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Author(s): Natalia S. Martínez-Curci and Juan P. Isacch
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Shorebird Population Estimates Using Seasonal Aerial and Terrestrial Surveys at Samborombón Bay, Argentina

Natalia S. Martínez-Curci* and Juan P. Isacch

Laboratorio Vertebrados, Instituto de Investigaciones Marinas y Costeras, Faculty de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata – Consejo Nacional de Investigaciones Científicas y Técnicas, Funes 3250, 7600 Mar del Plata, Argentina

*Corresponding author; E-mail: nanusmc@gmail.com

Abstract.—Information about shorebirds is essential for predicting the impact of natural and human-mediated changes on their populations. Aerial and terrestrial surveys were performed to characterize shorebird abundance, spatial distribution and assemblage composition at Samborombón Bay, Argentina, during different tide levels and seasons. Approximately 60,000 shorebirds were observed using the intertidal flats. Highest abundances occurred during austral summer, autumn and spring when Nearctic migrants dominate the assemblage. Significant percentages (> 1%) of the populations of three Nearctic migrants [American Golden-Plover (*Pluvialis dominica*), Hudsonian Godwit (*Limosa haemastica*), and White-rumped Sandpiper (*Calidris fuscicollis*)], one Neotropical migrant [Two-banded Plover (*Charadrius falklandicus*)], and two resident species [American Oystercatcher (*Haematopus palliatus*) and Black-necked Stilt (*Himantopus mexicanus*)] were estimated. Large numbers of Semipalmated Plovers (*C. semipalmatus*), Rufous-chested Dotterel (*C. modestus*), and Ruddy Turnstones (*Arenaria interpres*) were also recorded. Management measures aimed at maintaining healthy, viable populations should address species needs during all four seasons focusing on the southern and central sectors of Samborombón Bay, which are the most important feeding areas for shorebirds. *Received 9 May 2017, accepted 9 August 2017.*

Key words.—abundance, Argentina, assemblage composition, distribution, population estimates, Samborombón Bay, shorebirds, South America.

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Over 60% of shorebird species are migratory (Colwell 2010), some of them performing long distance flights between their breeding and non-breeding grounds (Piersma and Davidson 1992). Migratory shorebirds exhibit high site fidelity (the tendency to remain on or return to a particular area). They also have an aggregative behavior by which mono- or multi-specific flocks congregate at particular areas during the migratory and non-breeding seasons (Myers 1983). These strategies confer several benefits. The aggregation increases the efficiency and precision of migration as well as decreases the predation risks. The repeated use of specific locations provides familiarity with resources and conditions (Shuter *et al.* 2011). However, they also make populations more susceptible to habitat loss or degradation (Myers 1983; Shuter *et al.* 2011).

It is estimated that nearly 50% of the world's shorebird populations with known trends are in decline, mainly due to the degradation of habitats on which they rely (Zöckler *et al.* 2003; Colwell 2010). Efforts to manage and protect migratory species are often complex. They require sound knowledge of the sites used during the annual cycle together with implementation of actions that involve several countries. Thus, to preserve shorebirds and their habitats, scientists in the Americas have developed an international strategy named the Western Hemisphere Shorebird Reserve Network, which comprises the recognition and ranking of sites that hold large abundances or high percentages of a given biogeographic population (Western Hemisphere Shorebird Reserve Network 1993).

Samborombón Bay is one of the eight sites of outstanding importance officially declared in Argentina (Western Hemisphere Shorebird Reserve Network 2012). There, more than 100,000 shorebirds occur annually including 29 species of regular or occasional presence (Martínez-Curci and Petracci 2016). Even though some species are resident (~20%), most are migratory. Nearctic migrants represent 65% of the species and the remaining 15% are Neotropical migrants that breed in southern South America (Martínez-Curci and Petracci 2016). The area is particularly important for the grassland shorebird Buff-breasted Sandpiper

(*Calidris subruficollis*; Lanctot *et al.* 2010). In addition, it may be an important site for other shorebirds with coastal habits including the American Golden-Plover (Clay *et al.* 2010a), Hudsonian Godwit (Senner 2007), Lesser Yellowlegs (Clay *et al.* 2012), and Red Knot (Niles *et al.* 2008); scientific names are given in Table 1.

Information about shorebird abundance and distribution is essential for predicting the impact of natural and human-mediated changes on populations. Updated knowledge in much of South America is limited due to the small number of researchers and logistic constraints (Piersma *et al.* 1997). In Samborombón, Argentina, particularly, almost all of the extensive intertidal flats are inaccessible by land or water. Previous investigations were conducted using terrestrial methodologies that covered a small percentage of the area (Blanco *et al.* 1992, 2006; Martínez-Curci *et al.* 2015a). Only two earlier studies that conducted aerial surveys in the 1980s and 1990s included most or even all of these extensive intertidal flats, but neither of them considered the four seasons of the year. The first one included a single flight over the entire estuarine coast during the austral summer of 1982 (Morrison and Ross 1989). The second study, conducted in 1993-1994, covered more than 50% of the length of Samborombón Bay, which was overflown in each survey (Vila *et al.* 1994).

The objective of this study was to update and expand the information on shorebird abundance, spatial distribution and assemblage composition at Samborombón Bay during low and high tide periods and over the four seasons of the year. Based on this information, we estimated the percentage of different biogeographic shorebird populations that used the area in each season.

METHODS

Study Area

We conducted this study at Samborombón Bay, Buenos Aires Province, Argentina, which is part of the Río de la Plata estuary. The area is included within the Flooding Pampas phytogeographical region (Soriano 1992), having a temperate climate with a hot/warm summer without a dry season (Peel *et al.* 2007). It encompasses an estuarine coastline of ~150 km extending from Punta Piedras in the northern extreme to Punta Rasa in the southern end (Fig. 1). This coastline is characterized by a gentle slope affected by low-amplitude (< 1.5 m) and semidiurnal tides with brackish mesohaline waters. Large muddy intertidal flats, which are surrounded by saltmarshes dominated by several shallow lagoons and three plant species [smooth cordgrass (*Spartina alterniflora*), denseflower cordgrass (*Spartina densiflora*) and pickleweed (*Sarcocornia perennis*)], are exposed during low tide (Isacch *et al.* 2006). Given its biological importance, especially for migratory birds, the area is protected by Argentinian law and also has international recognition. It is a Wetland of International Importance under the Ramsar Convention (Ramsar Convention on Wetlands 2012), an Important Bird Area (AR205) according to BirdLife International (Coconier and Di Giacomo 2009), and a site of International Importance within the Western Hemisphere Shorebird Reserve Network (Western Hemisphere Shorebird Reserve Network 2012).

Shorebird Surveys

Counts were focused on shorebirds that used intertidal flats as feeding areas. For describing abundance and spatial distribution, one aerial survey using a Cessna 172—small, four-seat, single-engine, high wing, fixed-wing aircraft—was conducted in each of the Southern Hemisphere's seasons of 2014: austral summer from 28 January, austral autumn from 1 April, austral winter from 24 July, and austral spring from 26 September. Two transects, selected based on shorebird habitat-use patterns (Blanco 1998; Martínez-Curci *et al.* 2015a, 2015b), were overflown in each survey. The first one covered the saltmarshes during high tide (146-km length); the second one covered the intertidal flats during falling tide (140-km length) (Fig. 1). In summer, weather conditions were unfavorable during the morning, and only the low tide transect was overflown. Counts were made by one observer located on the right side of the plane. The high tide transects followed a line parallel to the coastline that crossed the potential roosting areas, such as small wetlands and saltpans. They had a width of ~500 m, which represents only a fraction of the available habitat for resting. The flights performed during low tide followed the high tide line, allowing the observer to look at birds as they flushed from the shore. These surveys were scheduled to coincide with the falling tide (3-4 hr after high tide), a period on which birds were feeding on beaches (Blanco 1998; Martínez-Curci *et al.* 2015a, 2015b). The width of transects was equal to the width of the intertidal flat, which was less than 500-m wide in most instances. The overflights were performed at an airspeed of 120 kmph on average and an altitude of 40 m above ground level on days with similar weather conditions (spring tides, no rain or fog, and wind speed lower than 20 kmph). Low altitude caused birds to fly, facilitating their detection. Each time a single shorebird or flock was observed, its location was georeferenced and the number of individuals was counted in flocks

Table 1. Percentage of shorebird relative abundance by species (terrestrial surveys) and size (aerial surveys) for each season of 2014 [austral summer (January), autumn (April), winter (July), and spring (September)] at Samborombón Bay, Buenos Aires Province, Argentina. Terrestrial count values indicate mean and standard deviation (in parentheses) of the percentage that each species represents from the total small/medium-sized (SM) and large-sized (L) shorebirds counted in aerial surveys. For terrestrial counts, species richness is also reported; for aerial counts, total abundance is reported.

	Shorebird Species						
	Common Name	Scientific Name	Size	Summer	Autumn	Winter	Spring
Terrestrial Counts							
Species richness				13	14	6	13
Percentage of abundance							
	American Golden-Plover	*Pluvialis dominica*	SM	1.7 (0.6)	0.4 (0.4)	0	31.2 (11.3)
	Black-bellied Plover	*Pluvialis squatarola*	SM	0.1 (0.1)	0.3 (0.3)	0	0.3 (0.3)
	Semipalmated Plover	*Charadrius semipalmatus*	SM	< 0.1 (< 0.1)	1.2 (0.7)	0	4.6 (4.2)
	Two-banded Plover	*Charadrius falklandicus*	SM	4.1 (1.8)	11.1 (4.8)	48.8 (22.4)	1.8 (1.7)
	Rufous-chested Dotterel	*Charadrius modestus*	SM	0	0	7.7 (3.4)	0
	American Oystercatcher	*Haematopus palliatus*	L	18.0 (15.9)	7.9 (5.3)	100	26.5 (17.5)
	Black-necked Stilt	*Himantopus mexicanus*	L	18.2 (15.1)	58.3 (9.8)	0	39.1 (21.5)
	Hudsonian Godwit	*Limosa haemastica*	L	66.5 (18.1)	25.3 (8.6)	0	33.7 (18.7)
	Spotted Sandpiper	*Actitis macularius*	SM	0	0.4 (0.3)	0	0
	Greater Yellowlegs	*Tringa melanoleuca*	L	0	18.6 (14.9)	0	0.8 (0.7)
	Lesser Yellowlegs	*Tringa flavipes*	SM	11.9 (11.1)	12.8 (11.2)	0	2.1 (1.9)
	Willet	*Tringa semipalmata*	L	0	0	< 0.1 (< 0.1)	0
	Ruddy Turnstone	*Arenaria interpres*	SM	< 0.1 (< 0.1)	1.9 (1.7)	0	2.1 (1.9)
	Red Knot	*Calidris canutus*	SM	0	3.0 (2.7)	22.1 (19.4)	2.5 (2.0)
	White-rumped Sandpiper	*Calidris fuscicollis*	SM	81.5 (11.5)	49.5 (17.2)	0	38.6 (10.7)
	Pectoral Sandpiper	*Calidris melanotos*	SM	0.5 (0.4)	0	0	0
Aerial Counts							
Total abundance				9,710	12,475	4,301	31,700
Percentage							
SM				83.4	76	94.3	91
L				16.6	24	5.7	9

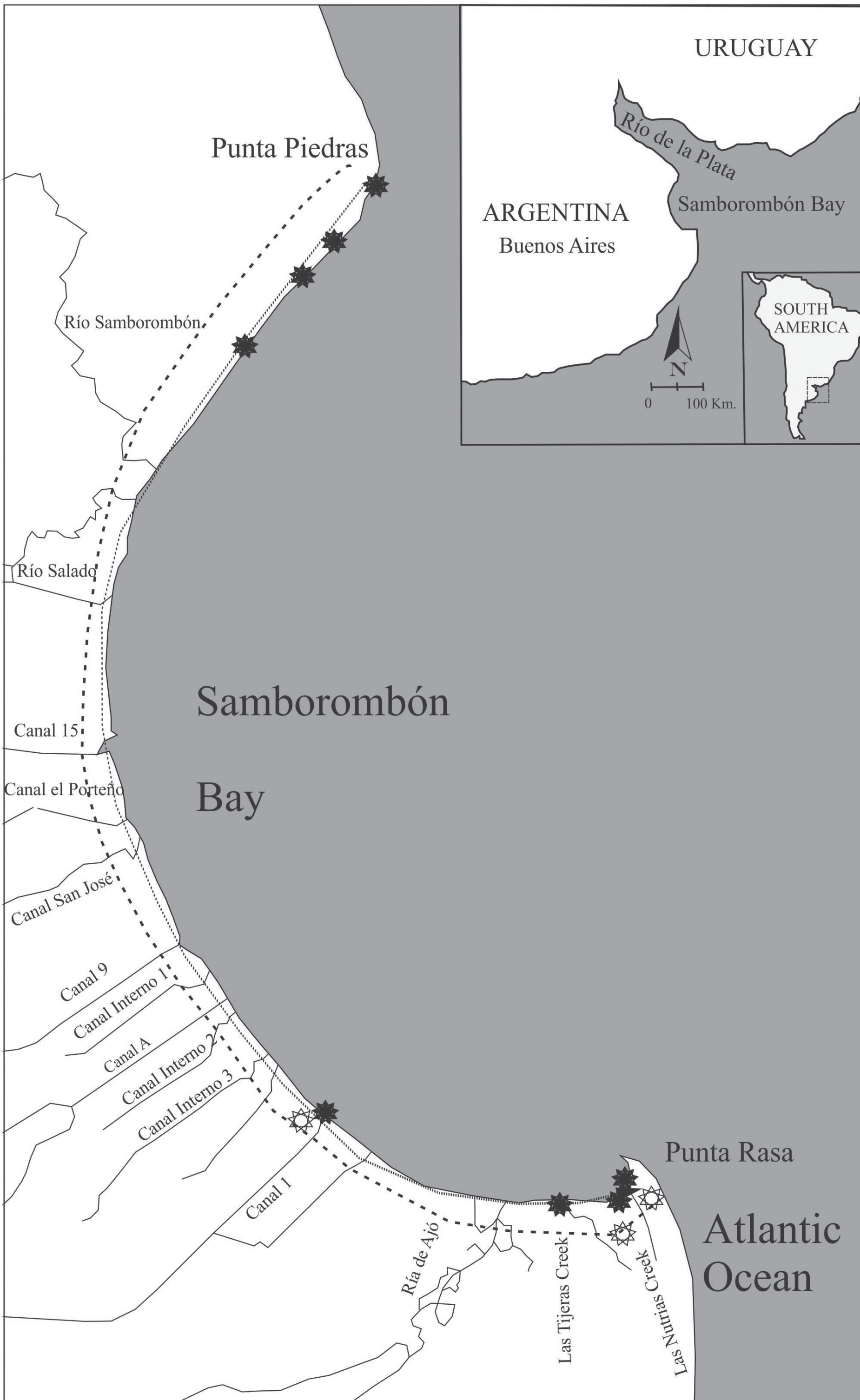

Figure 1. Study area showing the location of aerial transects surveyed during low (····) and high (—) tide, and terrestrial transects surveyed at intertidal flats (✸) and saltmarshes (✡). The inset maps display the location of Samborombón Bay in Buenos Aires Province, Argentina, and within southern South America.

with ≤ 30 shorebirds or estimated in flocks with > 30 shorebirds, discriminating between small/medium- and large-sized shorebirds (size categories following Morrison and Ross 1989).

To describe assemblage composition, terrestrial surveys were conducted during low tide on days immediately before and/or after aerial surveys (+ 3 days). Eight 1,000-m long transects, situated parallel to the wave zone and selected on the basis of their representativeness and accessibility, were surveyed in each season (Fig. 1). Shorebirds were identified to species and counted using a high-definition spotting scope (20-60x). Surveys started 1.5 hr before and ended approximately 1.5 hr after low tide. To corroborate the movement of birds between saltmarshes and intertidal flats according to the tidal level, the two transects near Las Nutrias and the one near Canal 1 (Fig. 1) were also surveyed during high tide. Three additional 1,000-m transects located in saltmarshes were also surveyed during low and high tide (Fig. 1). Both aerial and terrestrial counts were carried out by the same observer, except during summer when several trained observers performed terrestrial counts simultaneously.

Data Analysis

The total abundance and percentage of small/medium- and large-sized shorebirds observed in aerial surveys was calculated for each season and tidal level. Low tide abundances were used as an estimate of the minimum number of shorebirds using Samborombón Bay in each season. A Geographic Information System (Environmental Systems Research Institute 2014) was used to generate maps showing geographical distribution of shorebirds.

We estimated the abundance of each shorebird species by extrapolating the results of terrestrial surveys to those of low tide aerial surveys in which birds were classified by size. Bootstrapped mean and standard deviation of the percentage that each species represented in assemblages of small/medium- and large-sized shorebirds were calculated from terrestrial surveys. These values were then extrapolated to the total number of small/medium- and large-sized shorebirds observed in aerial surveys. The Red Knot was excluded from this extrapolation because it is known that the species is virtually absent in Samborombón Bay, except from Punta Rasa (Blanco *et al.* 1992; Vila *et al.* 1994; Martínez-Curci *et al.* 2015c). The minimum percentage of individuals of each biogeographic population using the area was calculated from mean abundance by applying population estimates obtained from the literature [American Oystercatcher (Clay *et al.* 2010b); American Golden-Plover, Semipalmated Plover, Hudsonian Godwit, Greater Yellowlegs, Lesser Yellowlegs, Ruddy Turnstone, and White-rumped Sandpiper (Andres *et al.* 2012); Two-banded Plover, Rufous-chested Dotterel, and Black-necked Stilt (Wetlands International 2017)].

Assemblage structure was assessed with the multivariate analysis of similarities one-way ANOSIM performed with PRIMER 5 (Clarke and Gorley 2002). Low tide terrestrial counts were pooled to analyze the differences in the structure of the assemblage among seasons. Abundance data were square root transformed, and analyses were conducted on a Bray-Curtis similarity matrix with 9,999 permutations. ANOSIM was used to test differences in assemblage composition by season, comparing similarities among samples within a given season vs. samples in different seasons. Finally, the SIMPER routine (Clarke 1993) was used to examine the overall dissimilarities among seasons and to assess the contribution of each species to the observed dissimilarities.

RESULTS

During low tide aerial surveys, a total of 58,186 individuals were counted over the four seasons combined. Abundance ranged from a minimum of 4,301 birds in austral winter to a maximum of 31,700 in austral spring. Most of them were small/medium-sized shorebirds. However, percentages of large-sized shorebirds increased during the periods of northward and southward migration (austral autumn and austral spring, respectively) (Table 1). The largest total abundances were observed between Canal 15 and Punta Rasa (Fig. 2). The southern sector of Samborombón Bay received the highest intensity of use during austral summer, while over the course of the year birds moved to the central area and they barely used the northern sector (Fig. 2).

In high tide aerial surveys, large numbers of shorebirds were only observed during austral autumn when we counted 3,632 individuals (2,852 small/medium-sized and 780 large-sized). Most of these were in close proximity to Canal 15 (Fig. 3). A total of 122 individuals (31 small/medium-sized and 91 large-sized) were counted in austral winter; in the spring, we counted 116 large-sized individuals (Fig. 3).

Terrestrial surveys confirmed the movement of individuals between the feeding areas located at intertidal flats and the resting areas located at saltmarshes according to tide level. Abundance in intertidal flats decreased during high tide and increased during low tide, while saltmarshes showed the inverse pattern (Fig. 4). We registered five large-sized and 11 small/medium-sized shorebird species belonging to the fami-

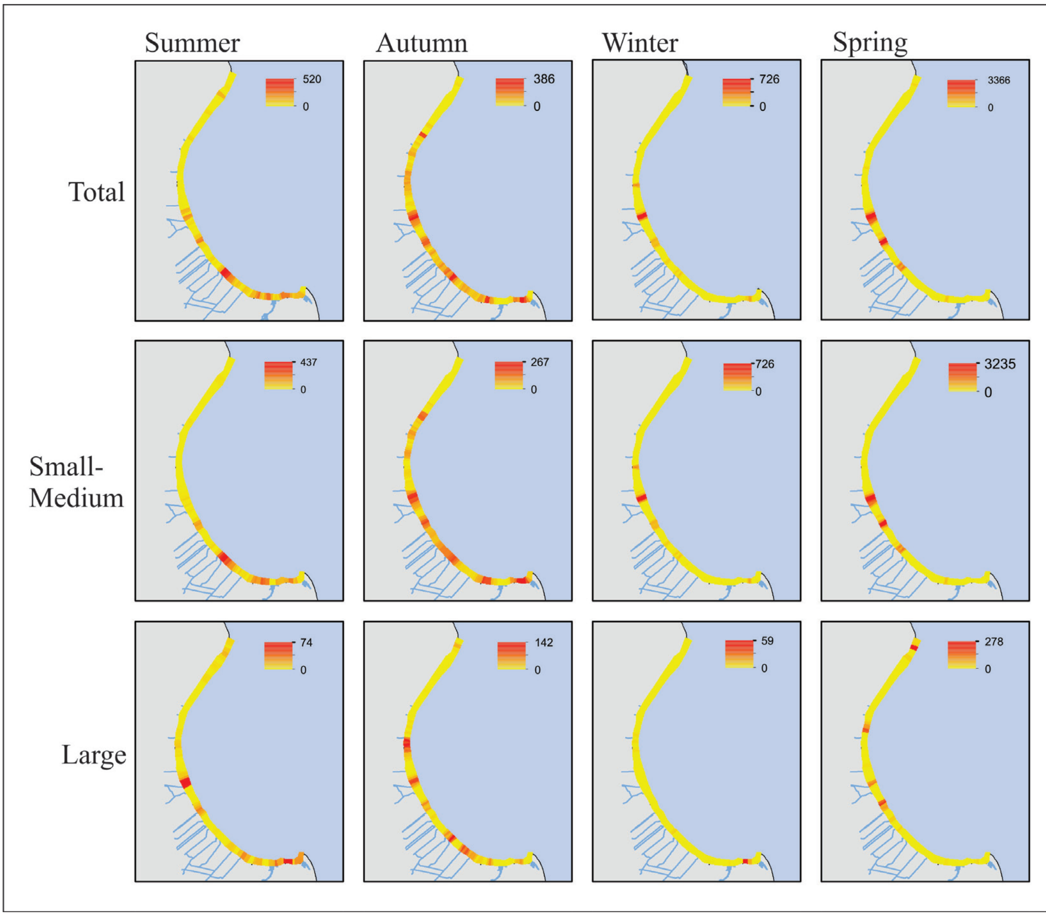

Figure 2. Abundance and distribution of total, small/medium-sized, and large-sized shorebirds observed during the low tide aerial counts conducted in 2014 at Samborombón Bay, Buenos Aires Province, Argentina. Seasons refer to the Southern Hemisphere schedule: austral summer (January), autumn (April), winter (July), and spring (September).

lies Charadriidae (5), Haematopodidae (1), Recurvirostridae (1), and Scolopacidae (9). Austral winter had the least species richness, while austral autumn had the greatest (Table 1). Small/medium-sized shorebirds dominated the assemblage during the four seasons. Nearctic migrants prevailed in austral summer, autumn, and spring, with the White-rumped Sandpiper being the most abundant species, accompanied by large numbers of American Golden-Plovers and Hudsonian Godwits. In austral winter, the most numerous species was the Two-banded Plover, a Neotropical migrant (Table 1).

The ANOSIM test showed overall significant differences in shorebird assemblage structure driven by season ($R = 0.423$, $P < 0.001$). Pair-wise tests showed significant differences between austral winter and the remaining seasons, and between austral autumn and two of the other seasons (astral summer and spring) (Table 2). About 50% of the differences between austral winter and the other seasons were explained by three species: White-rumped Sandpiper, Two-banded Plover, and Rufous-chested Dotterel. The first species is a Nearctic migrant that was not observed over the winter. The latter two species are Neotropical migrants that had maximum abundances in winter. Approximately 50% of the differences between austral autumn and two of the other seasons (austral summer and spring) were explained by two Nearctic migrants: Hudsonian Godwit and White-

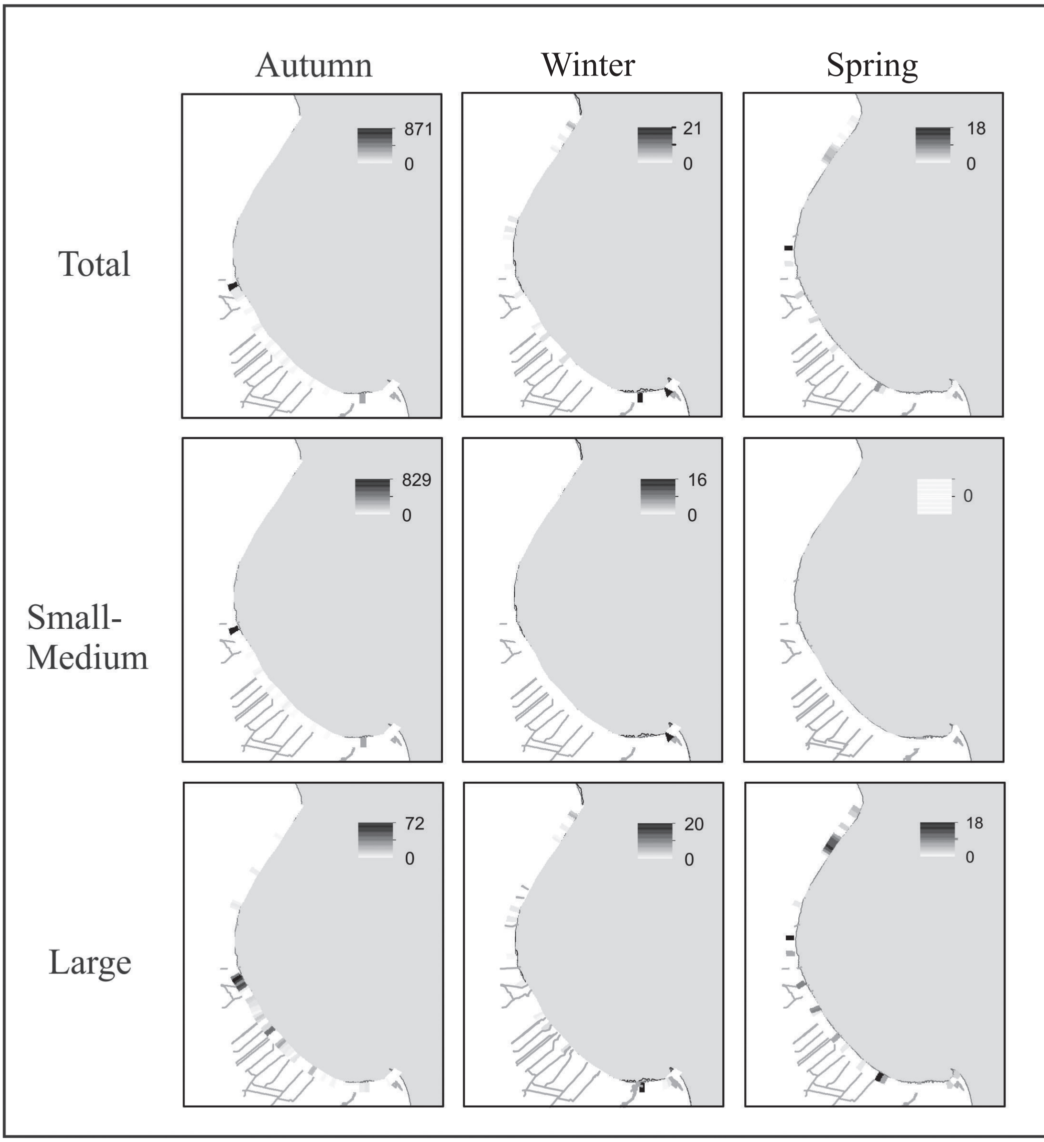

Figure 3. Abundance and distribution of total, small/medium-sized and large-sized shorebirds observed during the high tide aerial counts conducted in 2014 at Samborombón Bay, Buenos Aires Province, Argentina. Seasons refer to the Southern Hemisphere schedule: austral summer (January), autumn (April), winter (July), and spring (September).

rumped Sandpiper. The former species showed its maximum abundance during austral autumn, the latter during austral spring (Table 2).

Samborombón Bay hosted significant percentages of the biogeographic populations of six shorebird species in at least one season. At least 1% of the populations of American Golden-Plovers used the area during austral spring, Black-necked Stilts during austral autumn and spring, Hudsonian Godwits and White-rumped Sandpipers during austral summer and spring, and Two-banded Plovers and American Oystercatchers throughout the entire year (Table 3). The area also hosted large numbers, though less than 1% of populations, of Semipalmated Plovers and Ruddy Turnstones during austral spring, and Rufous-chested Dotterel during austral winter (Table 3).

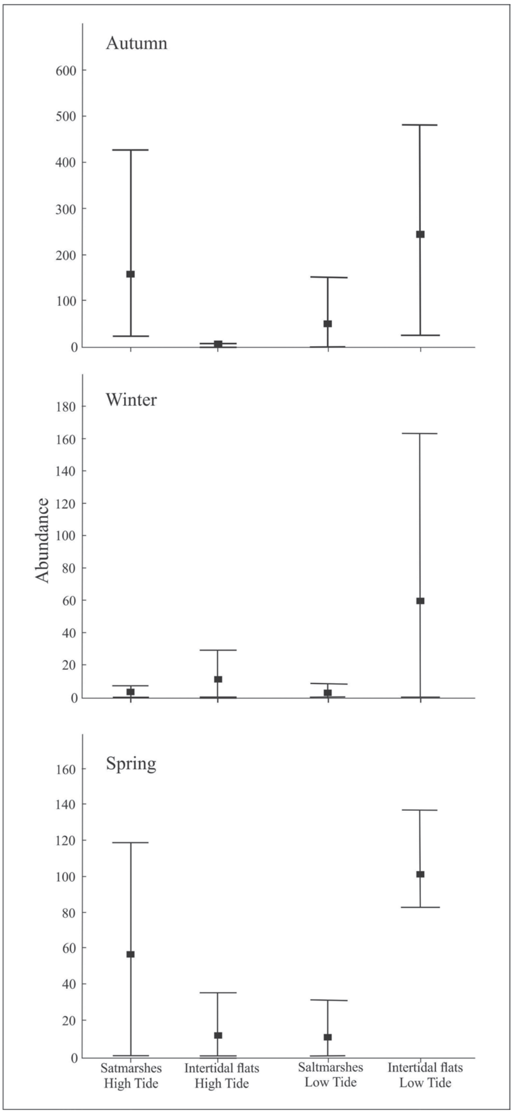

Figure 4. Mean, minimum and maximum shorebird abundance observed at saltmarshes and intertidal flats during high and low tide terrestrial counts conducted in austral autumn (April), winter (July), and spring (September).

DISCUSSION

The estuarine intertidal flats of Samborombón Bay hold a minimum of ~60,000 shorebirds per year. Nearctic migrants, especially the White-rumped Sandpiper, dominated the assemblage during austral summer, autumn, and spring. The Neotropical migrant Two-banded Plover was the most abundant species during austral winter. The largest numbers of shorebirds occurred during the seasons with a dominance of Nearctic migrants, and spatially in the area between Canal 15 and Punta Rasa. Distribution patterns at feeding areas do not remain constant during different seasons. Conversely, the areas with highest total abundances moved from the south to the center of Samborombón Bay during the course of the year. This might be related to the discharge of Canal 15, which diverts more than 70% of the water from the Salado River, the main watercourse in the area (Carol *et al.* 2013, 2014), into the estuary. This discharge could improve foraging conditions during winter, the driest season of the year. At resting areas, large shorebird numbers were only detected in austral autumn when flocks were concentrated at shallow lagoons in the vicinity of Canal 15.

Our estimated annual abundance is consistent with the Western Hemisphere Shorebird Reserve Network assessment, which stipulates at least 100,000 shorebirds per year (Western Hemisphere Shorebird Reserve Network 2012). Even though the present study only accounts for ~60,000 shorebirds, abundances and percentages of biogeographic populations are likely underestimated. Our aerial surveys covered only one day at each season, giving us an index to the total abundance. Thus, the real total abundance could be greater, particularly during austral autumn and spring when birds are engaged in migration and turnover rates are higher. On the other hand, we did not consider the presence of birds in non-surveyed environments. Shorebirds remaining at lagoons and creeks during low tide might represent approximately 14% of those observed at intertidal flats (Vila *et al.* 1994).

The seasonal abundances recorded in this study were similar to those reported in the 1990s, but more than twice the abundance reported in the austral summer of 1982. In 1993-1994, Vila *et al.* (1994) estimated a minimum of 58,249 to 69,762 individuals from spring to autumn. Our surveys accounted for 53,885 during the same seasons. Morrison and Ross (1989) reported 3,325 shorebirds using Samborombón Bay

Table 2. Differences in shorebird assemblage composition among the seasons of 2014 [austral summer (January), autumn (April), winter (July), and spring (September)] at Samborombón Bay, Buenos Aires Province, Argentina. Pairwise ANOSIM test and SIMPER analysis for differences in species composition driven by the effect of season. * indicates significant differences (significance level at $P \leq 0.05$).

Analysis	Winter-Summer	Winter-Autumn	Winter-Spring	Summer-Autumn	Summer-Spring	Autumn-Spring
ANOSIM						
R	0.886	0.683	0.861	0.25	0.172	0.231
P	0.003*	0.003*	0.005*	0.024*	0.055	0.043*
SIMPER						
% Average dissimilarity	91.98	90.41	95.24	71.53	68.31	79.01
% Species contribution to average dissimilarity						
American Golden-Plover	4.49	0.53	13.26	5.64	9.15	16.02
Black-bellied Plover	1	1.25	1.43	0.95	1.48	1.58
Semipalmated Plover	0.29	1.92	3.02	1.92	3.32	4.99
Two-banded Plover	13.72	20.95	19.79	9.63	8.63	6.51
Rufous-chested Dotterel	9.15	14.85	13.08	—	—	—
American Oystercatcher	7.45	9.1	7.41	5.18	5.12	3.94
Black-necked Stilt	3.23	12.16	4.28	9.71	6.69	14.9
Hudsonian Godwit	7.37	7.34	7.62	11.12	11.44	13.28
Spotted Sandpiper	—	0.86	—	0.79	—	0.93
Greater Yellowlegs	—	2.25	1.09	1.68	1.08	3.5
Lesser Yellowlegs	5.29	3.16	3.21	8.46	9.14	5.77
Willet	0.63	0.89	0.82	—	—	—
Ruddy Turnstone	0.21	1.09	1.86	1.4	1.99	3.19
Red Knot	5.3	8.16	8.31	1.49	2.44	4.16
White-rumped Sandpiper	40.84	15.49	14.84	40.8	38.21	21.24
Pectoral Sandpiper	1.02	—	—	1.23	1.3	—

Table 3. Mean abundance, standard deviation (in parenthesis) and percentage of the biogeographic population (calculated from the mean) of each shorebird species estimated to use Samborombón Bay, Buenos Aires Province, Argentina, over the four seasons of 2014 [austral summer (January), autumn (April), winter (July), and spring (September)]. Name and size of each biogeographic population are listed. Only species representing more than 1% of the assemblage in at least one season are shown. Red Knot was excluded because this species used the area of Punta Rasa almost exclusively.

	Biogeographic Population		Estimated Abundance				% Population			
Species	Name	Size	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
American Golden-Plover[3]	Americas	294,200-705,800	135 (50)	42 (38)	0	9,006 (3,265)	0.05-0.02	< 0.01	0	3.06-1.28
Semipalmated Plover[3]	Americas	200,000	3 (3)	117 (62)	0	1,319 (1,216)	< 0.01	0.06	0	0.66
Two-banded Plover[2]	South America	25,000-100,000	322 (143)	1,048 (546)	1,981 (908)	533 (485)	1.28-0.32	4.19-1.05	7.92-1.98	2.13-0.53
Rufous-chested Dotterel[2]	South America + Malvinas	133,000-1,063,000	0	0	728 (321)	0	0	0	0.73-0.07	0
American Oystercatcher[1]	*Durnfordi*	10,000-15,000	241 (218)	237 (160)	245	757 (498)	2.41-1.61	2.37-1.58	2.45-1.63	7.57-5.05
Black-necked Stilt[2]	Central South America	100,000-1,000,000	293 (243)	1,958 (329)	0	1,117 (614)	0.29-0.03	1.96-0.20	0	1.12-0.11
Hudsonian Godwit[3]	Hudson Bay + Alaska	77,000	1,072 (291)	799 (263)	0	963 (534)	1.39	1.04	0	1.25
Greater Yellowlegs[3]		137,000	0	560 (83)	0	23 (20)	0	0.41	0	0.02
Lesser Yellowlegs[3]	Americas	660,000	963 (901)	1,209 (1,060)	0	1,198 (937)	0.15	0.18	0	0.18
Ruddy Turnstone[3]	*Morinella*	180,000	1 (1)	177 (163)	0	604 (546)	< 0.01	0.27	0	0.93
White-rumped Sandpiper[3]	North America	560,100-3,827,900	6,597 (933)	4,693 (1,639)	0	11,149 (3,092)	1.18-0.17	0.84-0.12	0	1.99-0.29

[1]Clay *et al.* (2010b).
[2]Wetlands International (2017).
[3]Andres *et al.* (2012).

during the austral summer of 1982, while we observed 9,710. Differences between the latter two studies might be due to the extent of the spatial scale considered. Our research was limited to Samborombón Bay, whereas Morrison and Ross (1989) conducted surveys at a regional scale covering almost all of the coastlines of South America. Hence, our smaller scale research could have facilitated a selection of dates with better conditions to perform the aerial surveys and detect birds.

According to our research, Samborombón Bay holds significant percentages (≥ 1%) of biogeographic populations of three Nearctic migrants (American Golden-Plover, Hudsonian Godwit, and White-rumped Sandpiper), one Neotropical migrant (Two-banded Plover), and two resident species (American Oystercatcher and Black-necked Stilt). Previous knowledge indicates that the area is also important for Red Knots and Buff-breasted Sandpipers. The former species is mainly restricted to Punta Rasa, where significant numbers are present in austral autumn and winter (Martínez-Curci *et al.* 2015c). Buff-breasted Sandpipers make extensive use of grasslands habitats (Lanctot *et al.* 2010) that were not surveyed in the present study.

With regard to Nearctic migrants, our estimates are consistent with the information reported in the conservation plans for American Golden-Plover and Hudsonian Godwit (Senner 2007; Clay *et al.* 2010a). The American Golden-Plover uses Samborombón Bay mainly as a non-breeding area, arriving in late August and leaving in austral midsummer (Myers and Myers 1979). Given that this species feeds extensively on grasslands (Isacch and Martínez 2003; Isacch and Cardoni 2011) that were not surveyed during our study, numbers have probably been underestimated. On the other hand, Hudsonian Godwits use Samborombón Bay as a non-breeding area and a migratory stopover site (Vila *et al.* 1994; Blanco *et al.* 1995). Our results indicate significant numbers during the non-breeding season and both southward and northward migrations. The same pattern of use was observed for the White-rumped Sandpiper, a species with decreasing population trends (BirdLife International 2016a) which is the most abundant shorebird in the area.

Two-banded Plovers were present in significant numbers throughout the year. The dominance of this species during austral winter is in contrast to what was reported by Martínez-Curci *et al.* (2015a) for the southern tip of Samborombón Bay, where resident species showed the highest abundances. Differences may be due to the fact that small/medium-sized shorebirds concentrated mainly in the center of the study area during winter. Although some individuals might reproduce in the Pampas region (Narosky and Di Giacomo 1993; Alfaro *et al.* 2008; Scherer *et al.* 2013), the species typically breeds in Patagonia during austral spring (Piersma and Wiersma 1996). Thus, most of the birds recorded in that season could be primarily sexually immature individuals.

Although residents were a minority group during the four seasons, significant numbers of American Oystercatchers and Black-necked Stilts were recorded. The former species has variable (Clay *et al.* 2010b) but presumably stable (BirdLife International 2016b) population trends, while the latter has increasing population trends (BirdLife International 2017). The American Oystercatcher Conservation Plan does not list Samborombón Bay as an important area (Clay *et al.* 2010b), probably due to lack of information. However, according to our results, the area holds significant numbers of the southern South American population of American Oystercatchers (*H. p. durnfordi*) and also of the global population considering the five subspecies (Clay *et al.* 2010b).

This study highlights the importance of Samborombón Bay, not only for Nearctic migrants, as has been previously suggested, but also for Neotropical migrants and resident species. Future management actions taken to maintain healthy and viable shorebird populations should address species needs during all four seasons and should focus on the area between Punta Rasa and Canal 15. Punta Rasa is affected by mass tourism and several activities, including vehicular traffic on the beach and new extreme sports such as kitesurfing and kitebuggying, that alter shorebird resting and feeding activity patterns (Davenport and Davenport 2006; Schlacher *et al.* 2007; Martínez-Curci and Petracci 2016). The central area is not subject to these impacts due to the inaccessibility of its coasts. However, some of the main drainage channels (e.g., Canal 1, 9, and Canal A; Fig. 1) are currently being broadened. This might alter hydrogeochemical processes and sedimentation patterns and, consequently, the availability of food for shorebirds (Sutherland *et al.* 2012; Carol *et al.* 2013, 2014).

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