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FIRST INSIGHTS INTO THE MIGRATION PATTERN OF AN UPLAND GOOSE (*CHLOEPHAGA PICTA*) BASED ON SATELLITE TRACKING

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Resumen. – Primeros indicios del patrón de migración de un cauquén común (*Chloephaga picta*) basados en el seguimiento satelital. – Información detallada de las estrategias migratorias es necesaria para entender la ecología, evolución y conservación de especies de aves migratorias. Los cauquenes (*Chloephaga* spp.) fueron declarados como especies pestes por el gobierno Argentino en el 1931, asumiendo que estos reducen el rendimientos de los cultivos. Actualmente los cauquenes han sufrido severas reducciones poblacionales y son el foco de esfuerzos conservacionistas. Desde septiembre a abril nidifican en el sur de la Patagonia (Argentina y Chile), mientras que desde mayo hasta septiembre invernan en el sur de la provincia de Buenos Aires (centro-este de la Argentina). El conocimiento preciso de la ruta migratoria es esencial para asegurar que estas especies encuentren los recursos y sitios necesarios durante su migración anual. En este estudio, utilizamos un transmisor satelital para, por primera vez, estudiar la ruta migratoria de un individuo de Cauquén Común, (*Chloephaga picta*), una especie endémica del sur de Sudamérica. Se recibió información durante 121 días (desde septiembre, 2014 hasta enero, 2015). Durante este periodo el ave migró 1485 km desde los sitios de invernada en provincia de Buenos Aires hasta los sitios de reproducción en la provincia de Santa Cruz. Un tramo de la ruta migratoria fue realizado sobre el mar. El desplazamiento mayor fue de 817 km y fue realizado en 19 horas a una velocidad mínima de 43 km h^{-1}.

Abstract. – Detailed knowledge of the migratory strategies is important to understand the ecology and evolution of migration and the conservation of migratory birds The Argentinean federal government declared sheldgeese (*Chloephaga* spp.) pests in 1930, claiming that they reduce crop yield. Currently sheldgeese have suffered severe reductions in their populations and are the focus of serious conservation concern. From September to April they breed in southern Patagonia (Argentina and Chile) while from May to September they winter mainly in the southern Pampas (central east Argentina). The precise knowledge of their migratory routes is essential to ensure protection of necessary resources and sites needed on their annual journeys. Here, by using a satellite transmitter for the first time we unravel the migration route of an Upland Goose (*Chloephaga picta*), a species endemic to southern South America with an unknown migration strategy. We received data for 121 days (from September 2014 to January 2015). During this time, the bird migrated 1485 km from the wintering grounds in Buenos Aires Province to the breeding area in Santa Cruz province, Patagonia. Part of the migration route was over the sea. The largest displacement was 817 km in 19 hours, representing a minimum mean speed of 43 km h^{-1}.

Key words: Argentina, *Chloephaga picta*, migration strategy, Patagonia, satellite transmitter, Upland Goose.

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INTRODUCTION

The capability to track individual migration routes opens extraordinary opportunities to reveal not only migratory routes and connectivity (Trierweiler *et al.* 2014), but also hazards encountered during migration and environmental conditions in the wintering and breeding grounds (Stanley *et al.* 2012, Trierweiler *et al.* 2014). Detailed knowledge of the migratory strategies is important to understand the ecology and evolution of migration (Alerstam 2011), the effects of climate change on populations (Crick 2004) and the conservation of migratory species (Dolman & Sutherland 1994, Webster *et al.* 2012). Despite some long-term banding efforts, our understanding of the migration strategies for the majority of bird species is still rather limited because it is expensive and time-consuming to follow the annual movements of individuals using sophisticated methodology, such as satellite tracking (Seegar *et al.* 1996, Gillespie 2001, Bograd *et al.* 2010). In America, migratory routes are best known for many Nearctic migrants (Pan New World Migration system, *sensu* Joseph 1997), such as shorebirds and terns, while there have been no specific studies for Patagonian migrants (South American Cool-Temperate migration system, *sensu* Joseph 1997). Indeed, the basic natural history of bird migration in most of the Southern Hemisphere is poorly understood, largely because of the lack of infrastructure, fewer ornithologists and birders, and deficits in bird-banding, making tracking any organism across a large scale more difficult (Jahn *et al.* 2009). Bird migration in South America is the third-largest bird migration system in the world and exhibits different types (Chesser 1994, Jahn *et al.* 2004).

Waterfowl are aquatic birds that include, e.g., ducks, geese, and swans. Many of them have historically been an important human food source, and continue to be hunted as game, or raised as poultry for meat and eggs (Boere *et al.* 2007). In South America, the three species of sheldgeese (Ruddy-headed Goose *Chloephaga rubidiceps*, Ashy-headed Goose *C. poliocephala*, and Upland Goose *C. picta*), have a similar migratory pattern since they breed in southern Patagonia (Argentina and Chile) from September to April, while from May to August-September they winter mainly in the southern Pampas (central east Argentina) (Blanco *et* al. 2003, Schulenberg 2010). The Argentinean federal government declared these species pests in 1930, claiming that they reduce crop yield (Blanco *et al.* 2003, Chebez 2008, Pedrana *et al.* 2014). Hunting of this species has been encouraged across their entire range and allowed without restrictions in terms of number of birds killed (Martin *et al.* 1986, Blanco & De la Balze 2006). However, in 2008 all species were listed as endangered by the Argentine government, and hunting was banned although illegal hunting continues (Blanco *et al.* 2003, López-Lanús *et al.* 2008). Conservation efforts are needed to prevent local extinction or even extirpation of sheldgeese. The human-sheldgeese conflict in agricultural landscapes and the national endangered status of these species make it necessary to gather essential knowledge about their migratory patterns and to identify important areas for their conservation throughout their migration routes.

Precise knowledge of the migratory routes is essential to ensure that the sheldgeese have suitable habitat available along their annual journeys. Currently, both ornithologists and managers can obtain information about migratory routes using miniaturized tracking devices that can be attached to the birds, and provide highly detailed information on migration routes and habitat use (e.g., Robinson *et al.* 2009). Here, we use a satellite transmitter to unravel the migration route of an Upland Goose for the first time.

MATERIAL AND METHODS

Study area. The study was conducted in the southern Pampas of Argentina, which range between 36.46°–41.04°S and 63.39°–58.62°W, with extent surface of 106,000 km^2. The climate is sub-humid to humid-mesothermal, with a mean annual temperature of 10 to 20°C and a mean annual rainfall between 400 and 1600 mm (Soriano *et al.* 1991). The area is characterized by low to moderate undulations dissected by lakes and marshes, and large areas of crops and pastures. In the past, pristine vegetation was dominated by grassland steppes of several species of *Stipa* spp. and *Piptochaetium* spp. (Soriano *et al.* 1991). Nowadays, many portions of the original grasslands in the Pampas have been replaced by pastures and croplands, with a particular expansion of soybean in the last few decades (Baldi & Paruelo 2008).

Field work. On 3 September 2014, one male Upland Goose (hereafter *Angus*), Argos ID: 40467) was captured at the Estancia Alta Graciana (38°37’12”S, 60°04’48”W), Buenos Aires province, at the end of the wintering period using foot-noose carpets. Because the species shows a strong sexual plumage dimorphism (males: white, females: reddish-brown) (Narosky & Izurieta 2010) we could identify the captured individual as a male. The individual was weighed (body mass 3.3 kg), banded with a numbered metal band, and equipped with a satellite transmitter (Model K3H 179, 63 g; Kiwisat Argos Transmitters, Sirtrack, New Zealand). The device was attached to the birds’ back using a Teflon harness (Fijn *et al.* 2012, Humphrey & Avery 2014). The whole package weighed 76 g and did not exceed 3% of the individual’s body mass, thus minimizing the effects of carrying an additional weight during movements (Kenward 2001). The procedure used in this study was assessed and approved by the Buenos Aires Provincial Agency for Sustainable Development (OPDS).

Data analysis. Duty cycles were programmed in phases to save battery life while still collecting sufficient data: 1) During the migration period (March–May and mid August–October), we obtained positions every day between 10:00–16:00 h local time (GMT-3); and 2) during the breeding period (November–February), positions were obtained every three days between 10:00–16:00 h local time. Geographical locations were provided by the Argos service, with location accuracy (Class designation) calculated using the Kalman filtering method (Service Argos 2015). Only location classes 3 (accuracy $\leq$ 150 m) and 2 (accuracy $\leq$ 350 m) were used for further analysis (Pfeiffer & Meyburg 2009, Service Argos 2015), while positional fixes associated with less accurate location classes were removed. Positional data were then incorporated into a Geographical Information System (IDRISI Taiga, Eastman 2009).

RESULTS AND DISCUSSION

We received satellite-tracking data for 121 days from 4 September 2014 to 1 January 2015. During this time, the bird migrated a minimum distance of 1485 km from the wintering grounds in Buenos Aires province to the breeding area in Santa Cruz province, Patagonia (Fig. 1). This distance was calculated as the minimum distance travelled and is based on the assumption that the bird travelled in a straight line between two consecutive positions. Initially, *Angus* stayed for two days in an area dominated by crops near the village of Claromecó, Buenos Aires province, where it used an area of 5 km^2 during the day (Table 1, Fig. 1a). Afterwards, the bird headed southwest and migrated a minimum distance of 72 km to a region near the city of Oriente, Buenos Aires province, where it remained for 9 days using an area of 655 km^2 also dominated by crops and pastures (Table 1, Fig. 1b). From Oriente it travelled 120 km south, where it stopped for the second time near Hilario Ascasubi city (Villarino partido) (Table 1; Fig. 1a, b). During this migration from Oriente to Villarino, high-class positions were obtained over the sea, about 20 km from the nearest shore. This is the first finding that sheldgeese migrate over the sea and not only over mainland (Lucero 1992, Rumboll *et al.* 2005).

From Villarino, *Angus* migrated approximately 180 km south to reach an area near the city of Viedma (Fig. 1a, b). There, it stayed for another 3 days, moving around in an area covering ca. 5 km^2. From Viedma, *Angus* eventually travelled around 800 km to reach Santa Cruz province, the first stop in the potential breeding grounds, the 'Central Plateau', Southern Patagonia (Table 1, Fig. 1b), where it stayed again for 3 days before travelling a further 230 km to reach its final destination, Lago Argentino. In this area, further positions were recorded for 101 days covering an area of approximately 16,000 km^2 (Table 1, Fig. 1b), indicating final arrival at the breeding grounds. *Angus* stayed in the last three stopover sites for less than 2 days ('Villarino', 'Viedma', 'Central Plateau'), probably representing the time needed to restore energy reserves between stops. The whole migration from the wintering ground to the breeding ground was performed in two weeks.

The breeding ground selected by *Angus* was located in Santa Cruz province, which is one of the most remote and least populated areas in the world. Relatively low-impact land use, such as extensive livestocking, has been the dominant human activity in the region after colonization by Europeans c. 200 years ago. The area is characterized by hills and plains dissected by small streams and rivers flowing from the Andes. Vegetation is highly uniform and dominated by a mixed steppe of grass and shrubs, which rarely exceed 0.5 m in height (Movía *et al.* 1987) (Fig. 2). Associated with streams, river valleys, and endorheic depressions are ponds, lagoons, and temporarily flooded wet meadows, locally called *mallines*, with hydrophytic vegetation communities. The association of sheldgeese with wetlands, lakes, and streams reported in other studies (Summers & Grieve 1982, Martin *et al.* 1986, Pedrana *et al.* 2011) may reflect a dependence on relatively productive sites and freshwater. These habitats seem to be of special value for this species in the semiarid Patagonian steppe because they may provide an abundant food supply and perhaps also a higher quality substrate to build nests (Martin *et al.* 1986, Summers & McAdam 1993). The area adjacent to villages like El Calafate and El Chaltén, near *Angus*' breeding ground (Fig. 2), is the most important tourist destination in southern Patagonia and has good access by roads (Fig. 2). Although the hunting of sheldgeese is prohibited in Argentina, there are still some hunting lodges in the Patagonian region that continue to

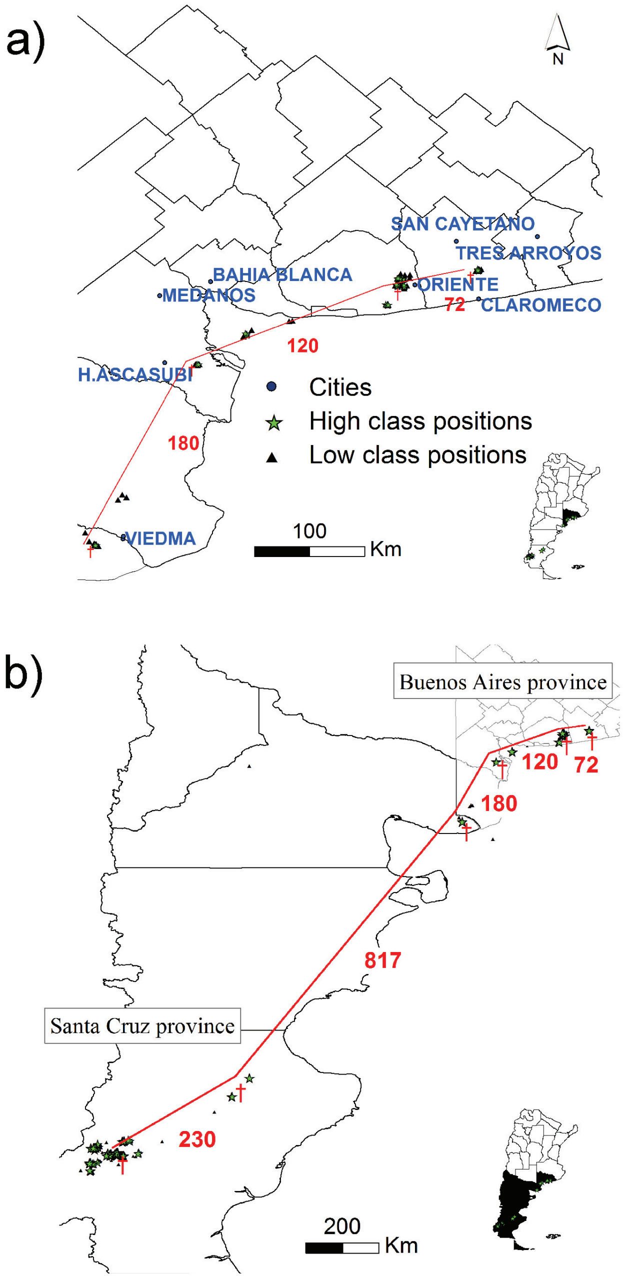

FIG. 1. Migration route of one male Upland Goose (*Chloephaga picta*) satellite-tracked from wintering ground to breeding ground: a) Movements registered in the wintering grounds, Buenos Aires province, Argentina; and b) Movement from wintering grounds to breeding grounds (Santa Cruz province, Argentine). Green stars are high class positions, black triangles low class positions (see Materials and Methods) and the red line is an estimate of the shortest distance between stops.

TABLE 1. Migration route of a male Upland Goose (*Chloephaga picta*) tracked between Buenos Aires and Santa Cruz provinces, Argentina (*cf.* Fig. 1). Minimum travel distance is the distance the bird traveled in a straight line between two positions; area used is the minimum area that enclosed all high class positions registered in a site, and speed between stops the minimum travel speed during migration.

Site name	Nearest town (latitude/ longitude)	Department/ province	N° days on each site	Dates	Min. travel distance (km)	Area used (km^2)	Speed between stops (km/h)
Claromecó	Claromeco 38.85°S, 60.08°W	Tres Arroyos/ Buenos Aires	2	4–5 Sep 2014	0	5	-
Oriente	Oriente 38.73°S, 60.62°W	Coronel Dorrego/ Buenos Aires	10	6-16 Sep 2014	72	655	4
Villarino	H. Ascasubi 39.37°S, 62.65°W	Villarino/ Buenos Aires	2	17–18 Sep 2014	120	2355	5
Viedma	Viedma 40.80°S, 63.10°W	Viedma/ Rio Negro	2	19–20 Sep 2014	180	5	7
Central Plateau	Pico Truncado 46.80°S, 67.96°W	Deseado/ Santa Cruz	2	21–22 Sep 2014	817	4125	43
Argentino lake	Gobernador Gregores 48.77°S, 70.25°W	Lago Argentino/ Santa Cruz	101	23 Sep 2014 to 1 Jan 2015	230	16,827	11

sponsor and advertise their hunting (JP pers. observ.).

From *Angus*'s geographical positions, it was also possible to calculate the minimum speed travelled between stopover sites using an estimate of the shortest distance between these areas. The speed varied from 4 to 11 km h^{-1}, except in the longest migration from Viedma (the last stopover site) to the Central Plateau (the potential breeding ground) where it reached values of 43 km h^{-1} (Table 1). The Satellite Tracking and Analysis Tool (STAT) provided the speed within stopover areas, and the mean speed of *Angus* varied between 2 and 46 km h^{-1} within stopover areas (Coyne & Godley 2005). The Argos service also reported the altitude calculated for each position. The mean altitude varied among the wintering and breeding sites, being lower than 100 m a.s.l. on the wintering ground (Claromecó, Oriente, Villarino, and Viedma) and between 1000–1500 m a.s.l. on the breeding ground (Central Plateau and Lago Argentino).

Based on data from banded sheldgeese two possible migration routes have been postulated (Lucero 1992, Rumboll *et al.* 2005): one over eastern Patagonia along the Atlantic coast and the second along western Patagonia over land. Lucero (1992) considered that the different migratory routes might be related to the breeding location. In our study, *Angus*'s breeding site is situated in southern Santa Cruz province (Fig. 2), and the bird apparently took the eastern Patagonian route, partly across the Atlantic Ocean.

Our study represents the first satellite-tracking study on sheldgeese migration, linking the wintering sites in Buenos Aires province with the breeding areas in Patagonia. Additional studies should be performed to understand the different migration routes and strategies, and to identify hazards that these species might encounter during migration and

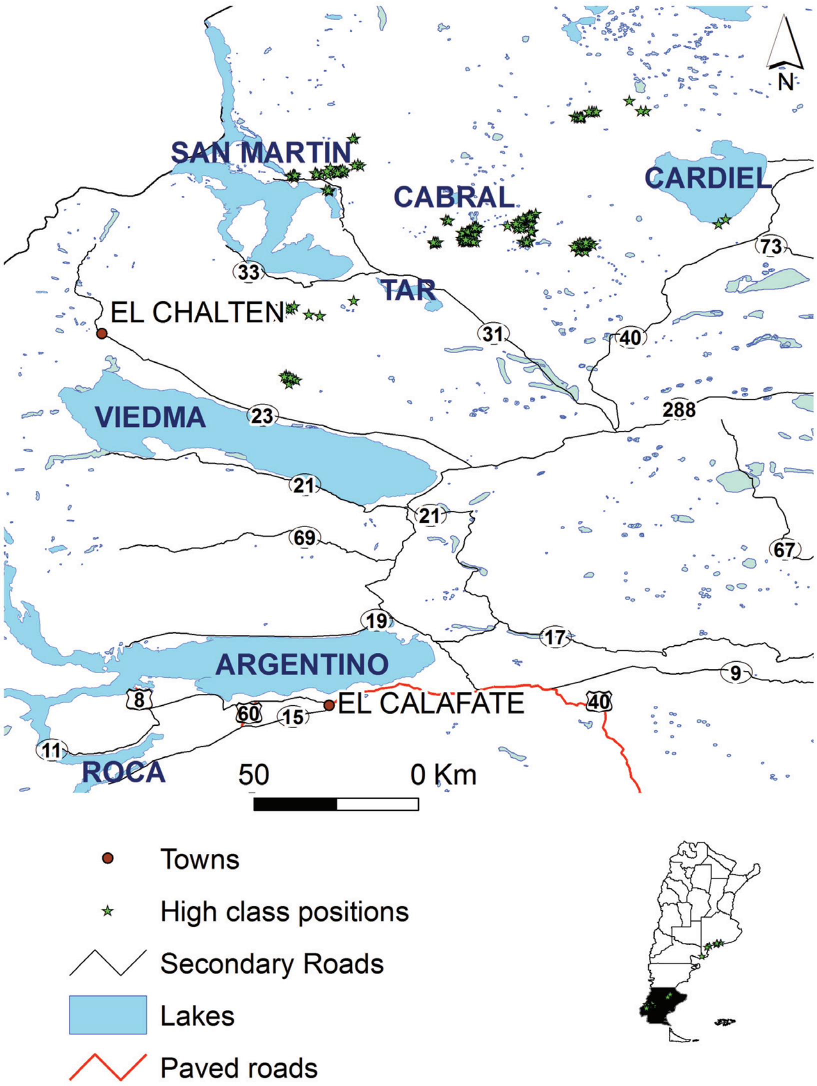

FIG. 2. Geographical positions (green stars) of a satellite-tracked male Upland Goose (*Chloephaga picta*) in Lago Argentino Department in Santa Cruz Province, Argentina (breeding grounds).

in their wintering and breeding grounds, respectively.

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