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Winter Population Size Estimations of Three Migratory Sheldgeese in the Southern Pampas, Argentina

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Abstract.—Sheldgeese [Upland Goose (*Chloephaga picta picta*), Ashy-headed Goose (*C. poliocephala*) and Ruddy-headed Goose (*C. rubidiceps*)] have similar migratory patterns, breeding in Patagonia (Argentina and Chile) and wintering mainly in the southern Pampas, Argentina. All of them are species of conservation concern in Argentina. The objective of this study was to estimate species densities using distance sampling and to calculate population sizes over three categories of habitat quality in the southeast of Buenos Aires Province, Argentina. Road surveys (9,200 km) were performed from a vehicle during two consecutive wintering seasons (13 June to 6 July 2011 and 9 June to 4 July 2012). Predicted probabilities of sheldgeese occurrence were divided into three classes of habitat quality. Upland Goose mean density was estimated at 3.72 individuals/km^2, Ashy-headed Goose at 1.62 individuals/km^2 and Ruddy-headed Goose at 0.04 individuals/km^2. Consequently, Upland Goose numbers were estimated at 348,255 individuals, Ashy-headed Goose at 151,803 individuals and Ruddy-headed Goose at 498 individuals in the southeast of Buenos Aires Province. The results confirm former studies regarding the small population sizes of these species in comparison with historic data and suggest a decline in sheldgeese populations. *Received 9 May 2017, accepted 9 September 2017.*

Key words.—Abundance estimation, *Chloephaga* spp., habitat-suitability maps, landscape ecology, road surveys, sheldgeese.

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Sheldgeese [Upland Goose (*Chloephaga picta picta*), Ashy-headed Goose (*C. poliocephala*) and Ruddy-headed Goose (*C. rubidiceps*)] are species endemic to South America. These species have a similar migratory pattern, breeding from October to April in southern Patagonia in Argentina and Chile, and wintering from May to August-September mainly in the temperate grassland ecosystems of the Pampas region of Argentina. Several areas of the original Pampas grasslands were replaced by sown pastures for livestock and croplands (Aizen *et al.* 2009). Thus, human-induced habitat homogenization in the Pampas agroecosystems together with hunting pressures have negatively affected these species (Blanco *et al.* 2008; Pedrana *et al.* 2014). Apart from the populations of Upland and Ruddy-headed geese in Argentina and Chile (hereafter, the continental population), there are other sedentary populations of these species that are restricted to the Malvinas (Falkland) Islands (Summers and McAdam 1993; Bulgarella *et al.* 2014; Kopuchian *et al.* 2016). During the last 40 years, the size of the continental population of Ruddy-headed Goose has been less than 800 individuals, around 10% of the estimated population in the 1900s (Cossa *et al.* 2017). As a consequence, the Ruddy-headed Goose has been listed as "Critically Endangered" in the national Red List of Argentina and declared a "Natural Monument" in Buenos Aires Province, Argentina (López-Lanús *et al.* 2008), although this species still has a global status of "Least Concern" (International Union for Conservation of Nature 2013). There have also been suggestions of a decreasing trend not only for the Ruddy-headed Goose but also

for the other two sheldgeese species (International Union for Conservation of Nature 2013). The continental populations of Upland and Ashy-headed geese declined by at least 50% in the last 30 years, with estimates of 100,000 to 1,000,000 pairs and 25,000 to 150,000 pairs, respectively (International Union for Conservation of Nature 2013). Although hunting of these species has been banned in Argentina, it is still promoted by several outfitters (Blanco *et al.* 2003; Chebez 2008).

Our objectives were to estimate Upland Goose, Ashy-headed Goose and Ruddy-headed Goose density using distance sampling and to calculate population size over three categories of habitat quality in the southern Pampas of Argentina.

Methods

Study Area

The study was conducted in the southern Pampas of Argentina, located in the southeast of Buenos Aires Province, Argentina (between 36° to 41° S and 63° to 58° W). The climate is sub-humid mesothermal with a mean annual temperature of 10 to 20 °C and a mean annual rainfall between 400 and 1,600 mm (Soriano 1991). This area includes the Ventania mountain range, characterized by low mountain ranges that are less than 1,100 m high and the coastal plain with a moderate slope toward the Atlantic Ocean. Currently, most of the original grasslands have been replaced by pastures and croplands, with a specific expansion of soybean croplands, since the 1970s (Baldi and Paruelo 2008).

Field Surveys

We randomly selected 110 road segments of 5 to 88 km totaling 4,600 km. These roads were primarily (90%) on gravel and secondary roads with very low traffic density: fewer than 10 vehicles per transect. Surveys were performed from a vehicle including both sides of the road during two consecutive wintering seasons (13 June to 6 July 2011 and 9 June to 4 July 2012). Data were collected at a speed of 40 kmph from 09:00 hr to 16:00 hr by the driver and one observer, who exchanged positions every 2 hr.

When one flock was detected, we stopped the vehicle and recorded flock size and species composition (aided with binoculars and monoculars). We recorded the distance to the flock center, our bearing relative to north obtained from the inertial compass reading of a GPS unit and the angle of the animal relative to our bearing. The perpendicular distance of contacts to the survey line was calculated from these data (Buckland *et al.* 2001). We avoided double counting of birds during line transects by staying at each sighting for a short period of time (less than 10 min) and by recording the direction of movement of the flock (Gregory *et al.* 2004; Gibbons and Gregory 2006).

Abundance

Using 4,600 km of transects surveyed during 2011, Pedrana *et al.* (2014) modeled sheldgeese distribution in southern Pampas and produced habitat suitability maps of the species for the southeastern Buenos Aires Province using habitat-suitability models. To facilitate interpretation and comparison between species, predicted probabilities of Upland Goose, Ashy-headed Goose and Ruddy-headed Goose occurrence were simplified into three classes of habitat quality (low: 0.00-0.33, medium: 0.33-0.66 and high: 0.66-1.00; Fig. 1). Abundance estimates were calculated for each category of habitat quality and for the whole study area (93,617 km^2). Line transect data surveyed during 2012 were analyzed using package "Distance" in statistical program R (Miller *et al.* 2013). Estimates of each species' density were determined by fitting a detection function to the perpendicular distances of bird groups to the survey line (Buckland *et al.* 2001). We first conducted exploratory analyses to detect and correct the presence of clustering and extreme values (Thomas *et al.* 2010). The key parameter is the detection function ($g(P)$), which models the probability of detecting an animal given its distance (P) from the transect.

The detection function was assessed using three models (Uniform, Half-normal and Hazard rate), and two adjustment terms (cosine and polynomial). We used the Akaike's Information Criterion (AIC; Burnham and Anderson 2002) to choose the best model for the detection function. To estimate the detection function for each species, we pooled sightings across all surveys. Although detectability might change among transects, the property of 'pooling robustness' guarantees the consistency of abundance estimates when all data were analyzed together (Buckland *et al.* 2001, 2008; Thomas *et al.* 2010). Distance sampling allows for identification of outlying observations at extreme distances and suggests appropriate levels of truncation for fitting detection function. Consequently, we truncated our data to 350 m to attain a line transect analysis after the elimination of outliers (Buckland *et al.* 2001).

We took into account the key assumptions to obtain reliable estimation of density using the line transect method and distance sampling (Buckland *et al.* 2001; Thomas *et al.* 2010): 1) individual birds on the road were always detected; 2) all flocks were detected at their initial location, prior to any movement in response to us; and 3) distances were measured accurately with a laser range finder. Another critical assumption in our study was that roads sample the environment at random and do not affect sheldgeese distribution (Thomas *et al.* 2010; Travaini *et al.* 2015). The relationship between species occurrence and distance to the nearest road was modeled by means of the generalized linear model procedure (McCullagh and Nelder 1989). As a result,

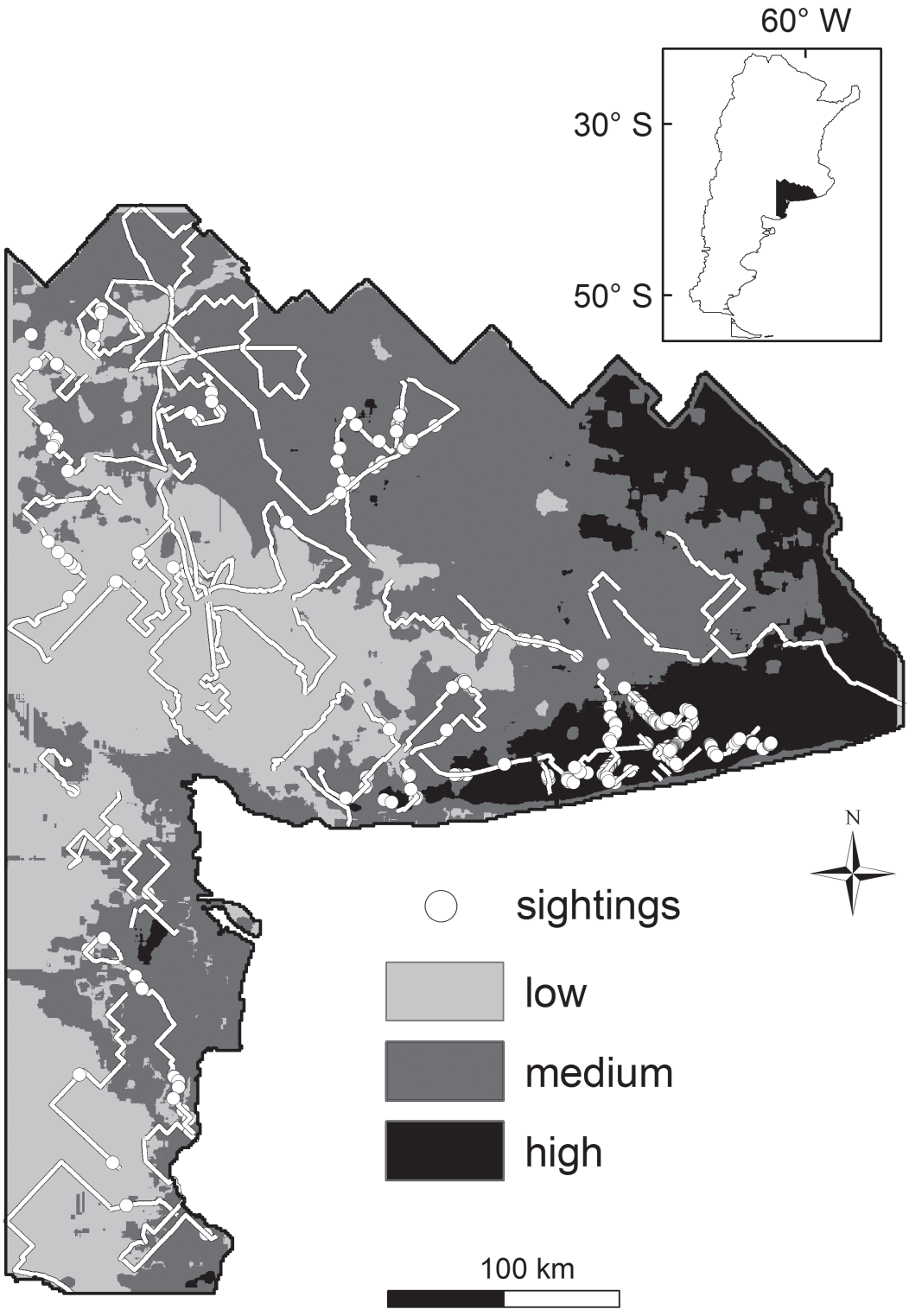

Figure 1. Habitat-suitability map for all sheldgeese (Upland Goose, Ashy-headed Goose and Ruddy-headed Goose) in the southeast of Buenos Aires Province, Argentina. Continuous probabilities of occurrence were categorized in three classes of habitat quality: low (0.00-0.33), medium (0.33-0.66) and high (0.66-1.00).

we found absence of relationship between species occurrence and distance to roads (Type II Wald $\chi^2_1 = 1.46$, $P = 0.22$). Thus, in agreement with Blanco *et al.* (2003), sheldgeese distribution did not seem to be affected by road presence.

RESULTS

In 2012, we registered 153 flocks totaling 11,156 individuals (Table 1). Almost 93% (n = 142) of the observations included individuals of Upland Goose, 46% (n = 70) of Ashy-headed Goose and 8% (n = 13) of Ruddy-headed Goose (Table 1).

The Hazard-Rate key was selected for all species. When we pooled all habitat suitability categories, we estimated Upland Goose mean density at 3.72 individuals/km^2 with a coefficient of variation of 0.22, Ashy-headed Goose at 1.62 individuals/km^2 with a coefficient of variation of 0.32 and Ruddy-headed Goose at 0.04 individuals/km^2 with a coefficient of variation of 0.64 (Table 2). Mean density varied considerably between areas classified as low habitat suitability (2.06 and 0.08 individuals/km^2 for Upland Goose and Ashy-headed Goose, respectively) and areas classified as high habitat suitability (10.21 and 10.10 individuals/km^2 for Upland Goose and Ashy-headed Goose, respectively). We could only estimate Ruddy-headed Goose density in areas categorized as high quality habitat since during the vehicle surveys the species was only seen in habitats of this class (Fig. 1). We estimated a total Upland Goose population of 348,255 individuals (Range = 226,553-535,489), a total Ashy-headed Goose population of 151,803 individuals (Range = 79,172-291,064) and a total Ruddy-headed Goose of 498 individuals (Range = 249-1,492) in the southern Pampas, Argentina (Table 2).

DISCUSSION

Upland and Ashy-headed geese density estimates increased with the categories of habitat quality; areas with better environmental and anthropogenic conditions held higher numbers of these species. Pedrana *et al.* (2014) defined high quality habitat for sheldgeese as areas of low elevation surrounded by water bodies and with croplands combined with a heterogeneous landscape, and far away from urban areas.

This is the first survey focusing on the abundance of sheldgeese across the Argentinean Pampas by applying a distance sampling approach. Comparison with previously published data is difficult since stratification of the study area, survey effort and estimation methods were different. Blanco *et al.* (2003) used a 300-m strip-transect method to calculate population density using 2,278 km of transects covering a total area of 6,180 km^2. In 2003, they estimated an Upland Goose density of 9.9 individuals/km^2, Ashy-headed Goose density of 10.68 individuals/km^2 and Ruddy-headed Goose density of 1.88 individuals/km^2 (Blanco *et al.* 2008). Our density estimates for Upland and Ashy-headed geese (10.21 and 10.10 individuals/km^2, respectively) fall within these estimations; however, our density estimates for Ruddy-headed Goose were 15 to 47 times lower.

Our study confirms previous studies regarding the small population sizes of sheldgeese in comparison with much higher historic data (Blanco *et al.* 2008; Cossa *et al.* 2017). This decline should be used to review the conservation status of sheldgeese species with regard to a modification of the current status of 'Least Concern' under the International Union for

Table 1. Sampling effort (road length sampled), area surveyed and number of sheldgeese flocks and number of individuals (within brackets) in three classes of habitat quality in the southeast of Buenos Aires Province, Argentina.

			Number of Flocks (number of individuals)		
Habitat Quality Category	Sampling Effort (km)	Area Surveyed (km^2)	Upland Goose	Ashy-headed Goose	Ruddy-headed Goose
Low	1,176	32,873	22 (1,571)	4 (42)	0
Medium	2,976	48,306	45 (3,657)	16 (427)	0
High	470	12,438	75 (3,119)	50 (2,207)	13 (133)
Total	4,622	93,617	142 (8,347)	70 (2,676)	13 (133)

Table 2. Estimates of sheldgeese density (individuals/km^2) and population estimate for three classes of habitat (low, medium and high) and for the whole study area (total) in the southeast of Buenos Aires Province, Argentina. Upper and lower limits of 95% confidence intervals for density estimates are given. Estimates of Ruddy-headed Goose density are only reported for high quality habitat since during the surveys the species was only seen in this class of habitat.

Species	Habitat Quality Category	Area Sampled (km^2)	Density (individuals/km^2)	Lower Limit	Upper Limit	CV	Estimated Population
Upland Goose	Low	32,873	2.06	1.12	3.77	0.31	67,594
	Medium	48,306	3.18	1.63	6.20	0.34	153,523
	High	12,438	10.21	4.89	21.31	0.37	126,980
	Total	93,617	3.72	2.42	5.72	0.22	348,255
Ashy-headed Goose	Low	32,873	0.08	0.02	0.29	0.70	2,668
	Medium	48,306	0.49	0.18	1.34	0.54	23,472
	High	12,438	10.10	4.80	21.25	0.36	125,663
	Total	93,617	1.62	0.85	3.11	0.32	151,803
Ruddy-headed Goose	High	12,438	0.04	0.02	0.12	0.64	498

Conservation of Nature criteria (International Union for Conservation of Nature 2013). We strongly believe that the continental populations of these species are of conservation concern due to their restricted range and the susceptibility to certain threats, such as egg collection, predation by introduced carnivores, unregulated hunting and poisoning (Matus *et al.* 2000; Madsen *et al.* 2003; Blanco and de La Balze 2006; Cossa *et al.* 2017). Furthermore, we believe that particular attention should be paid to the Ruddy-headed Goose, which we consider to be in danger of extirpation in Argentina and Chile. Only the application of adequate conservation measures may stop the decline of the Ruddy-headed Goose continental population.

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