.001$; Ruddy Duck (*Oxyura jamaicensis*) $U = 60$, $P < 0.01$; Giant Coot ($U = 40$, $P < 0.01$; Horned Coot $U = 11.5$, $P < 0.001$; Baird's Sandpiper (*Calidris bairdii*) $U = 55.5$, $P < 0.05$; Andean Gull $U = 59$, $P < 0.05$); in all cases $N_m > 9$ and $N_{wm} > 18$. The James' Flamingo was the only species that was more abundant in wetlands without macrophytes ($U = 67$, $N_m = 12$, $N_{wm} = 19$, $P < 0.05$). The differences in the N values indicates the impossibility of recording total number of individuals (p in Appendix A) or identifying all species (hyphen in Appendix A) in some cases, causing some wetlands to be excluded from the Mann-Whitney tests.

In the correspondence analysis of the summer community data, the first axis (Eigenvalue = 0.90) discriminates between communities in shallow wetlands and those in deep wetlands with macrophytes (Fig. 5): Andean and James' Flamingos and Andean Avocet are characteristic of shallow wetlands; and Giant and Horned Coots, Silvery Grebe, Crested Duck, Chilean Flamingo and Andean Goose of deep wetlands. The second axis (Eigenvalue = 0.43) markedly separates La Alumbrera, which had the highest richness and several species not recorded elsewhere in this study. The third axis (Eigenvalue = 0.11) is not plotted in Fig. 5 because it explained little of the variability.

In summer, four wetlands contained 68% of total individuals, with more than 3,000 waterbirds each: Grande, La Alumbrera (Catamarca Province), Vilama and Pozuelos (Jujuy Province). Nine wetlands hosted 86% of the total birds, including Arenal, Cerro Negro, Pululos, Isla Grande, and Catal, all belonging to the Vilama wetland system (Ap-

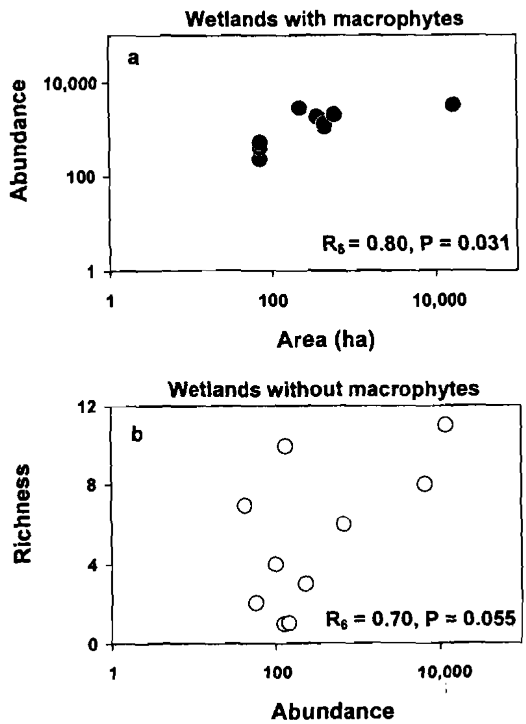

Figure 4. Altiplano wetlands in northwestern Argentina, January 1998 (summer). a) Abundance and area correlation in wetlands with macrophytes. b) Richness and abundance correlation in wetlands without macrophytes. Area and abundance are plotted in log scale.

pendix A). In winter, Pozuelos and Guayatayoc together held 50% of individuals, with more than 5,000 birds each (Appendix B).

Of the studied wetlands, 34% (N = 50) are within protected areas, however, only at Laguna de los Pozuelos Natural Monument has it actually been implemented (Table 1). In 42% of the sites visited, we detected land uses that present threats to the wetlands. The most severe threats are prospecting for minerals and unregulated tourism in Catamarca Province, abandoned mining operations in Salta Province, and unregulated tourism in Jujuy Province. We found evidence of egg consumption by local people in five of the wetlands. Vilama and Grande were the only two sites exposed to different threats (Table 1).

Discussion

The altiplano wetlands concentrate avifauna diversity, particularly in comparison with terrestrial environments. In the Pozuelos region, G. Nicolossi (unpubl. data) surveyed 91 terrestrial and aquatic species, 48% of which are associated with lakes, "salares" and bogs.

Seasonal and Spatial Fluctuations of Bird Abundance

We found strong seasonal fluctuations, thus richness and abundance values were considerable higher in summer than in winter, probably because of winter freezing of the High Andes wetlands and bogs, which also results in altitude movements of the waterbirds (Fig. 2). In Jujuy Province, the wetlands above 4,000 m were not surveyed during the winter, because they were frozen and no avifauna was present two weeks prior to the census (P. Perovic, Universidad Nacional de Jujuy, pers. comm.). During winter 2000, every wetland above 4,000 m was frozen, with almost no waterbirds. However some High Andes wetlands, e.g., Surire in Chile, do not freeze completely during the winter because they are fed by thermal springs, and therefore host some birds (Hurlbert and Keith 1979).

Other temporal variation in waterbird abundance may be related to rainfall. Some wetlands remain dry and uninhabited unless exceptional precipitation occurs. In our study, Salar de Diabillos, Rincón and Pasto Ventura were dry in both seasons, however filled with water in other surveys (Caziani pers. comm.), and more than the 80% of the wetlands were suitable habitat for waterbirds.

Besides the temporal fluctuations, we observed intense spatial waterbird variations between hypersaline and saline wetlands. Within the summer season, the higher waterbird richness observed in saline wetlands with macrophytes could result from: a) the greater zooplankton richness (Caziani and Derlindati 2000), b) food and nesting material availability for herbivorous species, e.g., coots (Caziani and Derlindati 1996), and c) a higher environmental heterogeneity related to the presence of submergent and emergent macrophytes (Weller 1994), (e.g., La Alumbrera). Waterbird richness appears to be independent of both abundance and wet-

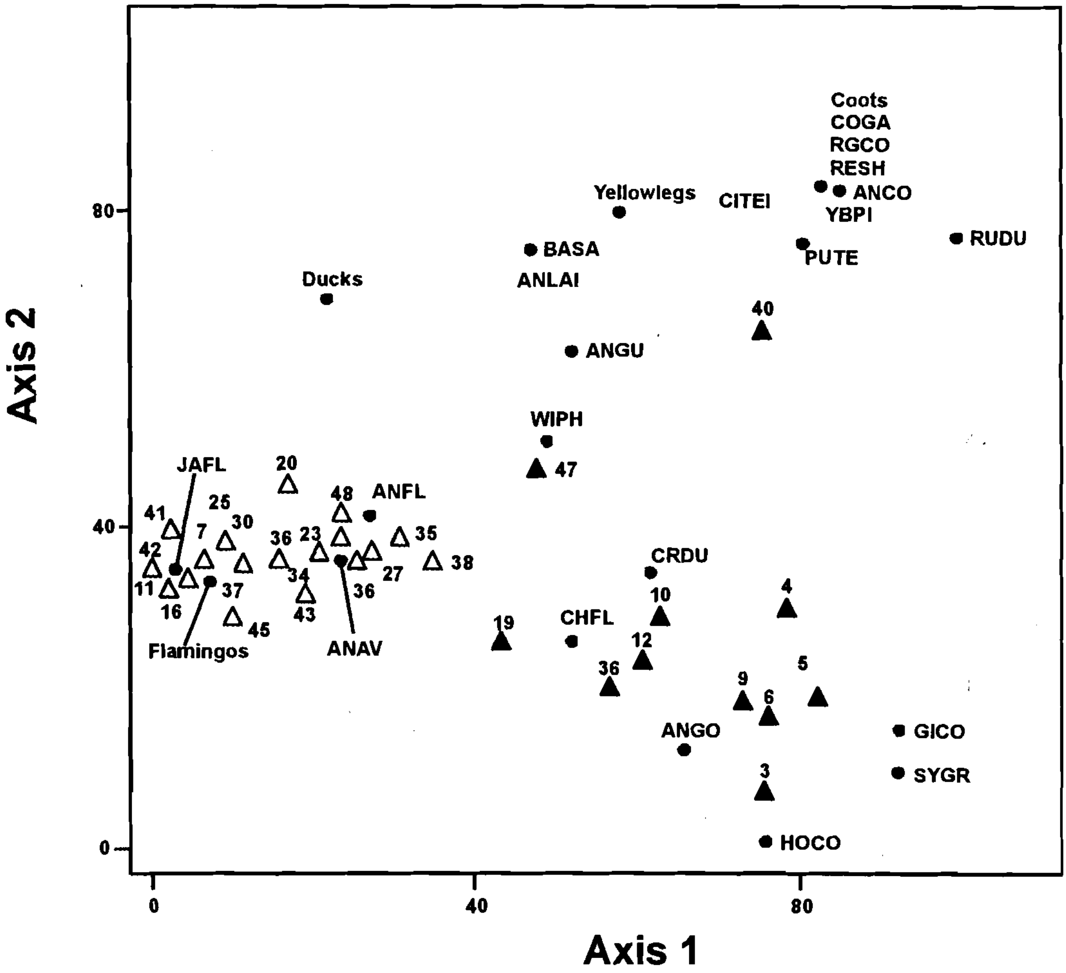

Figure 5. Detrended Correspondence Analysis (DCA) for a waterbird species-wetlands matrix in the Argentine altiplano, January 1998 (summer), axis 1 and 2. ●: Species, △: Wetlands without macrophytes, ▲: Wetlands with macrophytes. La Alumbrera (40) appears detached because of its highest richness and exclusive species. Common name codes are: SYGR (Sylvery Grebe), CHFL (Chilean Flamingo), ANFL (Andean Flamingo), JAFL (James' Flamingo), CRDU (Crested Duck), CITE (Cinnamon Teal), YBPI (Yellow-billed Pintail), PUTE (Puna Teal), RESH (Red Shoveler), RUDU (Ruddy Duck), ANCO (Andean Coot), RGCO (Red-gartered Coot), COGA (Common Gallinule), ANLA (Andean Lapwing), ANAV (Andean Avocet), ANGU (Andean Gull), ANGO (Andean Goose), GICO (Giant Coot), HOCO (Horned Coot), BASA (Baird's Sandpiper), WIPH (Wilson's Phalarope).

land area (Elmberg *et al.* 1994). Shallow wetlands are much more homogeneous, having more species as the numbers of individuals increased. In some places, we could have underestimated richness and abundance. In the extensive Pozuelos and Vega Los Patos wetlands, we only counted flamingos and may have failed to estimate numbers or identify other avian species because of poor visibility. In order to conduct a more accurate assessment of these wetlands, simultaneous observations would be advantageous.

Given the strong seasonal and spatial variation in the use of these wetlands by waterbirds, long-term conservation requires a landscape approach considering the wetland complex.

Richness and Abundance Relationships with Wetland Attributes

In previous studies, waterbird richness had been positively correlated with wetland size, shoreline extension, habitat and prey diversity (Elmberg *et al.* 1994), as well as physicochemical features and pH of the water (Fox and Bell 1994) in wetlands of equivalent conductivity to our saline wetlands. On the other hand, the abundance of certain waterbird species (e.g., ducks, coots and plovers) can be explained by several factors, such as the presence of macrophytes (Wicker and Enders 1995), water salinity and food resources availability (Kingsford and Porter 1994), wetland size and physicochemical conditions (Savard *et al.* 1994), and presence of predator species (Fjeldså 1985; Hurlbert *et al.* 1986). In aquatic environments with fish, diversity and abundance of herbivorous birds appears to be lower (revision in Fjeldså 1985), and in the altiplano wetlands of Perú, the Chilean Flamingo abundance was negatively correlated with fish abundance (Hurlbert *et al.* 1986). We lack information about fish in the wetlands studied, although they are probably present in the deepest wetlands with macrophytes, but not in the alkaline and shallow wetlands.

In our study, the relationship between area, waterbird richness and abundance should be considered with caution. These correlations are only valid for wetlands >70 ha, and wetland sizes were estimated from satellite images taken 12 years prior to the fieldwork. At a regional scale, wetlands exhibit a progressive shoreline retraction since 1993 (Mascitti and Caziani 1997; Caziani and Derlindati 2000). However, in spite of the great temporal variability of the wetlands, the relationship of relative sizes should remain within each wetland type (hypersaline vs. saline), with similar basin morphology and evaporation patterns. Shallow extensive hypersaline wetlands retract in higher proportion than deeper saline wetlands.

Vulnerable Species Abundance and Habitats

Altiplano wetlands of northwestern Argentina provide several vulnerable bird species with considerable habitat. The James' and Andean Flamingo numbers in Argentina represented 28% and 18%, respectively, of the world population estimated during 1998 summer census (Valqui *et al.* 2000). The Horned Coot is also abundant in the region, and in the summer census we counted 3,354 individuals, mainly distributed in the Vilama wetland system (Jujuy Province), Pabellón and La Alumbrera (Catamarca Province). Rose and Scotte (1994) estimated a total of 5,000 for this population, but in October 1995, the Vilama wetland system alone hosted almost 9,000 individuals (Caziani and Derlindati 1996). Other species are either endemic or presenting low local abundance (e.g., Andean Avocet, found in Grande, Vilama and Santa María, and Giant Coot, present in Caití, Isla Grande, Catal and Cerro Negro).

Long-term Conservation

We consider the following criteria to define sites relevant to altiplano waterbird conservation: a) large aggregations of waterbirds, either seasonal or permanent, b) abundance of vulnerable and/or endemic species and presence of nesting sites, c) ecological uniqueness, d) proximity to other complementary wetlands, e) high heterogeneity between and within sites. The Vilama wetland system (Vilama, Caití, Palar, Isla Grande, Cerro Negro, Catal, Arenal, and Colpayoc) stands out in terms of these criteria, as well as Pozuelos and Guayatayoc in Jujuy Province (wintering areas for waterbirds), Grande (summer aggregation area for James' flamingos) and La Alumbrera (holding great waterbird diversity and endemic species) in Catamarca Province.

The Vilama wetland system belongs to a Provincial Reserve that has not been yet implemented, and therefore it has no effective protection. The National Park Administration has proposed a National Reserve project for the Vilama complex and it is also being considered as a wetland of international importance under the Ramsar Convention (Caziani and Marconi 1997). The area is considered a priority for bird conservation in the Neotropics (Wege and Long 1995) because it hosts the largest known numbers of Horned Coot (Caziani and Derlindati 1996). Pozuelos is included in the Pozuelos Natural Monument, but the whole basin is not protected. Laguna de los Pozuelos National Reserve is being negotiated, with the objective to regulate land use within the basin (Caziani and Marconi 1997). Besides Grande and La Alumbrera, several wetlands near Antofagasta de la Sierra in Catamarca Province (Purulla, Carachi Pampa, Pabellón) are being considered inside a new protected area comprising all the wetlands in the area (National Reserve and Natural Monuments Las Parinas) (Marconi *et al.* 2000). Vega los Patos, a large bog in Catamarca Province, should be evaluated in more detail for its avifauna.

The altiplano wetlands and their species are threatened by the expansion of mining, groundwater pumping, geothermal energy production, gas pipelines and power lines, unregulated tourism, overgrazing of their basins, and egg collection (Caziani and Marconi 1997; Sarmiento *et al.* 1998). Although grazing is widespread in the altiplano, intensity and possible overgrazing have not been evaluated. Because of the potential to cause environmental transformation, we consider mining to be the biggest threat. According to local people, large nesting sites are the targets for egg collection.

The vulnerability of altiplano wetlands is even greater when we consider their natural variability. The occurrence of interannual dry-wet cycles, the dry weather and high evaporation conditions contribute to great spatial and temporary variations.

The lack of assessment of altiplano wetlands (Williams 1993) and the incomplete knowledge of the species distribution constitute a major obstacle to conservation. For example, there is almost no information on the winter distribution of the Andean Flamingo, a species recorded in different environments from Vilama in Jujuy Province (4,500 m) to Melincué in Santa Fe Province (84 m), (M. Romano, Ecosur, pers. comm.).

The complementary use of these environments by waterbirds suggests that long-term conservation goals would best be achieved by considering these wetlands from a landscape perspective. We propose protection and integrated management through cooperative action of the four nations sharing the altiplano.

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Appendix A. Abundance, richness and constancy (%) of waterbirds in the Altiplano wetlands, Argentina, January 1998 (summer); p: only presence recorded, *hyphen*: no data.

	Species													
Wetlands	Sylvery Grebe	Chilean Flamingo	Andean Flamingo	James' Flamingo	*Phoenicopteridae*[1]	Andean Goose	Crested Duck	Yellow-billed Pintail	Speckled Teal	Red Shoveler	Cinnamon Teal	Puna Teal	*Anatidae*[1]	Ruddy Duck
Pozuelos	0	1,112	1,939	170	0	p	p	p	0	0	0	p	0	0
Cerro Negro	89	50	4	0	0	70	113	43	0	0	0	20	0	2
Caiti	48	7	0	0	0	37	33	0	0	0	0	43	0	0
Pululos	442	14	0	0	0	213	94	0	8	0	0	37	0	127
Vilama	0	1	1,015	4,865	782	9	5	0	17	0	0	0	0	0
Isla Grande	340	50	29	0	0	102	230	0	0	0	0	24	0	9
Arenal	107	176	47	2	0	76	245	53	107	0	0	49	0	0
Colpayoc	94	9	0	0	0	42	148	0	11	0	0	1	0	1
Palar	0	0	0	134	0	0	0	0	0	0	0	0	0	0
Catal	22	71	197	10	0	6	369	8	8	0	0	0	0	0
Guayatayoc	0	—	—	—	64	0	0	0	0	0	0	0	0	0
Salar Rincón	0	90	48	10	11	0	0	0	0	0	0	0	0	0
Santa Maria	0	13	22	222	1	0	0	0	0	0	0	0	0	0
Socompa	0	0	6	1	0	0	0	0	0	0	0	0	0	0
Vega Arizaro	—	—	7	—	1	—	—	—	—	—	—	—	—	—
Pastos Grandes	0	4	20	125	70	0	0	0	0	0	0	0	0	0
Salar Llullaillaco	0	2	117	2	3	0	0	0	0	0	0	0	0	0
Diablillos	0	0	19	39	0	0	0	0	0	0	0	0	0	0
Vega los Patos	—	25	68	9	160	p	—	—	—	—	—	—	—	—
Verde	0	5	63	18	0	0	0	0	0	0	0	0	0	0
Sin Nombre	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Hombre Muerto	0	3	31	7	0	0	0	0	0	0	0	0	0	0
Caro	0	4	78	99	53	0	0	0	0	0	0	0	0	0
Diamante	0	9	14	2	0	2	1	0	0	0	0	0	0	0
Pabellón	34	52	2	62	5	70	49	0	149	0	0	10	0	0
La Alumbrera	121	55	68	2	0	48	324	749	241	33	42	270	37	129
Grande	0	34	274	11,374	0	18	21	0	p	0	0	2	237	0
Baya	0	0	0	127	0	0	0	0	0	0	0	0	0	0
Cabi	0	3	7	17	0	3	0	0	0	0	0	0	0	0
Aguas Dulces	0	—	1	30	30	0	0	0	0	0	0	0	0	0
Carachipampa	0	4	46	43	0	0	0	0	0	0	0	0	0	0
Blanca	0	2	19	4	0	5	29	0	2	0	0	0	0	0
Purulla	0	1	421	138	33	0	3	0	0	0	0	0	0	0
Total	1,297	1,796	4,567	17,512	1,213	701[2]	1,664[2]	853[2]	543[2]	33	42	456[2]	274	268
Constancy (%)	27	76	82	76		48	45	15	27	3	3	30		15

Cabi	0	0	0	0	0	0	0	0	0	0	0	0	1	31	5
Aguas Dulces	0	0	0	0	0	0	0	0	0	0	0	0	0	61	2
Carachipampa	0	0	0	0	0	0	0	0	7	0	0	0	0	100	4

Appendix A. (Continued) Abundance, richness and constancy (%) of waterbirds in the Altiplano wetlands, Argentina, January 1998 (summer); p: only presence recorded, *hyphen*: no data.

	Species														
Wetlands	Giant Coot	Horned Coot	Andean Coot[3]	Red-gartered Coot	*Fulica* spp.[1]	Common Gallinule	Andean Avocet	Andean Lapwing	Puna Plover	Yellow-legs[1]	Baird's Sand-piper	Wilson's Phalarope	Andean Gull	Abun-dance	Rich-ness
Blanca	0	0	0	0	0	0	5	1	0	1	0	0	57	125	10
Purulla	0	0	0	0	0	0	9	0	0	0	86	0	0	691	6
Total	114	3,354[2]	463[2]	2	82	6	186	1[2]	26[2]	3	432[2]	714[2]	119[2]	36,721[2]	
Constancy (%)	21	33	9	3		3	30	6	18	6	21	12	33		

[1]Identified only to family or genus level.
[2]More unrecorded individuals.
[3]*Fulica americana*.

Appendix A. (Continued) Abundance, richness and constancy (%) of waterbirds in the Altiplano wetlands, Argentina, January 1998 (summer); p: only presence recorded, *hyphen*: no data.

Wetlands	Species													Abundance	Richness
	Giant Coot	Horned Coot	Andean Coot[3]	Red-gartered Coot	*Fulica* spp.[1]	Common Gallinule	Andean Avocet	Andean Lapwing	Puna Plover	Yellowlegs[1]	Baird's Sandpiper	Wilson's Phalarope	Andean Gull		
Pozuelos	0	p	p	0	0	0	0	p	p	0	p	p	p	3,221[2]	14
Cerro Negro	11	1,356	0	0	0	0	0	0	0	0	0	0	4	1,762	11
Caiti	42	6	0	0	0	0	0	0	0	0	5	0	2	223	9
Pululos	8	324	0	0	0	0	0	0	0	0	0	0	0	1,267	9
Vilama	0	0	1	0	0	0	57	0	0	0	0	0	0	6,752	8
Isla Grande	28	311	0	0	0	0	0	0	0	0	0	0	2	1,125	10
Arenal	0	599	0	0	0	0	5	0	0	0	27	527	40	2,060	14
Colpayoc	2	93	0	0	0	0	4	0	0	0	0	0	0	405	10
Palar	0	0	0	0	0	0	0	0	0	0	0	0	0	134	1
Catal	14	457	0	0	0	0	0	0	11	0	69	0	3	1,245	13
Guayatayoc	0	0	0	0	0	0	0	0	0	0	0	0	0	64	1
Salar Rincón	0	27	0	0	0	0	0	0	0	0	0	0	0	186	4
Santa Maria	0	0	0	0	0	0	21	0	p	0	100	0	0	379[2]	6
Socompa	0	0	0	0	0	0	3	0	0	0	0	0	0	10	3
Vega Arizaro	—	—	—	—	—	—	—	—	—	—	—	—	—	8	—
Pastos Grandes	0	0	0	0	0	0	0	0	0	0	0	0	0	219	3
Salar Llullaillaco	0	0	0	0	0	0	0	0	0	0	0	0	0	124	3
Diablillos	0	0	0	0	0	0	0	0	0	0	0	0	0	58	2
Vega los Patos	—	—	—	—	—	—	—	—	—	—	—	—	—	262[2]	—
Verde	0	0	0	0	0	0	0	0	0	0	0	0	0	86	3
Sin Nombre	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
Hombre Muerto	0	0	0	0	0	0	0	0	0	0	0	0	0	41	3
Caro	0	0	0	0	0	0	0	0	0	0	0	0	0	234	3
Diamante	0	0	0	0	0	0	11	0	0	0	0	0	4	43	7
Pabellón	0	84	0	0	0	0	0	0	0	0	0	0	0	517	9
La Alumbrera	9	97	462	2	82	6	1	0	5	2	145	9	4	2,943	23
Grande	0	0	0	0	0	0	70	0	3	0	0	178	2	12,213[2]	11
Baya	0	0	0	0	0	0	0	0	0	0	0	0	0	127	1
Cabi	0	0	0	0	0	0	0	0	0	0	0	0	1	31	5
Aguas Dulces	0	0	0	0	0	0	0	0	0	0	0	0	0	61	2
Carachipampa	0	0	0	0	0	0	0	0	7	0	0	0	0	100	4

Appendix B. Abundance, richness and constancy (%) of waterbirds in the Altiplano wetlands, Argentina, August 1998 (winter); p: only presence recorded, *hyphen*: no data.

	Species													
Wetlands	Sylvery Grebe	Chilean Flamingo	Andean Flamingo	James' Flamingo	*Phoenicopteridae*[1]	Andean Goose	Crested Duck	Yellow-billed Pintail	Speckled Teal	Red Shoveler	Cinnamon Teal	Puna Teal	*Anatidae*[1]	Ruddy Duck
Laguna Larga	18	160	0	2	0	1	198	0	3	0	0	0	2	0
Pozuelos	—	73	17	2,029	14	—	—	—	—	—	—	—	—	—
Runtuyoc	0	144	47	279	14	119	6	3	12	0	0	3	4	0
Turilari	0	0	1	21	23	0	0	0	0	0	0	0	0	0
Guayatayoc	0	1	1,564	27	0	0	0	0	0	0	0	0	0	0
Vega Cantera	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Salar Rincón	0	42	0	0	0	0	19	0	0	0	0	0	0	0
Santa Maria	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Vega y Laguna Toro	0	153	6	437	0	31	0	0	0	0	0	0	19	0
Pastos Grandes	0	17	0	169	4	0	6	2	63	0	0	16	0	0
Salar Llullaillaco	0	6	7	0	3	0	0	0	0	0	0	0	0	0
Salar Centenario	0	0	0	46	0	0	0	0	0	0	0	0	0	0
Hombre Muerto	0	0	0	44	0	0	0	0	0	0	0	0	0	0
Caro	0	0	0	16	0	0	0	0	0	0	0	0	0	0
La Alumbrera	2	16	19	3	0	2	26	2	0	0	0	0	2	2
Grande	0	0	0	2	0	97	25	0	0	0	0	0	0	0
Cabi	0	0	2	20	57	0	0	0	0	0	0	0	0	0
Carachipampa	0	66	0	97	12	0	4	0	0	0	0	0	0	0
Purulla	0	32	0	79	0	0	0	0	0	0	0	0	0	0
Colorada	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Archibarca	0	0	0	24	0	0	0	0	0	0	0	0	0	0
Los Enamorados	0	0	0	155	139	0	0	0	0	0	0	0	0	0
Mina FMC	0	0	0	16	17	0	0	0	0	0	0	0	0	0
Vega Jama	0	0	2	4	8	0	4	0	6	0	0	3	0	0
Total	20	710	1,667	3,473	295	250	288	7	84	0	0	22	27	2
Constancy (%)	8	46	42	83		21	33	12	17	0	0	12		4

Constancy (%) 8 46 42 83 21 33 7 12 84 17 0 0 0 0 22 12 27 2 4

Appendix B. (Continued) Abundance, richness and constancy (%) of waterbirds in the Altiplano wetlands, Argentina, August 1998 (winter); p: only presence recorded, *hyphen*: no data.

	Species														
Wetlands	Giant Coot	Horned Coot	Andean Coot[2]	Red-gartered Coot	*Fulica* spp.[1]	Common Gallinule	Andean Avocet	Andean Lapwing	Puna Plover	Yellowlegs[1]	Baird's Sandpiper	Wilson's Phalarope	Andean Gull	Abundance	Richness
Laguna Larga	30	16	25	0	9	0	0	0	0	0	0	0	1	465	10
Pozuelos	—	—	—	—	—	—	—	—	—	—	—	—	—	2,133	—
Runtuyoc	0	0	3	0	21	0	2	0	0	0	0	0	2	659	11
Turilari	0	0	0	0	0	0	0	0	0	0	0	0	0	45	2
Guayatayoc	0	0	0	0	0	0	0	0	0	0	0	0	0	1,592	3
Vega Cantera	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Salar Rincón	0	19	0	0	0	0	0	0	0	0	0	0	0	80	3
Santa Maria	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
Vega y Laguna Toro	0	0	0	0	0	0	4	0	0	0	0	0	0	650	6
Pastos Grandes	0	0	0	0	0	0	9	0	0	0	7	0	4	297	9
Salar Llullaillaco	0	0	0	0	0	0	0	0	0	0	0	0	0	16	2
Salar Centenario	0	0	0	0	0	0	0	0	0	0	0	0	0	46	1
Hombre Muerto	0	0	0	0	0	0	0	0	0	0	0	0	0	44	1
Caro	0	0	0	0	0	0	0	0	0	0	0	0	0	16	1
La Alumbrera	0	0	0	0	254	0	0	0	0	0	0	0	0	328	9
Grande	0	0	0	0	0	0	30	0	0	0	0	0	137	291	5
Cabi	0	0	0	0	0	0	0	0	0	0	0	0	0	79	2
Carachipampa	0	0	0	0	0	0	2	0	0	0	0	0	0	181	4
Purulla	0	0	0	0	0	0	0	0	0	0	0	0	0	111	2
Colorada	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
Archibarca	0	0	0	0	0	0	0	0	0	0	0	0	0	24	1
Los Enamorados	0	0	0	0	0	0	0	0	0	0	0	0	0	294	1
Mina FMC	0	0	0	0	0	0	0	0	0	0	0	0	0	33	1
Vega Jama	0	0	0	0	0	0	1	0	0	0	0	0	0	28	6
Total	30	35	28	0	284	0	48	0	0	0	7	0	144	7,421	
Constancy (%)	4	8	8	0		0	25	0	0	0	4	0	17		

[1]Identified only to family or genus level.
[2]*Fulica americana*.