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REVIEW ARTICLE

Non-native bird species in Brazil

Espécies de aves não nativas no Brasil

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Abstract

Many non-native species of birds have been introduced beyond the limits of their natural geographic ranges, where they may subsequently establish viable populations and perhaps become invasive. Much attention in the literature has been devoted to the study of bird introductions, but relatively little of that attention has been focused on introductions to the continental tropics. Here, we compile published data on records of non-native bird species introduced to the wild in Brazil, with the aim of organizing and standardizing available information to facilitate future studies in this context. A total of 59 bird species were classified as introduced in Brazil, with one further species believed to be a recent natural colonist. Published information implies that 14 species have established or probably established non-native populations in Brazil, while a further 10 species have possibly established non-native populations. In this context, we map the non-native distributions of non-native species of birds in Brazil. Additional research is needed to confirm the status of these species, as well as to establish practical measures to combat and control introductions.

Key words: alien birds, biological invasions, exotic species.

Resumo

Muitas espécies não nativas de aves têm sido introduzidas para além dos seus limites geográficos naturais, onde elas posteriormente podem estabelecer populações viáveis e tornarem-se invasoras. Muita atenção tem sido dedicada a estudos com introdução de aves na literatura, mas relativamente pouca atenção tem sido focada em introduções nos continentes tropicais. No presente trabalho, compilamos os dados publicados sobre os registros de espécies de aves não nativas introduzidas à vida selvagem no Brasil, com o objetivo de organizar e padronizar as informações disponíveis para facilitar futuros estudos nesse contexto. Um total de 59 espécies de aves foi considerado introduzido no Brasil. Há, ainda, uma espécie adicional que acreditamos ser um recente colonizador natural. As informações publicadas indicam que 14 espécies têm estabelecido ou provavelmente estabeleceram populações não nativas no Brasil, enquanto outras 10 espécies têm a possibilidade de estabelecerem populações não nativas. Nesse contexto, mapeamos a distribuição das espécies não nativas de aves no Brasil. Pesquisas adicionais são necessárias para confirmar a situação dessas espécies, bem como para estabelecer medidas práticas para combater e controlar as introduções.

Palavras-chave: aves invasoras, invasões biológicas, espécies exóticas.

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Introduction

Pimentel *et al.* (2001) and Cox (2004) estimate that as many as 500,000 species worldwide have been introduced to the wild by humans in regions beyond the limits of their natural geographic ranges (such species are hereafter termed "non-native"), where they may subsequently establish viable populations and perhaps become invasive (for definitions and a description of the invasion process, see Blackburn *et al.*, 2011). It is no surprise, therefore, that this process of non-native species introduction is recognized as a significant component of environmental change. Non-native species may prey on, parasitize, compete with and hybridize with natives, and many are also considered agricultural pests and vectors of diseases related to humans (Lockwood *et al.*, 2007; Pimentel, 1997). Hence, invasions by non-native species often result in significant losses of economic value, biological diversity and function of the affected ecosystems (Hulme *et al.*, 2009; Wittenberg and Cock, 2001).

One of the best-studied taxa in respect of the invasion process is birds (Blackburn *et al.*, 2009). Almost 1,000 bird species have been introduced to the wild in areas beyond their natural range limits, while more than 400 appear to have established viable non-native populations (Dyer and Blackburn, unpubl. data). However, most studies of non-native birds have concerned translocations by Europeans to and from their colonies in other temperate zones (notably North America, South Africa, Australia, New Zealand), and to islands around the world (e.g. in the Mascarenes, Hawaiian Islands, Caribbean). Relatively few studies have considered translocations by non-Europeans or to continents in the tropical belt (Drake *et al.,* 1989; Pysek, 1995; Rodríguez, 2001; Pysek *et al.*, 2008). There is little systematic information on the occurrence of non-native bird species in Brazil. Therefore, we compiled published data on records of non-native bird species introduced to the wild in Brazil, summarizing what is known about the occurrence of these species. We also used this information to classify the establishment status of these species in the region to which they have been introduced.

Methods

We performed a systematic search of published books, papers and web databases for records of non-native bird species (as defined above) seen in a wild state (i.e. outside of captivity or domesticity) in Brazil, using search terms in both Portuguese and English. We used Google to search the internet for the phrases "birds introduced in Brazil", "exotic birds in Brazil", "non-native birds in Brazil", "list of birds in Brazil", "birds records in Brazil" and "birds community in Brazil". We also searched papers published in 16 journals (*Acta Biológica Paranaense, Acta Scientiarum Biological Sciences, Atualidades Ornitológicas, Biota Neotropica, Boletim CEO, Boletim do Museu Paraense Emilio Goeldi, Bulletin of the International Council for Bird Preservation, Comunicações do Museu de Ciências e Tecnologia da PUCRS, Cotinga, Iheringia, Ornitologia Neotropical, Papéis Avulsos de Zoologia, Revista Brasileira de Biologia, Revista Brasileira de Ornitologia, Revista Brasileira de Zoologia, The Wilson Bulletin*) from 1975 to 2011. We also obtained one as yet unpublished record through personal communication with Ricardo Castilho. We considered all records of non-native species seen in a wild state, regardless of whether or not the species went on to establish a self-sustaining population.

We used the descriptions of the distributions of the 14 non-native bird species with established or probably established populations, and the 10 non-native bird species with possibly established populations in Brazil to map their extents of occurrence. All maps were created using ESRI ArcMap GIS software version 9.3. Species distributions were mapped to the smallest area recorded, be that an individual park within a city, or at state level. In order to identify areas of high non-native bird density, a species richness map was created by projecting the range maps onto a hexagonal grid of the world, resulting in a geodesic discrete global grid, defined on an icosahedron and projected onto the sphere using the inverse Icosahedral Snyder Equal Area projection. This resulted in a hexagonal grid composed of cells that retain their shape and area (865.5 km^2) throughout the country.

Results

Fifty-five references including information on non-native bird species were found, from which a total of 59 species had populations classified as non-native in Brazil. Of these, two species (*Chloris chloris* and *Carduelis carduelis*) were introduced to neighbouring countries (Argentina and Uruguay) and subsequently expanded their distributions into Brazil, and one species (*Corvus albus*) was probably a ship-assisted vagrant. The remaining 56 species were non-native species recorded in a wild state in Brazil following the escape or release of individuals from captivity. A further species (Western Cattle Egret *Bubulcus ibis*) was identified as a recent arrival in Brazil, but one that may have arrived there following natural colonization of South America from Africa.

The 59 non-native bird species recorded as established or probably established non-native population (E) or possibly established non-native population (P) in Brazil are as follows:

Agapornis personata (Reichenow, 1887) – The Yellow-Collared Lovebird is native to north-eastern Tanzania (Forshaw, 1977). A breeding pair was seen in São Paulo in 2000, but a lack of subsequent records suggests that establishment did not occur in the area (Figueiredo, 2010). Individ-

uals of captive origin were also observed in 2005 in Curitiba (Straube *et al.*, 2009).

Agapornis roseicollis (Vieillot, 1818) – The Rosy-Faced Lovebird occurs naturally in south-western Africa (Forshaw, 1977). Individuals originating from captivity were observed in the wild in the city of Curitiba in 2003 and 2006 (Straube *et al.*, 2009).

Alopochen aegyptiacus Linnaeus 1766 – The Egyptian Goose is native to Africa (Gill and Donsker, 2012). Individuals were recorded in São Paulo city in 2006, where they were considered likely to have escaped or been released from captivity. A couple of individuals were still present the following year (Figueiredo, 2010), but it is too early to judge whether establishment has occurred.

Amazona aestiva (Linnaeus, 1758) (E) – The Turquoise-Fronted Amazon occurs naturally in north-eastern Brazil south to Paraguay and northern Argentina (Forshaw, 1977). For some years it has been recorded as introduced in the urban area of Porto Alegre, and has also been identified in other cities in the state (Bencke *et al.*, 2010).

Dozens of individuals escaped from a breeding facility in Curitiba, and today this species is established in the city (Straube *et al.*, 2009). It is also recorded as introduced in Maringá (Galina and Gimenes, 2006), and in the municipality of Vargem Grande Paulista, São Paulo State (Figueiredo and Lo, 2000). A pair of birds was recorded in Reserva Ecológica Guapiaçu in the state of Rio de Janeiro, having escaped from captivity (Pimentel and Olmos, 2011). Individuals of this species have also been seen in the city of Rio de Janeiro (Mallet-Rodrigues *et al.*, 2008), and it is considered common in places in Rio de Janeiro State (Gagliardi, 2011). It has also been recorded as introduced in the state of Espírito Santo (Simon, 2010) and on the northern coast of Bahia (Lima, 2006).

Amazona farinosa (Boddaert, 1783) – The Mealy Amazon occurs naturally in Brazil in the States of Pará, Mato Grosso, Maranhão, Bahia, Minas Gerais and São Paulo (Sick, 1997). Oren (1984) recorded attempts to introduce it to Fernando de Noronha Island in the 1960s, but without success.

Amazona rhodocorytha (Salvadori, 1890) – The Red-Browed Amazon occurs in Brazil from Alagoas to Rio de Janeiro, Serra do Mar and the highlands and coastal lowlands of east Minas Gerais (Sick, 1997). Individuals escaped or released from captivity were observed in Curitiba in 2006 (Straube *et al.*, 2009).

Anas flavirostris Vieillot, 1816 – The Yellow-billed Teal occurs naturally in Brazil in the southern State of Rio Grande do Sul (Sick, 1997). Individuals observed in 1993 in São Paulo city were probably of captive origin, but there is no evidence that the species is established there (Figueiredo and Lo, 2000).

Anas platyrhynchos (Linnaeus, 1758) – The Mallard shows a wide native distribution in the Northern Hemisphere, Europe and North America (Gill and Donsker, 2012). A couple of individuals observed in 2011 swimming in a river in the city of Aguas da Prata, in the State of São Paulo, were probably of captive origin (R. Castilho, personal communication, 2011). Mallards are common in captivity across the world.

Anodorhynchus hyacinthinus (Latham, 1790) – The Hyacinth Macaw is native to Brazil, occurring in the States of Pará, Maranhão, southern Piauí, Bahia, Minas Gerais, Goiás and Mato Grosso (Sick, 1997). Individuals of probable captive origin were recorded in São Paulo city in 1993 (Figueiredo and Lo, 2000; Höfling and Camargo, 1993).

Ara ararauna (Linnaeus, 1758) – The Blue-and-Yellow Macaw occurs widely in the Neotropics from Central America to São Paulo State in Brazil (Sick, 1997). Simon *et al.* (2007) recorded free-flying individuals of captive origin in Vitória.

Aratinga aurea (Gmelin, 1788) (P) – The Peach-Fronted Parakeet occurs naturally in Brazil from Amazonas south to Parana (Sick, 1997). Figueiredo (2010) recorded escaped or released individuals in 2007 and 2009 in the city of São Paulo. Gagliardi (2011) recorded this species as also introduced, although not common, in Rio de Janeiro State.

Aratinga cactorum (Kuhl, 1820) – Considered abundant in the scrublands and savannas of northeast Brazil (Sick, 1997), the Caatinga Parakeet was also recorded from 1999 to 2006 in the city of São Paulo (Figueiredo, 2010). It is not known whether populations are established at the site.

Aratinga jandaya (Gmelin, 1788) (P) – The Jandaya Parakeet is native to north-eastern Brazil from Alagoas, Pernambuco, Ceará and Maranhão south through Piauí State (Forshaw, 1977). Individuals introduced by "environmental organizations" or escaped from captivity were observed breeding in the wild on the northern coast of Bahia State (Lima, 2006). It is also recorded as introduced but uncommon in the State of Rio de Janeiro (Gagliardi, 2011).

Aratinga nenday (Vieillot, 1823) – According to Sick (1997), the Nenday Parakeet occurs naturally in Brazil only in the southwestern state of Mato Grosso, and is also present in the neighbouring countries of Bolivia, Paraguay and Argentina. Individuals released or escaped from captivity were observed in Curitiba in the years 1988, 1989, 2000 and 2003, but without evidence of establishment (Straube *et al.*, 2009).

Aratinga solstitialis (Linnaeus, 1766) –The Sun Parakeet occurs naturally in Brazil in Roraima, northern Amazonas and Pará, and probably north-western Amapá (Forshaw, 1977). Oren (1984) recorded one individual escaped from captivity on Fernando de Noronha island in 1982, followed by records of individuals between 1987 and 1991 (Soto *et al.*, 2000). However, there were no subsequent records of this species from the island (Silva, 2008).

Brotogeris chiriri (Vieillot, 1818) (E) – Yellow-Chevroned Parakeets occur naturally from southern Pará to central and eastern Brazil, and from northern Maranhão and Ceará to west of São Paulo (Pinto, 1978). The species has been introduced and is established in the city of Rio de Janeiro (Pacheco, 1994; Sick, 1997), and was recorded as locally common on the State Bird List in 2011 (Gagliardi, 2011). Captive individuals have also been released in the city of São Paulo (Höfling and Camargo, 1993; Willis and Oniki, 2003); in Curitiba, with records for 1989 (Straube *et al.*, 2009); and in Salvador, Bahia State (Lima, 2006). The species also appears well established in the urban area of Porto Alegre in the State of Rio Grande do Sul, where it has been observed since 1997 (Bencke, 2001; Efe *et al.*, 2001; Fontana, 2005), although there is no confirmation of breeding here (Bencke, 2010).

Brotogeris versicolurus (Statius Muller, 1776) (P) – The White-Winged Parakeet occurs naturally in Amazonian Brazil (Sick, 1997). Two specimens were collected on the margin of the Paraná River, possibly having escaped or been released from captivity, and the authors claimed that the species is established in the area (Scherer-Neto and Straube, 1995). It was also recorded as introduced on the northern coast of Bahia, possibly by "environmental authorities" or via escape from captivity (Lima, 2006).

Cacatua galerita (Latham, 1790) – The Sulphur-Crested Cockatoo is native to New Guinea, the Aru islands, and northern and eastern Australia (Forshaw, 1977). Individuals of captive origin were recorded in Curitiba in 1990 (Straube *et al.*, 2009).

Callipepla californica (Shaw, 1798) – The California Quail is a native of western North America from Canada to Baja California (Gill and Donsker, 2012). Individuals have been exported annually from Chile to Argentina and Brazil, but their status in the latter is unknown (Inskipp, 1975; Lever, 2005).

Carduelis carduelis (Linnaeus, 1758) – The European Goldfinch is found naturally in Eurasia and northern Africa (Dias, 2000; Long, 1981). It was introduced in the early 20th century to Uruguay, where it is apparently well established (Ridgely and Tudor, 1989). The first record of this species in Brazil was in 1994 in the state of Rio Grande do Sul, followed by others in 1998 and early 1999 (Dias, 2000). According to Dias, the Brazilian records indicate that the presence of this species in Brazil also results from immigration from the Uruguayan population.

Cariama cristata (Linnaeus, 1766) – The Red-Legged Seriema is a species typical of savanna regions, occurring naturally in central Brazil west to the State of Mato Grosso. It has benefited from deforestation, extending its range to the Amazon and Rio de Janeiro (Sick, 1997). Galina and Gimenes (2006) recorded this species as introduced in the central northern part of Parana State, where it is probably limited to Ingá Park.

Chloris chloris (Linnaeus, 1758) – The European Greenfinch is native to the Western Palearctic region (Cramp and Perrins, 1994; Merilä *et al.*, 1996). It was introduced in the late 19th century to Uruguay, where it is well established locally, and it has also been recorded as introduced in Argentina (Ridgely and Tudor, 1989). In 1990, two individuals were observed in the far south of the State of Rio Grande do Sul, with likely origin from Uruguay (Bencke, 2001), where they occur along the Uruguayan coast up to the border with Brazil (Azpiroz, 2001; Bencke *et al.*, 2010; Olmos, 2009; Rocha, 2008). This species seems a likely candidate to colonize Brazil by immigration from neighbouring countries.

Columba livia domestica (Gmelin, 1789) (E) – The Domestic Rock Pigeon is a descendant of the rock pigeon *Columba livia* of Mediterranean Europe (Sick, 1997). It is found on all continents and now has a large distribution throughout South America, especially in cities where they cause considerable damage to buildings and monuments due to their corrosive excrement (Matthews, 2005). The species was introduced to Brazil in the 16th century as a domestic bird, but individuals became partially wild and independent of human care (Sick, 1997). The Domestic Rock Pigeon now occurs in every State of Brazil (GISD, 2005; InfoNatura, 2007), and the National Database I3N Brasil (2012) lists records from 240 Brazilian cities.

Columbina minuta (Linnaeus, 1766) (P) – The Plain-Breasted Ground Dove occurs naturally from Mexico to Paraguay and southern and central Brazil (Sick, 1997). It was introduced on the northern coast of Bahia by the "environmental authorities", where it has been reported breeding (Lima, 2006).

Coragyps atratus (Bechstein, 1793) – Widely distributed in Brazil (Sick, 1997), the Black Vulture was introduced unsuccessfully to the island of Fernando de Noronha in the 1960s (Oren, 1984), probably to feed on the island's carrion (Silva, 2008).

Corvus albus Muller, 1776 – The Pied Crow is native to central and southern Africa (Laiolo and Rolando, 2003). It has been recorded in Brazil in the State of São Paulo (Silva and Olmos, 2007). According to these authors, it was observed in the port region of Santos in 2004, 2006 and 2007, with other records in 2006 and 2007 from Cubatão. Its arrival was likely to have been ship-assisted.

Cyanocorax cyanopogon (Wied, 1821) – The White-Naped Jay occurs from northeast Brazil to Goiás, Mato Grosso and Minas Gerais (Ridgely and Tudor, 1989). It was recorded as a release or escape from captivity in São Paulo city in 1987 and 2010, although further investigation is needed to clarify whether or not the species is maintaining an established population (Figueiredo, 2010; Figueiredo and Lo, 2000).

Cyanoloxia glaucocaerulea (d'Orbigny and Lafresnaye, 1837) – Sick (1997) recorded the Glaucous-Blue Grosbeak as naturally distributed from Argentina and Uruguay to Paraguay, and in Brazil in west São Paulo and Mato Grosso do Sul. It was recorded on the northern coast of Bahia in 1984 in a savanna area in the municipality of Dias D'Ávila having escaped from captivity (Lima, 2006). One isolated record in São Paulo city in 2010 also suggests the escape or release of caged individuals (Figueiredo, 2010).

Diopsittaca nobilis (Linnaeus, 1758) (E) – The Red-Shouldered Macaw is native to South America from the Guianas and eastern Venezuela south to southern Brazil (Forshaw, 1977). It was introduced to the city of Rio de Janeiro (Pacheco, 1994; Sick, 1997), and was recorded as common in the 2011 list of birds of Rio de Janeiro State (Gagliardi, 2011). A flock of captive origin was recorded in São Paulo in the 1980s, and today the species is established at several localities in the municipality (Figueiredo, 2010). This species was also introduced on the northern coast of Bahia State, from where there are breeding records (Lima, 2006).

Estrilda astrild (Linnaeus, 1758) (E) – Native to Africa, the Common Waxbill has been introduced around the world as a result of the global trade in wild birds (Stiels *et al.*, 2011). It is believed that this species was brought to Brazil on slave ships during the reign of Dom Pedro I, and there are records indicating that individuals of this species were released in various places in the interior of São Paulo State (Sick, 1997). According to Sick, this species was transported from there to other states, and was listed by I3N Brasil (2012) as present in 92 cities in Brazil.

Eudocimus ruber (Linnaeus, 1758) (E) – According to Sick (1997), there were originally two disjunct populations of Scarlet Ibis on the coast of Brazil: one located on the northern coast as far south as the mouth of the Amazon river, and the other in the south from Rio de Janeiro to Santa Catarina Island. The southern population declined perhaps to extinction by the 1980s. More recently, Lima (2006) records the introduction of this species on the northern coast of Bahia State through the release of individuals. They are now breeding and have spread to Aracaju State colonizing new areas including mangroves (Souza, 2009). Simon (2010) records the introduction of this species in the State of Espírito Santo from captive individuals.

Florisuga mellivora (Linnaeus, 1758) – The White-Necked Jacobin occurs naturally from Mexico to Bolívia, including Amazônia, Maranhão and Mato Grosso States in Brazil (Sick, 1997). According to Willis and Oniki (2002), this species was recorded in Santa Teresa, Espírito Santo State, in March 1994. It is not clear whether it was released from captivity or was a vagrant.

Geopelia cuneata (Latham, 1801) – The Diamond Dove occurs naturally in Australia (Gill and Donsker, 2012). Individuals of probable captive origin were observed in São Paulo city in 1995 (Figueiredo and Lo, 2000).

Icterus croconotus (Wagler, 1829) (P) – The Orange-Backed Troupial occurs naturally in Brazil from Amazonas to Pará and Mato Grosso (Pinto, 1944). Da Silvaxs and Oren (1990), who consider this taxon to be *I. icterus croconotus,* recorded the species as having been probably introduced in Belém from caged birds, and state that this has accelerated the expansion rate of the species in the region. It was also recorded as an escape or release from captivity in the city of São Paulo in 2010, although more observations are necessary before the establishment of this population can be confirmed (Figueiredo, 2010).

Icterus jamacaii (Gmelin, 1788) (E) – The Campo Troupial occurs naturally in Brazil from Maranhão, Piauí, Ceará and Pernambuco to Bahia and Minas Gerais (Pinto, 1944). It was introduced to Itamaracá island state of Pernambuco in 1928 (Sick, 1997), where it apparently persists.

Icterus pyrrhopterus (Vieillot, 1819) – Considered by Sick (1997) under *Icterus cayanensis pyrrhopterus*, the Variable Oriole is native to Mato Grosso do Sul, west of Paraná and Rio Grande do Sul. It was recorded as common in the List of Birds of São Paulo (Figueiredo, 2010). We believe that the record of *Icterus icterus* listed in Figueiredo and Lo (2000) for the city of São Paulo, deriving from the escape or release of captive individuals, in fact refers to this Variable Oriole population.

Lonchura oryzivora (Linnaeus, 1758) – Native to the island of Java, Indonesia (Gill and Donsker, 2012), released or escaped individuals of the Java Sparrow were recorded in Curitiba in 1985 (Straube *et al.*, 2009).

Lanio pileatus (Wied, 1821) – The Sooty-Capped Bush Tanager is native to northeast Brazil, Minas Gerais, Rio de Janeiro and central Brazil in Goiás, Distrito Federal and Mato Grosso (Sick, 1997). It has been recorded as an escape or captive release in São Paulo (Höfling and Camargo, 1993), but there is no evidence of establishment in the city (Figueiredo and Lo, 2000).

Melopsittacus undulatus (Shaw, 1805) – Budgerigars occur naturally in Australia and are undoubtedly the best known of all parrots due to their worldwide popularity as cage birds (Forshaw, 1977). Individuals of captive origin were observed in São Paulo between 1985 and 1998 (Figueiredo and Lo, 2000; Höfling and Camargo, 1993). This species has also been recorded for a number of years in Curitiba, with the first record of releases or escapes from captivity made in the 1970s (Straube *et al.*, 2009). According to Da Silvaxs and Oren (1990), Budgerigars occurred in Belém, Pará State, in the form of escaped cagebirds, but without successful establishment. One individual was seen having escaped from captivity on Fernando

de Noronha island (Oren, 1984), but there have been no additional records from this location (Silva, 2008).

Myiopsitta monachus (Boddaert, 1783) (E) – The Monk Parakeet is an abundant native in the south and southwest of Rio Grande do Sul, south of Mato Grosso do Sul and neighbouring Bolivia, Paraguay, Uruguay and Argentina (Sick, 1997). It is a popular species in the pet trade (GISD, 2005). Amorim and Piacentini (2006) recorded the species as established in the State of Santa Catarina from individuals that escaped from captivity. Individuals escaped or released from captivity were observed in Curitiba in 1999 (Straube *et al.*, 2009). Individuals have also been introduced to São Paulo city, with evidence of establishment (Gomes, 2003). Sick (1993) and Juniper and Parr (1998) believe that *M. monachus* was introduced in Rio de Janeiro, and it was recorded by Gagliardi (2011) as invasive and locally common in the city.

Numida meleagris Pallas, 1767 (E) – The Helmeted Guineafowl is a species native to Africa, which has been introduced and domesticated in many countries with a warm climate (Sick, 1997). Simon *et al.* (2007) report the presence of individuals released or escaped from captivity in the State Park Fonte Grande in Vitória (State of Espírito Santo). Lever (2005) records that Helmeted Guineafowl has been successfully introduced to the island of Trindade, also in Espírito Santo (AOU 1998; R.C. Banks, personal communication, 2004).

Nymphicus hollandicus (Kerr, 1792) – The Cockatiel is native to Australia (Forshaw, 1977). One individual was observed for approximately one month during the winter of 2005 near the Zoological Park of Curitiba, with another recorded for the year 2007 (Straube *et al.*, 2009).

Ortalis guttata (Spix, 1825) (E) – The Speckled Chachalaca occurs naturally in the States of Amazonas and Mato Grosso (Sick, 1997). Galina and Gimenes (2006) report that this species was introduced and is established in a park in the urban area of Maringá, Paraná State. However, it seems likely that its distribution here is restricted to the park area, because there are no other records in the city completely surrounding the park.

Paroaria capitata (d'Orbigny and Lafresnaye, 1837) (E) – The Yellow-Billed Cardinal occurs naturally in Brazil in western Mato Grosso, as well as in Bolivia, Argentina and Paraguay (Sick, 1997). There are records of populations escaped or released from captivity in Curitiba, where the species was considered established with evidence of successful breeding (Straube *et al.*, 2009). Records of introduction were also documented in Rio Grande do Sul State (Accordi and Barcellos-Silveira, 2005, Bencke *et al.*, 2010).

Paroaria coronata (Miller, 1776) – The Red-Crested Cardinal occurs naturally in Brazil in western Mato Grosso and Rio Grande do Sul (Sick, 1997). Fontana *et al.* (2008) record the release of cage birds in the region of Campos de Cima da Serra, in southern Brazil. It has also been recorded as introduced in the city of São Paulo (Höfling and Camargo, 1993), with records for the period 1992 to 1999 (Figueiredo and Lo, 2000).

Paroaria dominicana (Linnaeus, 1758) (E) – The Red-Cowled Cardinal is a typical species of northeastern Brazil, distributed from southern Maranhão to the interior of Pernambuco, and has expanded its range into Bahia (Sick, 1997). This species is a particular target of the illegal trade in wild birds. It was introduced to the city of Belém from individuals that probably escaped from captivity, being recorded between the years 1983 and 1988 though without evidence of reproduction (Da Silvaxs and Oren, 1990). The first record from Fernando de Noronha island was an immature individual in 1980, suggesting that the species may have bred in the wild there (Oren, 1982). Subsequent records were obtained from the island by Oren in 1984, and also between1987 and 1991 (Nacinovic and Teixeira, 1989; Oren, 1984; Silva, 2008; Soto *et al.*, 2000). It has been recorded from the savanna area in the northern state of Minas Gerais as a probable escape of captive birds (Faria *et al.*, 2009). Mallet-Rodrigues *et al.* (2008) record it as escaped or released from captivity in the city of Rio de Janeiro, while escapes of pairs were reported by Sick (1997) in Niterói, Santa Cruz and Enxadas Islands. It was recorded as an introduced species on the bird list of Rio de Janeiro State, and is considered common in the places in which it occurs (Gagliardi, 2011). Individuals escaped from captivity were recorded in the city of Santo André, São Paulo State, (Matarazzo-Neuberger, 1992), and it has also been introduced to São Paulo city (Argel-de-Oliveira, 1987), where it has established populations in some green areas (Figueiredo, 2010). It is also established in Curitiba (Straube *et al.*, 2009), where it was first found in 1995 following escape or release from captivity (Scherer-Neto and Straube, 1995).

Passer domesticus (Linnaeus, 1758) (E) – The House Sparrow is native to Eurasia and North Africa, and is currently well-established as a non-native species throughout the Americas (Calegaro-Marques and Amato, 2010; Lever, 1987). It was brought from Portugal to Rio de Janeiro by Antonio B. Ribeiro in 1906, with the intention that the species would help the public health doctor Oswaldo Cruz in his campaign to sanitize the city, combating mosquitoes and other insect transmitters of diseases (Sick, 1997). It is now extremely widespread in Brazil (InfoNatura, 2007), being recorded from 934 cities (I3N Brasil, 2012).

Pipraeidea bonariensis (Gmelin, 1789) – Occurring naturally in Brazil in Paraná (Sick, 1997), individuals of the Blue-and-Yellow Tanager were reported by Höfling and Camargo (1993) as having escaped from captivity in São Paulo city (Matarazzo-Neuberger, 1990).

Psittacus erithacus Linnaeus, 1758 – The Grey Parrot is native to central Africa (Forshaw, 1977). Straube *et al.* (2009) record this species in the city of Curitiba in 1990, having escaped from captivity or been purposefully released.

Pycnonotus jocosus (Linnaeus, 1758) (P) – The Red-Whiskered Bulbul is native to India, and is a popular cage bird worldwide (Clergeau and Mandon-Dalger, 2001). Serpa (2008) recorded individuals of this species in Rio de Janeiro city in 2006, with sightings of individuals in the wild since 1992 and 1994. These possibly originated as escapes from a pet shop. Serpa also identified a nest of the species in 2006, showing that it was reproducing outside captivity and suggesting that it may be establishing in the area (Mallet-Rodrigues *et al.*, 2008).

Pyrrhura lepida (Wagler, 1832) (P) – The Pearly Parakeet occurs naturally in Brazil in rainforests and transitional forests in eastern Amazonia and Maranhão (Collar, 1997). It has been recorded in Two Brothers Park in Recife, Pernambuco State, since 2004, with two flocks totalling twelve individuals deriving from releases (Pereira *et al.*, 2008).

Ramphastos toco Statius Muller, 1776 – According to Sick (1997), the Toco Toucan has a wide distribution in the interior of Brazil, but does not reach the coast of eastern Brazil. Lima (2010) recorded this species from the middle of the coastal State of São Paulo, in a restinga area of Itanhaém/Mongaguá, as a probable escape or captive release. It was also recorded in the city of São Paulo during the period 1990 to 1994 (Figueiredo and Lo, 2000; Höfling and Camargo, 1993), and has been introduced in the state of Espírito Santo from captive individuals (Simon, 2010).

Rhynchotus rufescens (Temminck, 1815) (E) – The Red-Winged Tinamou occurs naturally from the States of Alagoas to Rio Grande do Sul (Pinto, 1978). It was recorded from Marajó Island (Pará State) in 1897 and 1918, where it was possibly introduced. It was apparently still present in 1965 (Sick, 1993, 1997).

Serinus canaria (Linnaeus, 1758) (P) – The Atlantic Canary is found naturally on the Azores, Madeira and Canary Islands (Gill and Donsker, 2012). It was introduced to the city of São Paulo, where it was recorded between 1985 and 1994 (Figueiredo and Lo, 2000).

Sicalis flaveola (Linnaeus, 1766) (P) – The Saffron Finch occurs in Brazil from Maranhão south to Rio Grande do Sul and west to Mato Grosso. According to Sick (1997), this species "maintains itself well after introduction to protected places", including islands in Guanabara Bay: Brocoió and Ilha das Enxadas. It was introduced to Trindade Island, Espírito Santo, in 1963 where it was still present in 1975, though considered uncommon (Sick, 1997). A single free-living individual was observed on Fernando de Noronha island in 1982, where the local population had made several attempts at introduction in earlier years (Oren, 1984); it does not seem to have established there (Silva, 2008).

Sporophila albogularis (Spix, 1825) – The White-Throated Seedeater is typical of northeast Brazil and is naturally distributed in Piauí, Ceará, Pernambuco, Bahia, northern Minas Gerais and northern Espírito Santo (Sick, 1997). Ridgely and Tudor (1989) believe that the distribution of this species is from Piauí and Pernambuco to north Bahia, and question whether the few records in Minas Gerais and Espírito Santo are migrants or escapes. Da Silvaxs and Oren (1990) recorded the introduction of this species in Belém, via escape from captivity, but without successful establishment.

Sporophila caerulescens (Vieillot, 1823) – The Double-Collared Seedeater occurs naturally in Brazil from Bahia to Rio Grande do Sul (Sick, 1997). It has been recorded from areas in the mangrove-estuarine complex of Mamanguape and North Paraíba rivers in state of Paraíba, with possible captive origin (Araujo, 2005).

Sporophila leucoptera (Vieillot, 1817) – The White-Bellied Seedeater occurs naturally in Brazil in Pará, Mato Grosso, Goiás, Minas Gerais, São Paulo, Paraná and northeast of Rio de Janeiro (Sick, 1997). Three individuals of this species were observed in Fernando de Noronha Island following escape from captivity (Oren, 1984; Silva, 2008).

Streptopelia decaocto (Frivaldszky, 1838) (P) – The Eurasian Collared Dove occurs naturally in Europe and part of Asia (Gill and Donsker, 2012), but is an extremely successful invader in many parts of the world (GISD, 2005). Individuals of this species were observed in Curitiba in 1991 and 2007, and in São Paulo city between 1989 and 1995, having escaped or been released from captivity (Figueiredo and Lo, 2000; Straube *et al.*, 2009).

In addition to the above species, the Western Cattle Egret *Bubulcus ibis* (Linnaeus, 1758) is believed to have established naturally in the Americas, including Brazil. It was recorded for the first time on Ilha de Marajo in 1964, although its occurrence had been reported there since at least 1962 (Sick, 1965, 1997). The species was originally restricted to southern Portugal, Spain and Africa (Crosby, 1972), but between 1877 and 1882 it was recorded in Guiana (Wetmore, 1963), and since then, populations of Cattle Egrets have expanded to all the Americas (Crosby, 1972). According to InfoNatura (2007), the species has spread throughout Brazil.

Figure 1 shows the species richness of non-native birds possibly, probably and definitely established in Brazil. The map identifies the southeast of the country as the area with most non-native species, with particular hotspots of richness around the cities of São Paulo, Rio de Janeiro and Curitiba. A further richness hotspot coincides with the city of Salvador and the coastal region to the north, while the northeastern region of Pará around the city of Belém, also has reason-

able numbers of non-native bird species. The Domestic Rock Pigeon and House Sparrow are present in every state and most cities in Brazil, but across most of the country there are records of only these two non-native bird species in the literature.

Discussion

Brazil is home to a diverse native avifauna. Around 1,800 species have been recorded there (CBRO, 2011), placing it in the top three countries in the world in terms of bird species richness. More than 200 of these species are endemic to Brazil (van Perlo, 2009). Yet, despite its natural species richness, the Brazilian avifauna is still subject to augmentation through the introduction of species to areas beyond the limits of their native geographic distributions.

The primary route by which bird species are introduced in Brazil to areas where they do not naturally occur appears to be via the deliberate or accidental release of individuals from captivity. The trade in cage birds therefore contributes significantly to the occurrence of non-native species in Brazil, although as an unintended consequence. Another common route of introduction is species that have been deliberately released into the wild with the aim of establishing a non-native population, such as *Coragyps atratus* introduced unsuccessfully to the island of Fernando de Noronha. Two non-native species (*Carduelis carduelis, Chloris chloris*) have been recorded in Brazil as vagrants from introduced populations in neighbouring countries, while one species (*Corvus albus*) probably arrived in Brazil having hitchhiked across the Atlantic on ships from Africa, and therefore concerns individuals never actually in captivity.

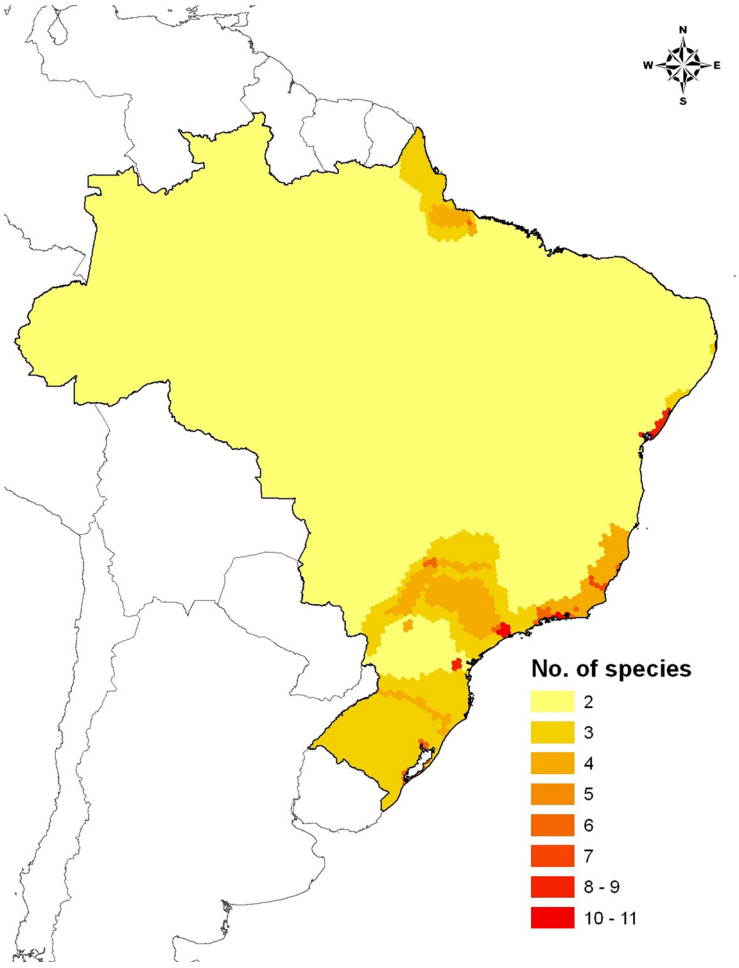

Figure 1. The non-native bird species richness of Brazil. Only species definitely, probably or possibly established were included.

Introduction into an area where it does not naturally occur does not guarantee that a non-native population will establish a self-sustaining population. Establishment implies that reproduction is occurring within the non-native population, and that the population is persisting beyond the natural lifespan of its constituent individuals. However, there are no universally accepted criteria for deciding when a non-native population can be considered to be established at a location, varying from authority to authority. It is known that successful establishment is positively related to propagule pressure (Blackburn *et al.,* 2009), and hence that reducing the number of individuals released and the frequency of releases will reduce the probability of establishment of non-native species (Kolar and Lodge, 2001).

Fourteen species have established or probably established non-native populations in Brazil, and confirming the status of other introduced species, as well as those for which evidence of establishment is currently lacking, would seem to be a priority for future research.

Seventeen of the 24 bird species with possibly or probably established non-native populations in Brazil also have native populations in a different part of the country, and hence are not additions to the Brazilian avifauna as a whole. They do nonetheless have populations in areas where they were not known to occur before human intervention. This emphasizes that the definition of a non-native population relates to the natural geographic distribution of a species, rather than to administrative boundaries like country borders. Of the seven species with non-native but not native populations

in Brazil, the Domestic Rock Pigeon, House Sparrow and Common Waxbill are relatively widespread across the country, as well as being invasive in other parts of the world. The distribution of the first two of these species explains why no part of Brazil is recorded as free from non-native bird species (Figure 1), although in practice there are likely to be substantial natural areas where the chances of encountering a non-native bird species are very low. Populations of the Helmeted Guineafowl appear to have established but are restricted in extent. Populations of the Eurasian Collared Dove, Red-Whiskered Bulbul and Atlantic Canary may have established populations, but there is insufficient published information to confirm this. The Dove and Bulbul are both invasive in several other parts of the world. Considering that some invasive species have the ability to cause changes in ecosystems and reduce biodiversity (Lovell and Stone, 2005; García-Llorente *et al.*, 2008) in process known as biotic homogenization of communities (McKinney and Lockwood, 1999), the eradication of these species would seem to be a priority if their establishment in Brazil is indeed in early stages.

The 59 species listed here as having non-native populations (established or not) in Brazil are only a subset of the species for which individuals have been recorded outside their natural geographic range in Brazil, and therefore is likely to be a conservative estimate for the number of species with non-native populations there. The tendency for records to be from major cities may also indicate that the list is conservative, if there is a sampling bias such that non-native species are mainly recorded from places with more informed observers; this may genuinely reflect the distribution of escapes and/or introductions, however, as it is likely that most non-native individuals will be kept in captivity in human population centres. Our literature review identified many records that could not be included because information on the origin of those individuals was either not investigated or not presented. The correct diagnosis of invasion status is necessary to understand patterns and changes in natural biodiversity, as well as for proposing measures to ensure the conservation of native species. This is particularly important at the early stage of an invasion, when control and eradication measures are likely to be at their most effective. Unfortunately, the lack of data combined with deficiencies in the official control by the agencies responsible for customs inspections, both handicap efforts to prevent invasions by non-native species in Brazil. There is thus a significant need in Brazil for incentives for a more specialized analysis of introduction and establishment, for incorporation of the legislative measures necessary to restrict the introduction of non-native species, and for practical measures to combat and control these introductions.

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