Status and Reproductive Outcome of the Breeding Population of Striated Caracaras (*Phalcoboenus australis*) at Franklin Bay, Staten Island, Argentina

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Status and Reproductive Outcome of the Breeding Population of Striated Caracaras (*Phalcoboenus australis*) at Franklin Bay, Staten Island, Argentina

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ABSTRACT.—The Striated Caracara (*Phalcoboenus australis*) is a poorly known raptor associated with seabird colonies, restricted to the islands of southern South America, and with an estimated extant population of <2,500 mature individuals. We evaluated the number of breeding pairs, described the characteristics and spatial pattern of nest sites, and estimated breeding output of a population of Striated Caracaras in Franklin Bay, Staten Island, Argentina. We found one of the lower breeding density values reported for this species, although this population is associated with one of the biggest colonies of Rockhopper Penguins. The main material used for the construction of Striated Caracaras' nests was tussac grass, though only half of nests were placed in grassland. The spatial pattern for nest sites corresponds with global and local clustering. All successful Striated Caracaras' nests were at least 250 m from the nearest neighboring nest, were generally closer to the colony of Rockhopper Penguins than failed nests, and had more Rockhopper patches around them. Breeding success was 0.73 successful nests/active nests, productivity was 1.27 ± 1.01 young/active nest, and brood size was 1.75 ± 0.71 young/successful nest. The presence of invasive wild goats and red deer is proposed as a factor that could be restricting

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The Striated Caracara (*Phalcoboenus australis*) is a large subantarctic bird of prey restricted to isolated shores and islands south of latitude 50°S in South America (Ferguson-Lees and Christie 2001). The species is classified as Near Threatened (IUCN 2015) with an extant population of <2,500 mature individuals. They reside mostly on Staten Island (Isla de los Estados) in the Fuegian region and in the Malvinas/Falkland Islands (BirdLife International 2013), with fragmented breeding records in southern Chile (Marín et al. 2006). The species is largely associated with seabird breeding colonies (i.e., Rockhopper Penguins [*Eudyptes chrysocome*], Black-browed Albatross [*Thalassarche melanophris*]). Its breeding season extends from October to February during which it lays 1–4 eggs in a single clutch. It primarily nests on the ground in tussac grasslands of *Poa flabellata* <10 m from seabird nests and feeds its offspring on eggs, chicks, and adults from the nearby colony (Strange 1996, Catry et al. 2008, Liljesthröm et al. 2008).

Striated Caracaras on the Malvinas/Falklands declined as a consequence of direct persecution during the 1900s, and their numbers have not recovered despite the legal protection being formalized in 1999 (Woods 2007). In this archipelago, breeding territories have been recorded as close as possible to the seabird colony, and at the same time as far as possible from the nearest conspecific territory, following an apparently regular pattern (Strange 1996). The published mean distance between breeding pairs during the breeding season ranges 47–700 m, depending on the island studied (Strange 1996, Catry et al. 2008).

It is unclear whether the population on Staten Island is threatened. Unlike populations on the Malvinas/Falkland Islands, persecution by humans has not been recorded on Staten Island, which has long been a Provincial Reserve, and has recently been declared as a National Reserve. However, two factors could potentially affect the viability of the population of Striated Caracaras on Staten

Island in the long term: a) the negative population trend of their apparent main food resource during the breeding season, the globally threatened Rockhopper Penguins (IUCN 2015), which has been declining in numbers in the area for the last decades at a yearly rate of 2% (Raya Rey et al. 2014); and b) the probable, but unknown, impact on the tussac grassland produced by two exotic herbivores, the wild goat (*Capra hircus*) and the red deer (*Cervus elaphus*), introduced in 1856 and 1973, respectively (Valenzuela et al. 2014).

In this context, the main objective of this work is to increase our knowledge on the current status and breeding biology of the Striated Caracaras' population in Franklin Bay, Staten Island, the only breeding population known to coexist with large exotic herbivores, as far as we know. In this study we, a) estimate the number of breeding pairs and describe the characteristics of accessible nests; b) analyze the spatial pattern of nests and productivity; c) estimate the breeding success, productivity, and brood size and; d) evaluate the variation of breeding success in relation to the presence of nearest neighbors, and the distribution and density of the main seabird reproductive patches.

METHODS

We carried out this study between 14 November and 19 December 2014, which corresponds with late incubation period and early chick rearing of Striated Caracaras (Strange 1996).

Study Site.—Our study took place in Franklin Bay, Staten Island, Argentina (Fig. 1; 54° 53′ S, 64° 39′ W), where the mean annual temperature varies from 2.7–9.0 °C, and the mean annual precipitation is 1,500 mm. Strong winds, mainly from the SW are predominant throughout the year (Dudley and Crow 1983). The island is characterized by tussac grassland on the shores and subantarctic forests inland, dominated by evergreen beech (*Nothofagus betuloides*) and winter's bark (*Drimys winteri*). The understory is rich in shrubs, ferns, lichens, and mosses, including diddle dee (*Empetrum rubrum*) which is one of the most abundant shrubs in the area (Niekisch and Schiavini 1998). Several species of seabirds and marine mammals breed on the shores of Staten Island (Chebez and Bertonatti 1994, Schiavini 2000, Schiavini and Raya Rey 2001, Schiavini et al. 2004). Franklin Bay holds one of the biggest
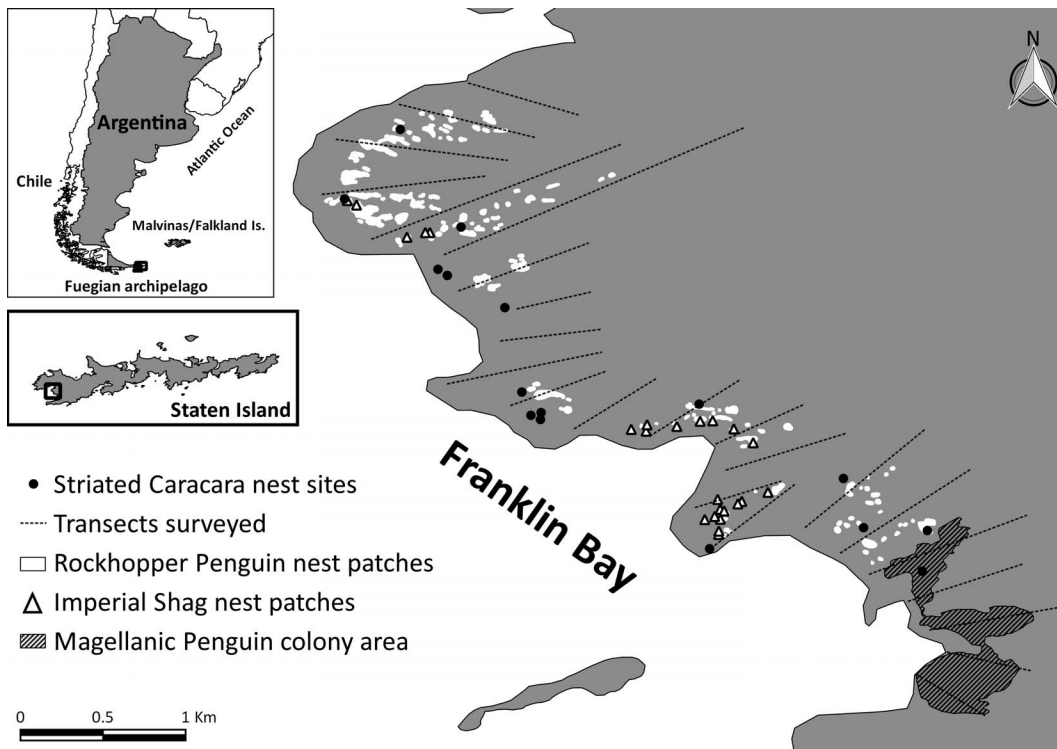
FIG. 1. Study site showing the location of Striated Caracaras' nests sites, the main seabird colonies, and the transects surveyed during the breeding season of 2014–2015.

colonies of Rockhopper Penguins (127,000 breeding pairs; *Eudyptes chrysocome*), a colony of Imperial Shags (4,600 breeding pairs; *Leucocarbo atriceps*), and a colony of Magellanic Penguins (1,600 breeding pairs; *Spheniscus magellanicus*; Raya Rey et al. 2014). Nests of Rockhopper Penguins are arranged in 133 discrete patches around the bay which vary largely in area (range 30–5,848 m^2) and density of breeding pairs within each patch (range 0.22–1.74 nest/m^2), while Magellanic Penguins' nests are scattered in a colony in the southern area of Franklin Bay. Imperial Shags breed in 24 discrete patches which overlap with the colony of Rockhopper Penguins, ranging 11–1,442 breeding pairs per patch (ARR, unpubl. data) (see Fig 1).

Breeding Population Survey.—To obtain a census of breeding pairs of Striated Caracaras, we surveyed 24 transects in a SW-NE direction, perpendicular to the coastline, with variable lengths (range: 250–1,250 m), and a 200-m separation between each one (Fig 1). The study area (i.e., the area bounded by the band transects) included all the main seabird colonies on the site and its total area was 3.69 km^2. We followed Woods (2007) to identify active territories, and when territorial behavior was observed, we searched exhaustively for the active nest and aged the members of the breeding pairs following Strange (1996). Nests were georeferenced, and when accessible, standard variables were measured to record basic characteristics of emplacement, dimensions, and construction materials following Tapia et al. (2007). In some cases, nests were inaccessible because of the steepness of cliffs where they were placed. We visited each accessible nest every 7–10 days to record its breeding output, and depending on the time of encounter, each nest was visited 2–4 times during the study.

Spatial Analysis of Nest Sites.—We analyzed the spatial pattern of nest sites in the study area using three Ripley's functions, which have the advantage that all point-to-point distances are

evaluated to show spatial clustering at different scales (Ripley 1977, Getis and Ord 1992, de la Cruz Rot 2008). We used Global-K and Local-K functions to identify global or local clustering of events (i.e., nest sites). By contrast, Weighted-K function measures the degree of clustering of points by some mark, in this case by productivity (i.e., number of young produced/nest) at the time of the last visit of each nest. For both global analyses, we used radial distances ranging between 50–800 m with distance categories every 50 m. For the local analysis, we used radial distances ranging between 20–500 m with distance categories every 20 m. In each case, we ran 99 Monte Carlo simulations to build a confidence envelope over the null hypothesis of complete spatial randomness of the points. In all cases, if the statistical $L(d)$ (for global and local analysis) and $L_w(d)$ (for global analysis of weighted points) lie within the confidence envelope at a certain distance, then the points (or the weighted points) are randomly distributed. If the statistic lies in the upper confidence interval, the events tend to be clustered and conversely, if it lies below the confidence envelope, the events follow a regular pattern. We compared the distance between nesting sites and the closest breeding patches or areas of colonies of Rockhopper Penguins, Magellanic Penguins, and Imperial Shags in the study area using paired t-tests and also measured the distance between nest sites of Striated Caracaras.

Breeding Output.—Finally, we estimated the apparent breeding success as the proportion of breeding pairs that produced at least one young by the end of the study. We also measured apparent productivity as the mean number of young produced per active nest and the apparent brood size, as the mean number of young produced per successful nest at the same time. Breeding success, productivity, and brood size are interpreted as apparent because we were not able to monitor each nest until fledging, which is the traditional way to estimate these parameters (Newton 1979, Steenhof and Newton 2007). The values obtained are an overestimation of the real values, because we assume no more breeding attempts occurred between the end of the study and the end of the breeding season. We also analyzed breeding success in relation to the distance to the nearest conspecific neighbor and variables relative to the

distribution and breeding density of seabird colonies.

RESULTS

We found 16 nests of Striated Caracaras in the study area, yielding a density of 4.34 breeding pairs/km². Half of these nests were placed on cliffs of variable height (mean 39.8 m, range 6–100 m) at different heights from the cliff bases (mean 30.6 m, range 2–90 m). The other nests were built on the ground, in most cases associated with one individual tussac grass (*Poa flabellata*). All breeding birds presented full-adult plumage (>5 years old, Strange 1996). In accessible nests ($n =$ 11), pairs were found either incubating eggs or raising nestlings. All accessible nests were constructed mainly with tussac grass fibers. However, two nests also contained branches of diddle dee and one nest included anthropogenic elements (pieces of rope and fishing lines). Nest area was 0.34 ± 0.14 m² (mean, SD), ranging 0.20–0.69 m². Nests were nearer patches of Rockhopper Penguins (68 ± 58 m, mean, SD) than patches of Imperial Shags (376 ± 222 m, $t = -5.74$, $P <$ 0.001) and the colony of Magellanic Penguins ($1,822 \pm 1,126$ m, $t = -6.18$, $P < 0.001$). Indeed, three nests were placed at the edge or inside Rockhopper Penguins' breeding patches. The distance between nest sites of Striated Caracaras in this study was 298 ± 184 m (mean, SD).

The global spatial pattern analysis indicated scale dependent clustering (Fig. 2A). However, productivity did not correlate with spatial location, as its pattern showed no difference with the complete spatial randomness (Fig. 2B). In the latter case, the statistical $L_w(d)$ takes non-null values starting from a radial distance of 250 m. Given that $L_w(d) = 0$ for null values of the mark (i.e., a failed nest), all successful nests (i.e., ≥1 young produced) were separated at least 250 m from the nearest neighbor. For the local spatial pattern analysis, three nests located in the center of the study area (see Fig. 1) presented significant local clustering at radial distances of 140–240 m, 280 m, and 360–440 m respectively. All other nests showed values of $L(d)$ which corresponded with randomly distributed events.

The apparent breeding success for the accessible nests was 0.73 successful nest/active nest, apparent
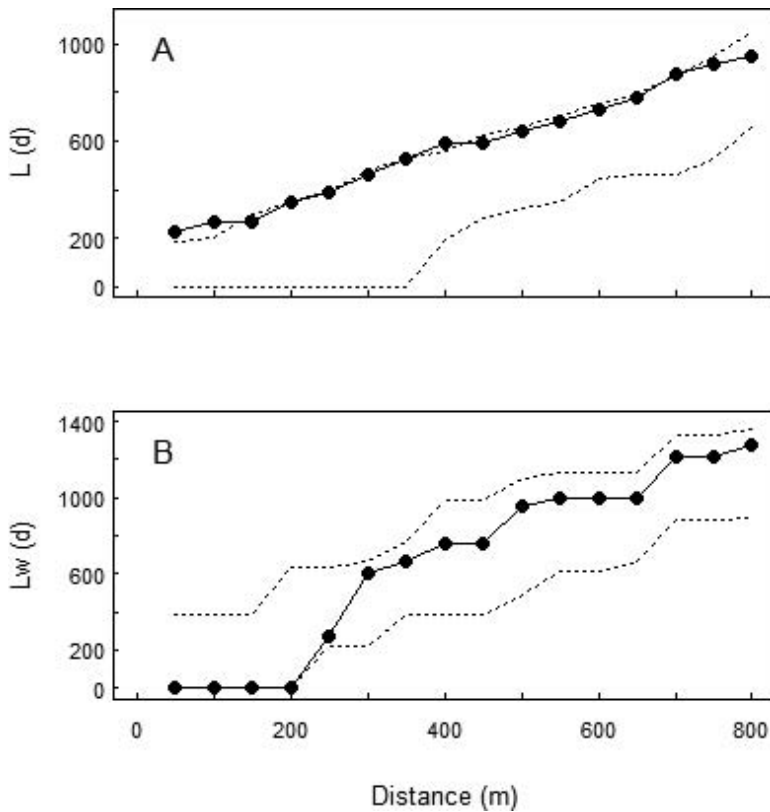
FIG. 2. Spatial patterns analysis using K-Ripley's functions. A) Global pattern analysis using Global-K function for events (presence of a Striated Caracaras' nest) in the study area. B) Weighted-K function for a subsample of accessible Striated Caracaras' nests using productivity as a mark (see text).

productivity was 1.27 ± 1.01 young/active nest, and apparent brood size was 1.75 ± 0.71 young/successful nest (range: 1–3 young/successful nest). When analyzing the distance to the nearest neighbor, failed nests were consistently closer to other nests of Striated Caracaras compared to successful nests (Fig. 3A). Also, successful nests were generally closer to reproductive patches of Rockhopper Penguins and had more patches in a 200-m radius around the nest, with respect to the failed ones (Fig. 3B, C). We did not carry out any statistical inference in any of these data sets because of small sample sizes.

DISCUSSION

Breeding density in birds of prey is mainly limited by food and nest site availability (Newton 1979). In this case, food limitation seems not likely, since this population of Striated Caracaras is associated with one of the largest Rockhopper Penguin colonies in the world. The breeding density estimate in our study area is similar to that reported by Catry et al. (2008) for a growing population on New Island but lower than the value reported for a stable population on Beauchene Island (Lewis Smith and Prince 1985, Strange 1996), both in the Malvinas/Falkland Islands (Table 1). The values found for apparent breeding success, productivity, and brood size do not seem particularly large, and we found the lowest mean brood size reported until now for the species.

Nest placement in this study differs from that previously reported. In our case, half of the nests were built in cliffs, in contrast with the report of
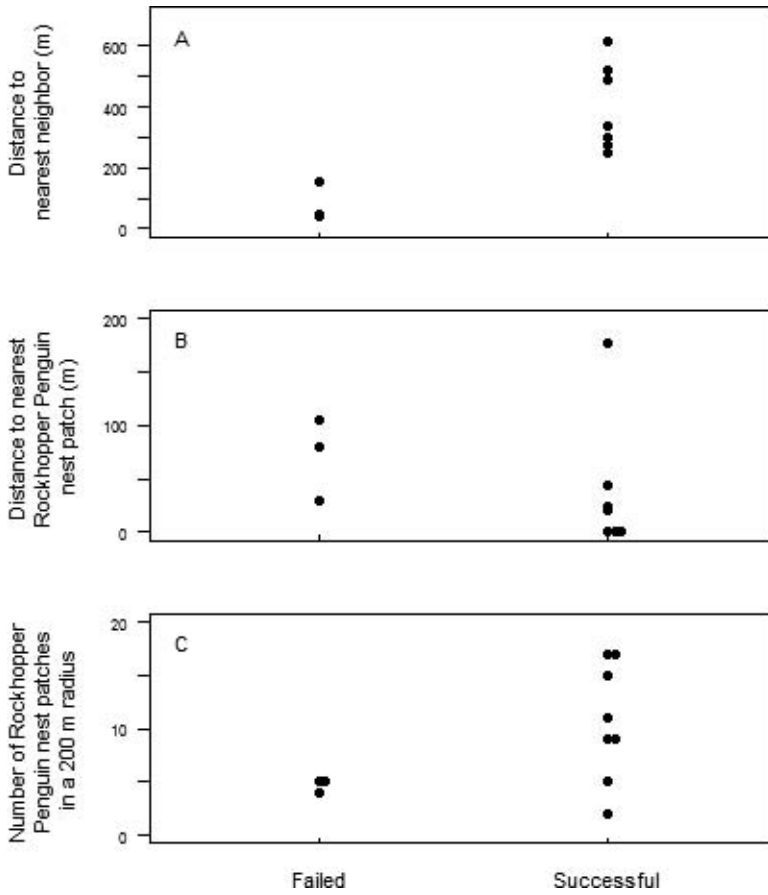
FIG. 3. Relationship between reproductive success and ecological variables in the study area for a subsample of accessible nests.

Strange (1996), which found 95% ($n = 53$) of the nests on the ground. Simultaneously, even though the nests of Striated Caracaras were relatively close to patches of Rockhopper Penguins, separa-

tion between the two seems to be greater than the distance previously described. Strange (1996) reports that 74% of his surveyed nests ($n = 19$) were 10 m or less from seabird colonies, while in

TABLE 1. Reproductive parameters of Striated Caracaras published in the literature and presented in this work.

Season	Location	Density (territorial pairs/km²)	Surveyed active nests	Breeding success (successful nests/ total nests)	Productivity (young/ active nests)	Brood size (young/ successful nests)	Source
1979/80	Beauchene Island (Malvinas/Falkland Is.)	35.83[a]	64	0.42[a]	0.88 ± 1.16[a]	2.07 ± 0.83[a]	Lewis Smith and Prince 1985
2005/06	New Island (Malvinas/Falkland Is.)	-	18	-	-	2.50 ± 0.51	Catry et al. 2008
2006/07	New Island (Malvinas/Falkland Is.)	4.31	36	-	-	2.36 ± 0.59	Catry et al. 2008
2014/15	Franklin Bay, Staten Island (Argentina)	4.34	11	0.73	1.27 ± 1.01	1.75 ± 0.71	This study

[a] Indicate values calculated from original data.

our study only 19% ($n = 16$) were consistent with that metric. It could be possible that the difference in nest placement along with the low breeding density found could be a response to the absence of suitable nesting sites near penguin patches. The spatial pattern analysis showed that nesting sites tended to be clustered in our study area, while in other sites the distribution of breeding pairs tended to be regular (Strange 1996), which in birds of prey is expected when availability of nesting sites is not a limitation and the population has reached carrying capacity (Newton 1979). Nests showing local clustering could be influencing the global pattern, as they represented 19% of the nest sites we studied.

Populations that reach their carrying capacity show non-breeding or non-territorial adults during the breeding season, which reproduce only when a given site becomes available as a consequence of the death of one or both members of a breeding couple (Newton 1979). Catry et al. (2008) reported several flocks of non-breeding individuals (up to 65 birds) foraging near seabird colonies, but none of these individuals presented full-adult plumage. Moreover, the authors reported three territorial pairs with at least one of the members of the couple presenting immature plumage, which is a typical sign of a growing population with available breeding sites (Newton 1979). In our case, not only did all breeding birds present full-adult plumage, but we anecdotally recorded several non-breeding adults foraging or eating carrion in flocks with juveniles and immature birds. Even though we could not estimate the abundance of Striated Caracaras, it seems likely that most adult birds in the study area are non-reproductive, and thus we hypothesize this population has reached its carrying capacity limited by nest site availability.

We propose that population dynamics of the Striated Caracaras in Franklin Bay could be complex and include the effect of the presence of introduced herbivore species known for their detrimental effect on native flora communities, the negative effect over the reproductive outcome of seabirds and other vertebrates in oceanic islands, and the promotion of local extinctions in areas where similar species are absent (Cronk 1989, Veblen et al. 1989, Takatsuki 2009, Pafilis et al. 2013). In our case, two main effects of the exotic goats and deer are proposed.

On the one hand, these herbivores could be affecting the abundance and/or cover of tussac grassland. In ungrazed islands of the Malvinas/Falkland Islands, this grass covers >60% of the land, forming a monospecific community with some individuals 3.5 m high and >300 years old which provide favorable conditions for nest placement (e.g., temperature on the ground surrounded by tussac is between 4–20 °C higher than in uncovered soil; Lewis Smith and Prince 1985). The reduction or the lack of this resource could be affecting the caracaras in three ways. First, direct reduction of potential nesting sites could be limiting the maximum number of breeding pairs in the study area. Second, the relative distance to their main food resource, the nearest reproductive patch of Rockhopper Penguins, may be increased thus augmenting their foraging energy expenditure. Third, nesting in other emplacements, like cliffs, could be in this context, suboptimal for egg incubation, chick development, or both.

On the other hand, during the winter, while seabirds are not present, both goats and deer could potentially be an important component of the carrion portion of Striated Caracaras' diet, a well-documented situation for raptors in other invaded scenarios (Speziale and Lambertucci 2013). Striated Caracaras in the Malvinas/Falklands Islands apparently move in winter to farmland settlements, where they feed partly on livestock as carrion (Rexer-Huber and Bildstein 2013). If something similar happened on Staten Island, it would be expected that winter survival will be higher than in a non-invaded system. These two situations would be resulting in a lower population recruitment rate because of fewer breeding pairs and more intraspecific competition.

The total eradication of the invasive species is proposed for the restoration of island environments (Glen et al. 2013), but in this case it seems important to have more information to assess the consequences of this intervention, as Striated Caracaras' population could be suddenly losing an important winter-time subsidy, thus abruptly changing its dynamics with unknown consequences. It would be important to know the current status of other populations of Striated Caracaras in other potential breeding locations of Staten Island, Año Nuevo Island, and in Tierra del Fuego main Island, including the seasonal

movements of individuals, where seabird colonies are not so important in numbers, but goats and deers are absent (Schiavini 2000, Schiavini et al. 2005).

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An Indigo Bunting (*Passerina cyanea*) Transporting Snails During Spring Migration

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ABSTRACT.—Organisms with limited motility may use animal transport as a mechanism for dispersal. Migratory birds can provide a vehicle to move small organisms great distances, which may allow them access to areas that are otherwise inaccessible. During normal mist netting operations at a spring migration banding station along the northern Gulf of Mexico coast in Louisiana, USA, we encountered an Indigo Bunting (*Passerina cyanea*) with numerous snails, possibly *Galba cubensis*, underneath its breast feathers. While encounters of songbirds carrying snails appear rare, long-distance migrating songbirds represent a possible mechanism to transport small snails great distances to expand ranges, colonize new areas, or maintain genetic continuity. *Received 12 October 2016. Accepted 28 February 2017.*

Key words: animal transport, chenier, Gulf of Mexico, Louisiana, migration, snails, stopover.

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Migratory animals are capable of traveling considerable distances, often traversing diverse habitats along their journey (Rappole 1995, Dingle 1996, Newton 2008). Through these large-scale movements, migratory animals may act as dispersal agents for both plants and animals (e.g., Raven 1963, Rees 1965, Mukherjee et al. 2014). Migratory birds can provide a mechanism for dispersal over great distances to habitats that some organisms may not otherwise reach, such as habitats located on isolated mountain summits, islands, and across ecological barriers (e.g., Cockerell 1921, Rees 1965, Mukherjee et al. 2014). Additionally, many migratory birds stop to rest and refuel *en route* (Rappole 1995, Newton 2008) as they encounter a number of habitats on a single journey.

Animals like snails might seem limited in their dispersal abilities, but birds have been shown as a mechanism to transport them across great distances (Rees 1965, Dundee et al. 1967, Vagvolgyi 1975, van Leeuwen et al. 2012). Migratory landbirds, shorebirds, and waterfowl have been found to transport snails either internally or externally (e.g., Rees 1965, Dundee et al. 1967, Wesselingh et al. 1999, van Leeuwen et al. 2012,