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TRANSATLANTIC MOVEMENT OF DOMESTIC PIGEONS *Columba livia domestica*

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Abstract: Historically, Domestic pigeon (*Columba livia domestica* Gmelin, 1789) (Columbiformes, Columbidae) breeders use the species to promote race competitions which over the time could select traits to increase the flight performance and spatial orientation capabilities. Although the species has remarkable navigational abilities, it is possible that these birds sometimes become disoriented pushing the individuals to fly off-course and over distances larger than usual. Here we report a Domestic Pigeon ringed in the Canary Islands (Spain) observed in the Abrolhos Archipelago, eastern Brazil, and compiled similar events (N = 5) in the Southwest Atlantic Ocean coast. Our results indicate that these events are largely unnoticed in the scientific literature as most of them were found in non-scientific newspaper and academic conferences, thus, untraceable from scientific databases as Scopus and Google Scholar. As domestic pigeons are possible intermediate hosts of diseases, we encourage the creation of a systematized database of this kind of movements of these birds, including the profile of these vagrants and the circumstances in which these events occur, which can be a basis to be used for scientists and decision makers.

Keywords: Abrolhos archipelago; alien species; citizen science; coastal islands; ring recovery

INTRODUCTION

The Rock Pigeon *Columba livia* is native to the Palearctic regions and is one of the most successful non-native globally spread birds (Baptista *et al.* 1997). This species is mostly sedentary, with daily-trip records up to 20 km between roosting sites and feeding sites (Baptista *et al.* 1997). However, over many generations of artificial selection, the long-distance flight capacity of pigeons has been enhanced together with their ability to return to their geographic origin (Shapiro & Domyan 2013). The artificial selection was intensified by the fact that most pigeon breeders are involved in racing competitions where well-trained birds fly over long distances to reach their home base, which can be highly lucrative for the most successful trainers (Baptista *et al.* 1997). This long history of artificial selection created a flight performance and spatial orientation capabilities unprecedented for Columbidae (Batista *et al.* 1997, Shapiro & Domian 2013).

One of the remarkable navigational abilities in Domestic Pigeons is the capacity to track reference points and mapping the geographical surface, which allow Domestic Pigeons to return to their home lofts from distant and unfamiliar sites (Wiltschko & Wiltschko 2017). These navigational abilities are mainly oriented by the Earth's magnetic field, although many factors such as storms, magnetic anomalies, and the initial orientation behavior seem to interfere on the precision of navigation (Dennis *et al.* 2007). The effect of environmental conditions on this intricate mechanism of navigation might explain the fact that these birds sometimes become disoriented. Occasionally, pigeons land on vessels and use them to overnight (Nicol 1945, Smith 1987), a behavior consistent with other terrestrial birds (*e.g.* Hutto 1998, Dell'Ariccia *et al.* 2009). Their ability to fly long distances and the possibility to rest aboard ships might allow these pigeons to move far from their origin when disoriented. Finally, these disoriented individuals might integrate with local conspecifics. This species is spread throughout the world in association with human populations (GISD 2019) and therefore presents opportunities for vagrants to interbreed with local populations. The long history of domestication and synanthropy which remotes at least 4000 years ago in the Mediterranean region has spread this species around the world (Shapiro & Domyan 2013), very often reaching high densities even in oceanic islands (*e.g.* Haag-Wackernagel 1995, Sacchi *et al.* 2002, Przybylska *et al.* 2012).

Invasive birds have been assumed to cause minor or minimal impacts when compared with invasive mammals. Rodents (*Rattus* spp.), for example, are responsible for major impacts on insular wildlife (Towns *et al.* 2006). For this reason, some authors claim it is more appropriate to adopt control measures against the populations of invasive birds than eradication (Strubbe *et al.* 2011, Spatz *et al.* 2017, but see Adelino *et al.* 2017). Nevertheless, these invasive birds, especially columbid species, are still potential vectors for many diseases to native birds. Evans *et al.* (2016) in an exhaustive review assessed the impact of 415 species with self-sustaining alien population and detected impact for 116 of them. For Columbiformes, particularly, Evans *et al.* (2016) compiled 31 invasive populations, including *Columbia livia* and 27 other columbid species; Columbiformes was ranked sixth in the number of impacts and was notably associated with disease transmission, although other types of impacts have also been documented for columbid alien populations, such as hybridization with native species (Table 1). Unfortunately, for most alien bird population, the available data are insufficient to accurately assess their impacts (Evans *et al.* 2016), especially in less studied regions as islands of the South Atlantic Ocean (Martin-Albarracin *et al.* 2015).

The Rock Pigeon is a potential vector of several different pathogens to both humans (Haag-Wackernagel & Moch 2004) and poultry (Chong *et al.* 2013). Feral pigeons are carriers of at least 60 human pathogens, including bacteria, viruses, fungi and protozoans (Haag-Wackernagel & Moch 2004), and may also spread diseases and parasites to native birds (Gottdenker *et al.* 2005, Bunbury *et al.* 2008, Chong *et al.* 2013), including in insular environments (Harmon *et al.* 1987). Considering the potential threats of transatlantic movements to native fauna, vagrants should be monitored closely and with scrutiny, even if reports in the scientific literature and details are scant (see Sick 1997, Piacentini *et al.* 2003).

In order to highlight the need for better monitoring practices, we present a new record of transatlantic movement of a Domestic Pigeon, which was encountered in the Abrolhos Archipelago, in eastern Brazil. We also assessed how common these events are by compiling the available records from the Brazilian coast and oceanic islands. Thus, we discuss the frequency and potential threats of these events for native bird populations as well as the necessity of a protocol for environmental agencies and public health authorities to handle such events. We also suggest some best practices for managing similar occurrences and practical ways to make these records more accessible.

MATERIAL AND METHODS

To compile similar records, we conducted a bibliographic survey on Google Scholar and Scopus databases, using the following keywords: "transatlantic movement", "accidental dispersal", "homing pigeon" and "*Columba livia*". We also expanded our searching into the Google

Table 1. Mechanism classes, magnitudes and descriptions of the environmental impacts recorded for columbid alien populations, according a global review by Evans *et al.* (2016). Source of magnitude and description of impacts: Blackburn *et al.* (2014).

Impact mechanism	Magnitude and description
Competition	**Minor**: Competition affects fitness (*e.g.,* growth, reproduction, defense, immunocompetence) of native individuals without decline of their populations. **Minimal**: Negligible level of competition with native species; reduction of fitness of native individuals is not detectable.
Hybridization	**Massive**: Hybridization between the alien species and native species is common in the wild; hybrids are fully vigorous and fertile; pure native species cannot be recovered by removing the alien, resulting in replacement or local extinction of native species by introgressive hybridization (genomic extinction). **Minor**: Hybridization between alien species and native species is observed in the wild, but rare; hybrids are weak and never reach maturity (reduced hybrid viability), no decline of pure native populations. **Minimal**: No hybridization between alien species and native species observed in the wild (prezygotic barriers), hybridization with a native species might be possible in captivity.
Transmission of disease to native species	**Moderate** (includes *Columba livia*): Transmission of diseases to native species resulting in a decline of population size of at least one native species, but no changes in community composition. **Minor**: Transmission of diseases to native species affects fitness (*e.g.*, growth, reproduction, defense, immunocompetence) of native individuals without decline of their populations.
Interaction with other alien species	**Minor**: Interaction of an alien species with other aliens (*e.g.*, pollination, seed dispersal) affects fitness (*e.g.*, growth, reproduction, defense, immunocompetence) of native species' individuals without decline of their populations; changes would not have occurred in the absence of the species. These interactions may be included in other impact classes (*e.g.*, predation, apparent competition) but would not have resulted in the particular level of impact without an interaction with other alien species. **Minimal**: Interaction of an alien species with other aliens (*e.g.*, pollination, seed dispersal) but with minimal effects on native species; reduction of fitness of native individuals is not detectable.

Search using the previous keywords, in addition to the equivalent terms in Portuguese. All occurrences recorded up to October 2019 were compiled. We also present a primary record of transatlantic movement of a Domestic Pigeon, which was obtained opportunistically during the participation (18-24 March) of one of us (GSS) in the 2014 season of the Program for Seabirds Monitoring in Abrolhos Archipelago, carried out by the Associação Vila-Velhense de Proteção Ambiental (AVIDEPA).

The Abrolhos Archipelago is located off the southern coast of Bahia state, Brazil, approximately 70 km from the mainland (17º20'–18º10' S, 38º35'–39º20' W). It is an important nesting site for at least seven species of seabirds (Mancini *et al.* 2016): Red-billed Tropicbird *Phaethon aethereus*, White-tailed Tropicbird *P. lepturus*, Masked Booby *Sula dactylatra*, Brown Booby *S. leucogaster*, Magnificent Frigatebird *Fregata magnificens*, Brown Noddy *Anous stolidus*, and Sooty Tern *Onychoprion fuscatus*. The archipelago comprises five islands protected as a National Marine Park, to which visits are only authorized for scientific purposes (IBAMA 1991). The only exception is Santa Bárbara Island (17°57'50" S, 38° 41'44" W), which is under the jurisdiction of the Brazilian Navy, and has a small population of Navy personnel, researchers, and employees of the Chico Mendes Institute for Biodiversity Conservation (ICMBio). The infrastructure consists of eight houses, which are supported by supply ships (IBAMA 1991).

RESULTS

On 21 March 2014, one of us (GSS) detected an adult Domestic Pigeon during fieldwork on Santa Bárbara Island. The bird was observed foraging with a small flock of House Sparrow *Passer domesticus*, a second exotic species already established on the island. The pigeon was later found inside one of the houses and was captured manually without offering any resistance. The pigeon was ringed (Figure 1), and the ring (#093986 2013) identified the Federacíon Columbófila Gran Canária pigeon breeder's association located in the Canary Islands, Spain. We contacted this association, which confirmed that the pigeon belonged to the Noroeste club and probably got lost during a local competition (Federacíon Columbófila Gran Canarias, *in litt.* 2015). However, the contact was unable to provide any further information on the pigeon's last known location or date, and no data were obtained from the Noroeste club. The association confirmed that similar events had been recorded previously but was not able to provide further details.

In addition to this primary observation, we found five records of transatlantic movement of homing pigeons arriving in the Brazilian coast (Figure 2), two of them available from non-scientific newspapers, one from an academic conference, and two records from specific literature. We decided to not include a prospective additional record of Domestic Pigeon from the Canary Islands at the state of Bahia in 2011 because we were unable to contact the pigeon breeder who posted this record. The record description as well as the photograph were available on a personal website which is currently deactivated. None of

Figure 1. Adult Domestic Pigeon *Columba livia domestica* recorded in March 2014 in the Abrolhos Archipelago, eastern Brazil, with a ring of the Federacíon Columbófila Gran Canária, association located in the Canary Islands, Spain (photos by Gabriel S. Santos).

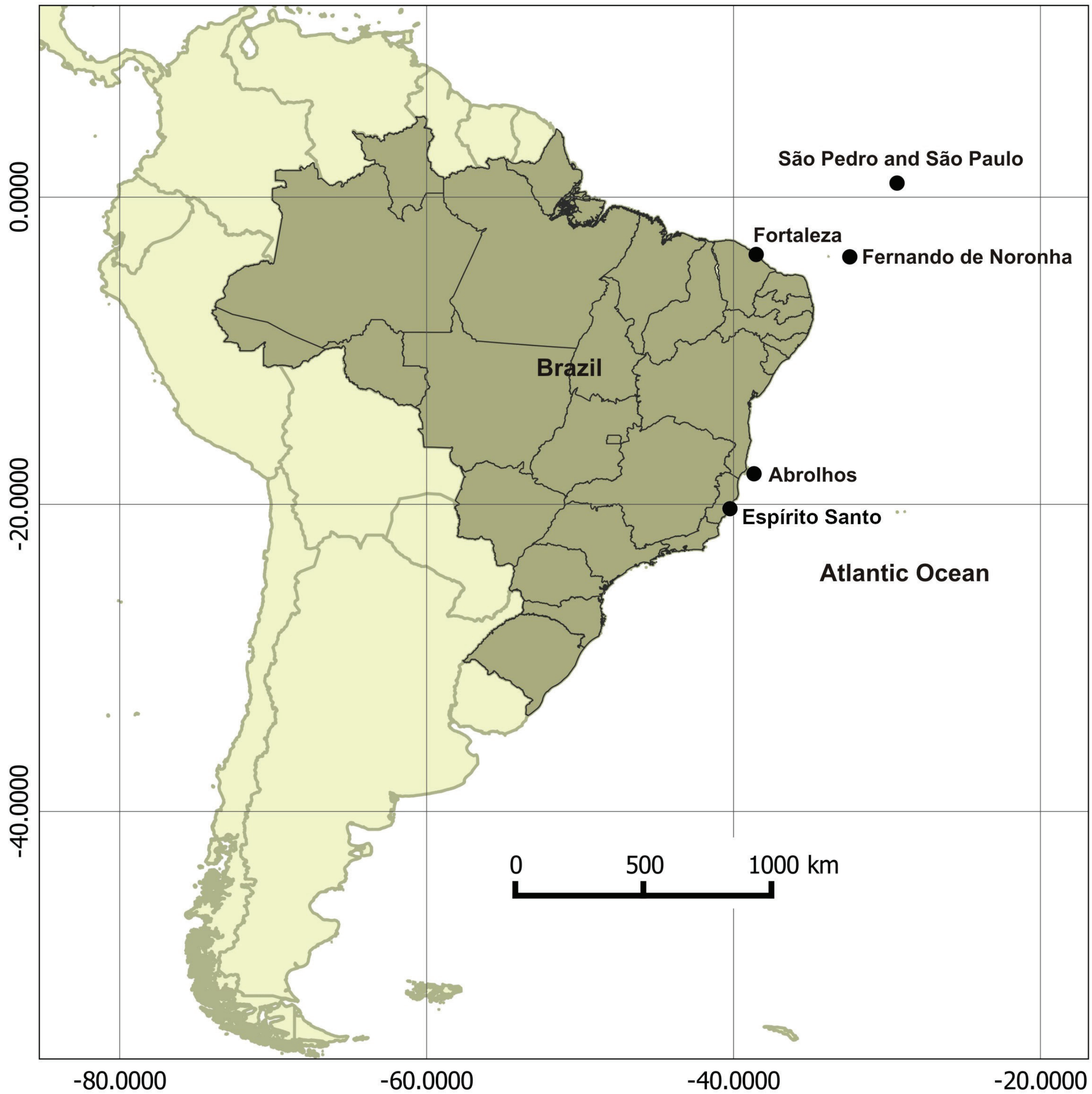

Figure 2. Localities with records of transatlantic movement of the Domestic Pigeon *Columba livia domestica* on the Brazilian coast and oceanic islands, indicating the original record in Abrolhos Archipelago (present study) and three localities with available secondary records.

the five records compiled were indexed in the Scopus or Google Scholar. They are:

Fortaleza, Ceará state (03°44' S, 38°31' W): the earliest record available, Sick (1997: 345) reported that a Domestic Pigeon from Guelley - England, arrived on the northern coast of Brazil in 1986. The author noted that the pigeon had covered "a distance of 5,700 miles to land at Fortaleza in Ceará, Brazil, still in good physical condition!" (Sick 1997: 345).

Espírito Santo state (20°17' S, 40°18' W): Sick (1997) also provided a second record from a Homing Pigeon from the Canary Islands recovered in the coast of the Espírito Santo state in 1990. The author stated that at that time it was suggested that the bird had "hitched a ride" on ships (Sick 1997: 345). No further details are available for this record.

São Pedro and São Paulo Archipelago (00°55'00" N, 29°02'05" W): This archipelago comprises five small rocky islands in the equatorial mid-Atlantic under the jurisdiction of the Brazilian Navy, approximately 1000 km off the northeastern coast of

Brazil. On 10 February 2003, Piacentini *et al.* (2003) recorded a Domestic Pigeon ringed (171043 RFCE 2002) by the Real Federacíon Columbófila Española (Royal Spanish Columbian Federation) from the Canary Islands. Seven days later, the pigeon had left the archipelago (Piacentini *et al.* 2003). On 6 March 2012, the presence of a second individual, also from the Canary Islands, was reported from the archipelago (Globo 2012), but no further details are available.

Fernando de Noronha (03°51' S, 32°25' W): An archipelago of volcanic origin approximately 350 km off the northeastern coast of Brazil, with a total land area of 18 km^2, most (90 %) of which constitutes the main island. A ringed Domestic Pigeon (supposedly the same individual) was photographed in April and September 2015. The ring was identified as being from the Kingdom of Morocco, in North Africa (Globo 2015), but the bird disappeared before being captured for examination and the ring number was lost (L. Fukui *in litt.* 2016), impeding the confirmation of details at the home club or federation.

DISCUSSION

A total of six unambiguous occurrences (five compiled plus our original record) reporting transatlantic dispersions of trackable Domestic Pigeons cited above suggest that it should be considered as a potential pathway of new diseases introduction and should be not neglected. Furthermore, these records represent only trackable pigeons which could represent but a small portion of pigeons crossing the Atlantic Ocean. Thus, these records reinforce the need for a more systematic recording of these long-distance movements when possible, especially to reveal the origins and the potential parasites and diseases they might transport. Additionally, to provide a useful protocol to handle these occurrences, we should start tracing the ways which these individuals arrived on the Brazilian coast.

We believe that all these recorded pigeons benefitted from ships that provided stopovers for them. Is largely accepted that human activities facilitate species movements over larger distances than expected in natural conditions (Gallardo *et al.* 2015). Additionally, there is an abundant literature reporting terrestrial birds resting in overseas ships (Nicol 1945, Casement 1983, Smith 1987) which seems to be the case of at least one of these records, on Espírito Santo state (Sick 1997). We are aware that a unique explanation for these records might not hold because we cannot check detailed information, such as day and geographic coordinates, from departure to time of arrival. However, it is unlikely that pigeons might flight such long distances without rest. The Abrolhos Archipelago, for example, is approximately 5,600 km from the Canary Islands, in a straight line. Even considering the possibility of natural stopovers on oceanic islands, this trajectory would require a nonstop flight of more than 1,500 km. It is not impossible if we consider an average of 74 Km/h by flights over 300 km, as reported by Gessaman & Nagy (1988), however, it requires high energetic demand (Gessaman & Nagy 1988) and seems unlikely for a pigeon.

The transportation of species far from their origins is increasing with globalization (Levine & D'Antonio 2003, Hulme *et al.* 2009). Indeed, three of the six transatlantic movements of Domestic Pigeons reported here occurred within the past eight years, suggesting that these transatlantic vagrants are becoming more frequent as the ship traffic and the international maritime commerce increase. This hypothesis is well-supported for many alien plants, insects, and mollusks (Levine & D'Antonio 2003), and should hold for these transatlantic vagrant pigeons which were likely ship-assisted to arrive in Brazilian coast. Global and Brazilian shipping statistics also seem to support this hypothesis. According to Brazilian syndicate of shipping companies (Sindicato Nacional das Empresas de Navegação Marítima – Syndarma – [www.syndarma.org.br]), the number of seagoing vessels increased almost threefold in the last four decades, and the volume of cargo circulating in Brazil has increased approximately fourfold in the last eight years. Nevertheless, tracking a temporal trend between alien species records and international trade is challenging (Levine & D'Antonio 2003), because national commerce policies vary from country to country (Sánchez & Pinto 2016, Laxe *et al.* 2016). Moreover, birds using ships as stopovers may only do so briefly, taking more advantage of a number of potential stepstones.

The profile in where these transatlantic movements have been reported reveals that they have been largely overlooked by both breeders and researchers. Most reported occurrences come from local newspapers and academic conferences, which are not trackable by the searching databases accessed in our review. Additionally, Federations only have the numbers of rings distributed for the breeders and additional information as departure date or health conditions are only possible by contacting the breeders in which have no obligation to provide such information. The lack of personal or business interest in providing information about their birds might be one reason for why such information was not reported in any occurrence compiled here as well as we have experienced by ourselves. As these records are been systematically compiled for the first time, two constraints to find and compile these records are critical to our conclusions (i) local newspapers might not report similar records because the public audiences might not be interested in reading about vagrancy events every year, and (ii) only ringed pigeons are recordable in cases of accidental movement. Consequently, our reports represent only a small proportion of possible similar events and we cannot figure out the real implications for public health.

The negative effects of invasive species, especially in oceanic islands, are currently well supported (Doherty *et al.* 2016, Spatz *et al.* 2017). However, the magnitude of impacts varies from case to case and assessing these impacts is not a simple task. Impacts of alien species might be expressed in different levels of biological organization (*e.g.* physiological, populational, community), take decades before becoming detectable, and exert different magnitude of impact on different sites (Crystal-Ornelas *et al.* 2020). Unfortunately, these effects have been the subject of increasing denialism, which occurs when, far beyond the legitimate informed skepticism, doubts are created on a current scientific consensus (Russell & Blackburn 2017).

Given the magnitude of the potential impacts which these transatlantic vagrants might offer to native fauna, we cannot wait for an unequivocal evidence of direct impact before bringing these records formally for the scientific literature. Being cautious about potential invasions or disease transmission from vagrant Domestic Pigeons is prudent. Disease spreading or the establishment of an invasive population of Domestic Pigeons can result from just few individuals reaching high densities within a few years (Harmon *et al.* 1987, Smith 1987). In the Galapagos archipelago, Domestic Pigeons are suspected to have introduced the protozoan *Trichomonas gallinae* for the endemic and critically endangered Galapagos Dove *Zenaida galapagoensis* (Harmon *et al.* 1987), resulting in a long-term and expensive eradication project (Phillips *et al.* 2012). The establishment of new parasites and pathogens are among the most harmful alien groups to the faunal health (Young *et al.* 2016), and sporadic dispersions of a few pigeons may potentially introduce pathogens to novel habitats, as reported for long-distance migrant species (Altizer *et al.* 2011). Thus, we recommend the implementation of a systematic reporting system for vagrant ringed Domestic Pigeons recorded. Whenever members of the public, including sailors, find a ringed bird, they should record details (including photographs) and report the findings to the relevant bodies, such as environmental agencies and public health authorities.

The technology now available greatly facilitates this process, in particular cell phones that can photographically document these events. Allied to the technology, citizen science ornithological platforms, such as eBird (www.ebird.org), iNaturalist (https://www.inaturalist.org/), Wikiaves (www.wikiaves.com.br), have experienced a recent expansion of functionalities and there are many users around the world including Brazil as well as all South America (Schubert *et al.* 2019). These platforms provide a great contribution for the development of a bigger and more accurate database, particularly in poorly explored areas (*e,g.* Alexandrino *et al.* 2018). These platforms also allow us to regularly record species occurrences in a given place which might be extremely useful for monitoring alien species (Vanderhoeven *et al.* 2017), although, regular records of non-rare species (*e.g.* Domestic Pigeons) are unincentivized (Alexandrino *et al.* 2018). Furthermore, taking a clear picture of ring numbers and reporting the picture is an important piece of information that should be spread for these platforms, however, there is currently no place to accommodate that information on these platforms. Finally, researchers such as ornithologists and/or ecologists should interact more with breeders to provide open-access online information about their ring system (color and sequence), which is important information for citizen science.

Our results indicate that transatlantic movements of domestic pigeons are largely unnoticed in the scientific literature. As domestic pigeons are possible intermediate hosts of many diseases, it is important to have more control of these vagrants, including their profile and health status, and the circumstances in which these events occur. Thus, a database summarizing these records can basis scientists and decision makers if some intervention is necessary. This systematic report can be facilitated by the use available technologies, including the use of citizen science ornithological platforms, such as discussed in the present review. Additionally, a better interaction between researchers and bird breeders can improve substantially information about these events and is strongly recommended.

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