

Worldwide distribution of non-native Amazon parrots and temporal trends of their global trade

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Abstract

Worldwide distribution of non-native Amazon parrots and temporal trends of their global trade.— Alien species are the second leading cause of the global biodiversity crisis, after habitat loss and fragmentation. Popular pet species, such as parrots and parakeets (Aves, Psittaciformes), are often introduced outside their native range as a result of the pet trade. On escape from captivity, some such species, such as the ring-necked parakeet and the monk parakeet, are highly invasive and successfully compete with native species. Populations of Amazon parrots (*Amazona* spp.) can be found throughout the world, but data on their status, distribution and impact are incomplete. We gathered and reviewed the available information concerning global trade, distribution, abundance and ecology of Amazon parrots outside their native range. Our review shows that at least nine species of Amazon parrots have established populations outside their original range of occurrence throughout the world (in Europe, South Africa, the Caribbean islands, Hawaii, and North and South America). Their elusive behaviour and small population size suggest that the number of alien nuclei could be underestimated or at undetected. Despite international trade bans, the large trade of wild-caught Amazon parrots in past decades appears to have contributed to the establishment of alien populations worldwide. Establishment success seems to differ geographically. While European populations are still small and growing slowly, USA populations are large and expanding geographically. This difference is not related to large propagule pressure (trade) but possibly to a better niche match between native and introduced ranges. *Amazona aestiva* is the most frequently encountered *Amazona* parrot, with at least eight alien populations reported to date. All these populations, with the exception of those in the USA where the climate is more suitable for their establishment, are composed of a low number of individuals even though they have been established for a long period of time. Further research is required as little information is available on the ecology and potential impact of these alien populations.

Key words: Alien species, *Amazona*, Distribution range assessment, Establishment success, Impacts

Resumen

Distribución en el mundo de los loros introducidos del género Amazona y tendencias temporales de su comercio a escala mundial.— Las especies exóticas son la segunda causa de la crisis de biodiversidad mundial, precedida por la pérdida y la fragmentación del hábitat. Algunas especies populares como mascotas, como los loros y las cotorras (Aves, Psittaciformes) suelen introducirse fuera de su área de distribución nativa a consecuencia del comercio de animales de compañía. Si escapan de su cautiverio, algunas de estas especies, como la cotorra de Kramer y la cotorra argentina, son sumamente invasivas y compiten con las especies autóctonas. Las poblaciones de loros del género *Amazona* pueden encontrarse en todo el mundo, pero los datos relativos a su estado, distribución y efectos son incompletos. Recopilamos y examinamos la información disponible relativa a la ecología, abundancia, distribución y comercio en el mundo de los loros del género *Amazona* fuera de su área de distribución nativa. Nuestro examen revela que al menos nueve especies de loros de este género han establecido poblaciones fuera de su área de distribución original en todo el mundo (en Europa, Sudáfrica, las islas del Caribe, Hawaii y América del Norte y del Sur). Su comportamiento esquivo y el reducido tamaño de la población sugieren que se ha infravalorado el número de núcleos introducidos o

que no se han detectado todos. Pese a las prohibiciones impuestas al comercio internacional, parece que el gran volumen de loros *Amazona* capturados en libertad que se ha comercializado en los últimos decenios ha contribuido al establecimiento de poblaciones foráneas en todo el mundo. Parece que éxito del establecimiento varía en función de la zona geográfica. Mientras que las poblaciones europeas siguen siendo de pequeño tamaño y de crecimiento lento, las de los Estados Unidos son numerosas y están en expansión. Esta diferencia no guarda relación con una elevada presión del propágulo (comercio), pero sí lo haga posiblemente con una mejor correspondencia de nichos entre las áreas de distribución originales y las de introducción. *Amazona aestiva* es la especie del género que se observa con mayor frecuencia y hasta la fecha se han notificado al menos ocho poblaciones foráneas. Todas estas poblaciones, salvo aquellas que se encuentran en zonas de los Estados Unidos donde el clima les es más propicio, están formadas por unos pocos individuos, a pesar de que lleven establecidas un largo período de tiempo. Es necesario seguir estudiando debido a la escasa información disponible sobre la ecología de estas especies exóticas y sus posibles repercusiones.

Palabras clave: Especies exóticas, *Amazona*, Evaluación del área de distribución, Éxito del establecimiento, Repercusiones

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Introduction

Human-assisted transport of live animals has occurred since ancient times (Meyerson & Mooney, 2007; Tella, 2011). Recent globalization trends, however, have facilitated the international wildlife trade and the consequent introduction and spread of alien species (Hulme, 2009). Throughout the world, introduced species have led to a large number of local and global extinctions, and the population decline of native species (Wohnam, 2006). Introduced species may also damage human activities (e.g., agriculture), resulting in economic damage and loss of wellbeing (Vitousek et al., 1996; Mack et al., 2000). In spite of this, the impact of many introduced species remains poorly known or hard to assess, especially that concerning birds (Kumschick & Nentwig, 2010). Thus, it is important to determine the extent of species distribution in non-native environments in order to observe trends in population growth and spread and to predict and manage the impact of introduced species.

Many species kept as pets or attractions in urban parks, in zoos and in private homes may escape from captivity, sometimes establishing self-sustainable populations (Reino & Silva, 1996; Duncan et al., 2003; Abellán et al., 2016). Parrots (Aves, Psittaciformes) are prominent among internationally traded birds because of their worldwide popularity as pets (Tella & Hiraldo, 2014), likely leading to the establishment of a number of non-native populations (Duncan et al., 2003; Cassey et al., 2004; Mori et al., 2013a; Abellán et al., 2016). Currently, approximately 60 out of 355 known parrot species have established at least one breeding population outside their native ranges (Menchetti & Mori, 2014). Although these species may be widely distributed and have easily-detectable populations (Mori et al., 2013a), the impact of introduced parrots on native biodiversity/environment has been largely overlooked and is still poorly understood (Juniper & Parr, 1988; Menchetti & Mori, 2014). To date, the impact of such invasion has mainly been competition with native hole-nester species (Strubbe et al., 2010; Mori et al., 2013b; Menchetti et al., 2014; Hernández-Brito et al., 2014), and damage to crops and infrastructures (Avery et al., 2002; Stafford, 2003; Menchetti & Mori, 2014), but it should be kept in mind that parrots and parakeets are also potential reservoirs of a variety of diseases transmittable to humans, domestic animals and wildlife (Fletcher & Askew, 2007; Runde et al., 2007), thus emphasizing the need for early detection and assessment of introduced populations in order to reduce risks of damage to local wildlife and society.

The genus *Amazona* includes 32 species of medium-sized parrots, native to Central and South America (cf. Menchetti & Mori, 2014). Hybridization between species is known to occur both in nature and in captivity (McCarty, 2006). Amazon parrots are very popular in the pet trade due to their sociability and ability to imitate human voices (Tella & Hiraldo, 2014). Global population trends of Amazon parrots in their native distribution ranges have not been assessed for all the species, but several population

declines have been related to legal and illegal capture of wild individuals (Tella & Hiraldo, 2014). According to CITES (www.cites.org), over 31,660 wild-caught individuals were recorded in the international trade database between 1981 and 2005.

Although anecdotal and fragmented, some information is available on the presence of alien populations of Amazon parrots throughout Europe (*A. aestiva*, *A. oratrix* and *A. ochrocephala*) and USA (*A. viridigenalis*, *A. aestiva*, *A. autumnalis*, *A. albifrons*, *A. finschi*, *A. oratrix*, *A. ochrocephala*). Menchetti & Mori (2014) analysed the known, certified effects of introduced parrots on native biodiversity but the status and impact of these populations and their worldwide ranges has not been systematically assessed. Given the importance of assessing the distribution of alien species (Genovesi & Shine, 2004), we aimed to fill this gap by reviewing the occurrences of alien populations of Amazon parrots worldwide and by assessing the status of these populations from the available literature, local experts and web-portals for bird observations. Trade data were also obtained for each country to explore temporal trends in trade and relationships with the establishment of non-native populations.

Material and methods

Occurrences were first searched for through online databases (i.e., ISI Web of Science, Scopus, Google Scholar). Search terms included all possible combinations of these words, in several languages (English, French, Italian, Portuguese, German, Dutch and Spanish): *Amazon**, *Amazona aestiva*, *Amazona ochrocephala*, *Amazona oratrix*, *Amazona amazonica*, *Amazona autumnalis*, *Amazona viridigenalis*, *Amazona*, alien population*, introduction*. Information on detected introduced populations was also obtained by contacting 64 local ornithologists and birdwatchers, including the authors of ornithological bulletins and the mailing list of the COST funded project named 'Parrot-Net' (Action ES1304), i.e. a network of researchers, practitioners and policy-makers in Europe studying distribution and impacts of free-ranging parrots. Additional occurrences were searched on citizen science based databases, i.e. iNaturalist (www.inaturalist.org) and eBird (www.ebird.org). Owners of data uploaded on these databases were also contacted for further information on their observations. We also checked National European databases of birds and non-native species and we reviewed the Christmas Bird Count (CBC), the American citizen-science, peer-reviewed database of the National Audubon Society, to assess the status of Amazon parrots populations introduced in North America (www.audubon.org; www.christmasbirdcount.org).

A GLMM with binomial distribution (response variable: established or not) and logistic link function was used to assess the relation between the number of individuals of each *Amazona* species per country (i.e., a proxy of propagule pressure) and the establishment success. The model fitted the number of

individuals of each species imported per country as an explanatory covariate. Species and country identities were used as random effects.

All records of worldwide trade on *Amazona* spp. between 1980 and 2013 were obtained from the CITES trade database, to detect temporal trends in the international trade. Some discrepancies were identified between reported exports and imports; in these cases, trade data were filtered to obtain records of gross imports for wild birds. Data were taken from the CITES Trade Database of the United Nations Environment Programme (World Conservation Monitoring Centre: www.trade.cites.org/cites_trade_guidelines/en-CITES_Trade_Database_Guide.pdf [Accessed on 22nd July 2016]). The CITES gross trade output compares the quantities reported by the exporter and importer, providing an estimate of the total number of individuals recorded in international trade. In other words, gross imports were used to take into account records of imports and re-exports.

Results

Records of wild populations of *Amazona* spp.

A total of 22 papers, books and book chapters mentioning the genus *Amazona* outside its native range were identified through our literature screening. Publications were written in five languages: English (N = 11), German (N = 5), Italian (N = 3), Portuguese (N = 2) and Dutch (N = 1). Another six reviews summarizing the distribution of alien species in France, the Arab Peninsula, the Far East and North America were checked, although no data on Amazon parrots were found. Furthermore, 64 ornithologists or local experts were contacted from all countries reported in the 'Results' paragraph; of these, only 36 provided us with feedback and 16 sent us unpublished data (see 'Acknowledgements'), or other published works we missed in our research (N = 7 papers in English, on North American populations). None of the others (N = 20 experts) added any relevant data on the population of *Amazona* spp. Furthermore, three papers from local newspapers provided us with data on Amazon parrots in Italy and Germany. Figure 1 shows the distribution of introduced breeding populations of *Amazona* parrots. A total 44 records from 24 geographical areas of 9 countries were obtained from citizen-science platforms, as well as from social networks (e.g., Facebook) and online forums (e.g., Natura Mediterraneo: www.naturamediterraneo.com). Detailed data on breeding population trends were only available for three European populations, two from Italy and one from Germany (see data in the paragraphs below: fig. 2). These showed a linear increase in population size, though the oldest one (*A. oratrix* in Stuttgart) best fitted an exponential growth curve (fig. 2).

Establishment success of each species was not related to the number of individuals imported by each country (GLMM: Estimate $\pm$ SE: 88 ± 2.31 , $df = 1$, $P = 0.26$).

Italy

Two reproductive populations of Amazon parrots are currently present in Italy, one in Genoa (Liguria, North-Western Italy) and one in Milan (Lombardy, Northern Italy).

In Genoa, the earliest presence of *A. aestiva* dates back to 1991, with the first breeding event documented in 1993 (Maranini & Galuppo, 1993, 1998). In recent years, mixed flocks of *A. aestiva* $\times$ *A. ochrocephala*, together with individuals with intermediate phenotypes, suggested that hybridization has occurred (Andreotti & Piacentino, 2009). McCarthy (2006) showed that hybridization among these species is possible in captivity, possibly because of their genetic similarity (Ribas et al., 2007). Recorded dietary preferences of the wild populations in Genoa comprised tree seeds and fruits, but no evidence of damage to plants has been documented (Andreotti & Piacentino, 2009). In 2009, 5–6 breeding pairs were present within two city districts of Genoa (i.e., Castelletto and Albaro districts). The number of breeding pairs might have been underestimated because of the elusive habits of these parrots during the breeding season (Seixas & de Miranda Mourão, 2002; Andreotti & Piacentino, 2009). About 20–30 individuals of *Amazona* are currently present in Genoa (fig. 2). No chicks produced by hybrid pairs have been observed, suggesting a probable low fitness of the hybrids/mixed pairs (Andreotti & Piacentino, 2009). Andreotti & Piacentino (2009) reported rats and jackdaws *Corvus monedula*, as possible predators of chicks, although aggressive interactions have only been observed among jackdaws. A single *A. amazonica* was also repeatedly observed in 2008 and 2009 (Andreotti & Piacentino, 2009). In Milan (Northern Italy), free-ranging *A. aestiva* were first documented in 1994 (2 individuals, N. Ferrari and A. Peruz, pers. comm., 2015). A group of 8–10 *A. aestiva* has been observed at a roost within the Indro Montanelli Gardens. The roost is shared with several individuals of *Psittacula krameri*. Two *A. ochrocephala* have also been observed at the same roost since 2014 (A. Peruz, pers. comm., 2015). These parrots feed in the Botanical Garden of Milan (N. Ferrari, pers. comm., 2015), and in Parco Lambro (4.5 km North-East to the roost: E. Mori, pers. obs., 2015), and roost mainly on the canopies of *Platanus orientalis* and *Ginkgo biloba*. Although nests of this species are often located very high on the tree trunks and are hard to detect, the long-term reported presence of this population in Milan, as well as the observation of young individuals (< 1 year), suggests that they are successfully reproducing (Andreotti & Piacentino, 2009). Only one breeding occurrence has been recorded, with a nest and two chicks observed in a hole of a *P. orientalis* in Piazza della Repubblica, Milan (April 2011: A. Marangoni, pers. comm., 2015). Furthermore, new releases and escapes may have maintained the population of *A. aestiva* in Milan (at least 2 individuals have escaped in the last 5 years: cf. fig. 1s in supplementary material). In addition to the populations in Genoa and Milan, 2 *A. aestiva* were documented nesting in a tree hole in a private garden from January to May 2007 in Giaveno (Province of Turin, North-Western Italy):

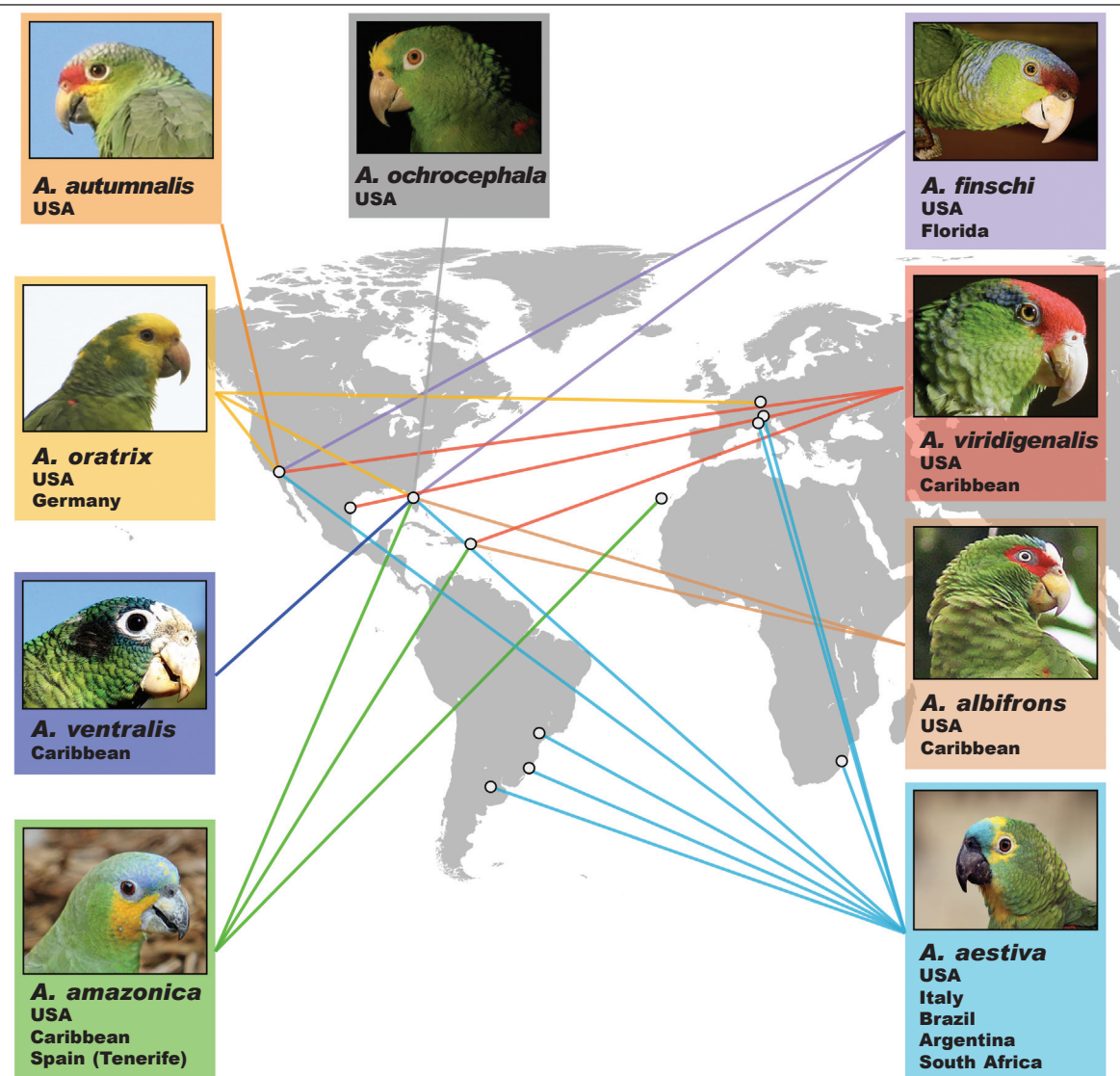


Fig. 1. Global distribution of introduced, breeding *Amazona* populations. Photos by: iNaturalist (jmoralesrbpc) and Wikimedia Commons (Brian Gratwicke, Leonhard F, Charlesjsharp, DickDaniels, Joe Quick, Smartneddy and Joseph C Boone). Map from Wikimedia Commons (Crates).

Fig. 1. Distribución mundial de las poblaciones reproductoras de *Amazona* introducidas. Fotografías por cortesía de iNaturalist (jmoralesrbpc) y Wikimedia Commons (Brian Gratwicke, Leonhard F, Charlesjsharp, DickDaniels, Joe Quick, Smartneddy y Joseph C. Boone). Mapa de Wikimedia Commons (Crates).

M. Colonna, pers. comm., 2015). The parrots nested within the hole of a *P. orientalis*, at a height of 5 m. The female Amazon showed aggressive behaviour towards *Corvus monedula* that tried to enter the nest. Two fertilized eggs were laid, but both adults and eggs were recaptured and caged before hatching. A number of incidental observations and escapes from captivity were also recorded throughout Italy; an average of 2.66 ± 2.42 escapes were reported per year, with a total of 34 Amazon parrots recorded to have escaped between 2004 and 2012 in Italy (see map in fig. 1s in supplementary material).

Germany

According to the recent review by Nehring & Rabitsch (2015), the current status of *A. aestiva* in Germany is unclear, as many breeding events were observed in the past, but no established population of this species seems to occur currently. Bauer & Woog (2008), referring to Herkenrath (1995), mentioned that a breeding pair of *A. aestiva* was observed in Nordrhein–Westfalen in 1883. However, in Herkenrath (1995), there is no reference to this and it may represent a confusion with Niethammer (1963), who mentioned a breeding pair of *A. aestiva* in 1893 in

Switzerland, where the species has never established (Mori et al., 2013a). Four individuals of *A. aestiva*, erroneously recorded as *A. ochrocephala*, were observed between 1984 and 1998 in the Schlosspark Von Wiesbaden–Biebrich (Hessen) (Zingel, 1990). Cross-breeding events between *A. aestiva* and *A. amazonica* were observed between 2000 and 2003 (Stübing et al., 2010). This small population does not seem to increase, as it never exceeded four parrots, individually identified by observers (D. Franz, pers. comm., 2015). Between 1991 and 1993, a breeding pair of *A. aestiva* was observed close to Köln (Kretzschmar, 1999), and in 1999 two individuals were observed in Rosensteinpark, Stuttgart (Hoppe, 1999).

Since 1984, a breeding population of yellow-headed Amazon parrots (*A. oratrix*) has established in Stuttgart (Martens et al., 2013), starting with a single pair which bred for the first time in 1985; reproduction occurred every year, bringing the population to nearly 50 individuals in 2015 (D. Franz, pers. comm., 2015). A few individuals of *A. aestiva* and hybrids of *A. aestiva* × *A. oratrix* (i.e. individuals with intermediate phenotype) are also regularly observed (Martens et al., 2013). Amazon parrots in Stuttgart feed on a variety of cultivated and wild plant species, with a preference for Rosaceae and Betulaceae; eaten parts include unripe fruits, seeds and blossoms (Martens et al., 2013). Native and non-native plants do not seem to be affected by the feeding behaviour of Amazon parrots in Stuttgart, possibly because of the small population size and the wide foraging area (Martens et al., 2013). In Stuttgart, *A. oratrix* have been observed while mobbing *C. monedula* coming close to a nesting hole on a plane tree (D. Franz, pers. comm., 2015).

Spain

Abellán et al. (2016) reported the observations of free-ranging exotic birds recorded in Spain between 1912 and 2012, including 94 records (165 individuals) belonging to seven *Amazona* species.

Amazona aestiva was the most commonly recorded species (46 records, 79 individuals) following detection for the first time in Santa Cruz de Tenerife (Canary Islands) in 1992: this population decreased and became extinct before 2000. Further isolated individuals were recorded in Mallorca (Balearic Islands) and in the continental provinces of Barcelona, Burgos, Girona, Málaga, Toledo and Valencia. In Valencia, the reproduction of *A. aestiva* was recorded in 2009 (one breeding pair). There appear to be no established populations currently, and most sightings throughout the country appear to involve escaped birds.

Amazona ochrocephala was the second most recorded species (23 records, 53 individuals), closely followed by *A. amazonica* (18 records, 25 individuals), observed for the first time in 1995 and 2001 respectively. *Amazona ochrocephala* was recorded as a breeding species in Tenerife in 2003, 2004 and 2005, while single escaped individuals were observed in the provinces of Alicante, Barcelona, Seville and Valencia. Reproduction of *A. amazonica* was recorded in Barcelona only once, in 2004 (Abellán et al., 2016), and in Tenerife in 2014 (grupodeave-

sexoticas.blogspot.com.es [Accessed on 23rd March 2016]). A possible successful hybridization between *A. amazonica* and *A. ochrocephala* was recorded in Tenerife in 2015 (D. Hernández-Brito & G. Blanco, pers. comm., 2015). A group of four individuals of *A. amazonica* was observed in Tenerife in 2011. Single individuals were observed in the provinces of Alicante, Barcelona, Madrid, Málaga, Seville and Valencia, and two individuals were observed in Mallorca (Balearic Islands). Additional records include three *A. amazonica* individuals (provinces of Tenerife, Seville and Vizcaya, in 2013–2015) and three *A. ochrocephala* (Tenerife, in 2013 and 2014). A pair of *A. leucocephala* was also recorded in 1997 in Tenerife, successfully breeding in 1998. These birds were then captured (R. Zamora, pers. comm., 2015) and only two additional records of escaped individuals in mainland Spain are known. Single records were obtained from *A. albifrons*, *A. farinosa* and *A. festiva* in mainland Spain. One individual of *A. oratrix* was observed in Córdoba in 2014 (grupodeavesexoticas.blogspot.com.es [Accessed on 23rd March 2016]). To conclude, despite the relatively high number of observations and a few reproduction events of Amazon parrots in Spain, a breeding population, small and mixed (*A. amazonica*/*A. ochrocephala*), is known only in Tenerife.

Portugal

Single records of *A. ochrocephala*, *A. amazonica* and other unidentified Amazon parrots have been reported for Lisbon. Matias (2011) reported a sighting of *A. ochrocephala* (one individual in 2007) and a group of four individuals of *A. amazonica* in a small city park in 2009 (Matias, 2011). New records have since described a group of three individuals of *A. amazonica* in 2012 and one individual in 2014 (Gomes, 2014). In 2014, a single individual was observed in an urban park in Póvoa do Varzim (NW Portugal) over several months (Gomes, 2014).

Netherlands

In the Netherlands, 13 individuals belonging to four *Amazona* species (*A. aestiva*, *A. ochrocephala*, *A. viridigenalis* and *A. amazonica*) were observed between 1984 and 2012, mostly in the urban centres surrounding The Hague (waarneming.nl; van Kleunen et al., 2014). Among these, *A. aestiva* was observed in Bunnik (August 1994) and in Voorburg (December 2006) in a roosting flock mixed with *Psittacula krameri*. *Amazona amazonica* was observed in Brabantse Biesbosch (June 2011) and Losser (March 2012). No evidence of reproduction was reported. Since 2012, no *Amazona* species have been reported for the Netherlands.

USA–Florida

At least 12 *Amazona* species have been reported for Florida, mainly concentrated within the greater metropolitan Miami area (Florida Fish and Wildlife Conservation Commission, 2003). *Amazona aestiva* was recorded as breeding in Miami–Dade County, where it appeared to take hold in the late 1980s (Kale et al., 1992; Florida Fish and Wildlife Conservation

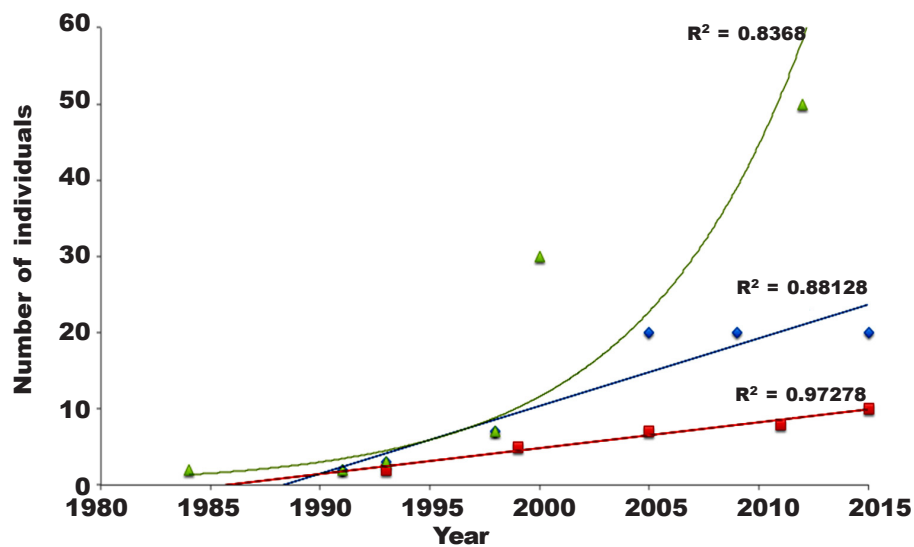


Fig. 2. Trend on the number of breeding adults in *Amazona* populations in Europe: *A. aestiva*, Genoa, Italy (◆) and Milan (■); *A. oratrix*, Stuttgart, Germany (▲). Data sources were provided by local ornithologists or taken from publications regarding these populations (see text).

Fig. 2. Evolución del número de adultos reproductores en las poblaciones de *Amazona* en Europa. *A. aestiva*, Génova, Italia (◆) y Milán (■); *A. oratrix*, Stuttgart, Alemania (▲). Las fuentes de los datos fueron proporcionadas por ornitólogos locales o se tomaron de publicaciones referentes a estas poblaciones (véase el texto).

Commission, 2003). Recent assessments indicate a positive population trend for this species, but reliable quantitative data are not available (Runde et al., 2007).

Amazona viridigenalis was released in Florida between the late 1960s and the early 1970s, with at least 11 individuals. Owre (1973) reported this species as the most abundant Amazon parrot established in Florida, counting a flock of 32 individuals in 1972 (Robertson & Woolfenden, 1992). The population experienced a rapid growth since the 1980s, although a negative trend occurred since 2005 (Runde et al., 2007), with only a few scattered individuals observed in Broward, Miami-Dade, Fort Lauderdale, Palm Beach and in the Florida Keys, where hybrids with *A. ochrocephala* were also observed (cf. National Audubon Society, 2016). Epps & Karalus (2007) suggested that competition with *A. amazonica*, locally much more abundant, may have occurred for food resources.

Amazona finschi was first reported in the 1970s (Robertson & Woolfenden, 1992) in Broward County and Southern Miami (N = 4). In 2006, a population was still present (Epps & Karalus, 2007) and a positive trend in population size was recorded (Runde et al., 2007). In 2016, about 15–20 individuals have been observed (D. Marty, pers. comm., 2016). A single population of *A. amazonica* is present in Southern Florida (Miami-Dade and Broward Counties). No population estimate is available, but the species is currently considered to be the most abundant parrot in Southern Florida (Epps & Karalus, 2007). *A. ochrocephala* was considered as

established in Florida in 1986 (Troops & Dilley, 1986), although, apart from isolated records of a single or few individuals within flocks of other species in Miami, no observation has been reported since 2007 (Epps & Karalus, 2007). A few individuals of *A. auropalliata* have been recorded in Florida (Broward County), with successful breeding by one pair documented (i.e., observation of fledged chicks) in 2000 and 2001 (Epps & Karalus, 2007). Groups of *A. oratrix* have been bred in Broward County since 1985, most likely in small numbers, and hybridization with *A. viridigenalis* has also been observed (Epps & Karalus, 2007); *A. ochrocephala* has been also recorded as a breeding species in Florida (Toft & Wright, 2015). Escapes of other *Amazona* species are often reported in Florida, mainly in the Miami area (*A. albifrons*, *A. autumnalis*, *A. petrei*, *A. ventralis*: Robertson & Woolfenden, 1992), with groups of up to 30 *A. albifrons* reported in 2015 by the eBird portal. No data on the initial propagule pressure are available.

USA–California

Six species of Amazon parrots have been reported in California. *Amazona aestiva* has been introduced, with a small number of individuals (N = 2) reported in the Los Angeles basin, the San Gabriel Valley, and urban Orange County, possibly sustained by repeated escapes, and often detected in mixed flocks with other parrot species. Breeding has been reported for one pair in the San Gabriel Valley (Mabb, 2002) and in

Orange County, where 8–20 *A. aestiva* are currently individually monitored (www.californiaparrotproject.org; National Audobon Society, 2016).

Amazona viridigenalis is present in California with a population founded in 1963 by two pairs, released in near Pasadena. This geographical area hosts the largest population of this species in California, with about 750 individuals in 1996 (Mabb, 1997); in 2015, a total of 263 individuals was counted. Other groups are present in the north-eastern area of Los Angeles, in Malibu, Mill Creek, San Diego and Orange County (National Audobon Society, 2016). Garrett (1997) conservatively estimated a total population count of 1,080 individuals in California, subsequently finding a significant population increase over time, reaching about 2,500 individuals in 2016 (www.forbes.com/sites/grrlscientist/2016/04/07/are-there-more-free-living-mexican-red-headed-parrots-in-us-cities-than-in-all-of-mexico/#12412ac4675a [Accessed on 25th April 2016]; National Audobon Society, 2016). Mixed pairs *A. viridigenalis* × *A. finschi* were also observed in Pasadena in the late 1990s, with no recent confirmations (Mabb, 1997). *Amazona finschi* was recorded in California in 1976 for the first time, and has been considered to be established in Los Angeles since 1987. Garrett (1997) estimated 100 individuals in this population, although the current count is no more than 55 individuals (National Audobon Society, 2016). Mabb (1997) observed a breeding pair, nesting in a utility pole, aggressively chasing *Sturnus vulgaris* and *Corvus brachyrhynchos*.

Two individuals of *A. autumnalis* were recorded in San Bernardino in 1972 by Hardy (1973) and in 1997 by Mabb (1997); 4–6 individuals were observed in 2002 in the San Gabriel Valley (Mabb, 2002), with evidence of breeding. This species exhibited an evident increase in population size (Runde et al., 2007), and a total of 32 individuals were counted in 2015 in Orange County (National Audobon Society, 2016). *Amazona ochrocephala* is present in California, with the first 10 breeding pairs in 1963; around 30 individuals were counted in 1973 (Hardy, 1973), but no recent population count is available, and only 1–2 individuals have been observed since 2010 (National Audobon Society, 2016). Although possibly confused with *A. ochrocephala*, *A. oratrix* was once widespread in southern California (Los Angeles, San Diego, Pasadena) but its population seems to have declined in recent years (Lever, 2005), with 5 individuals observed in 2015 in San Diego and 5 in Pasadena (National Audobon Society, 2016). The total population for California was estimated at about 60 individuals in late 1990s (Garrett, 1997). Toft & Wright (2015) also reported *A. albifrons* as an established species in Los Angeles County; observations of fewer than 10 individuals occurred in 2015, also in Orange County and Pasadena (National Audobon Society, 2016).

USA—other States

A small population of *A. viridigenalis* persisted in Southern Texas (La Feria) between the 1920s and 1930s (Lever, 1987, 2005). Two groups of *A. viridigenalis* were

present in 1973–75 in Texas (total N = 12, in Rio Grande), with an estimated population of about 400 individuals in 1995 (Butler, 2005) and about 700–1000 individuals (Brownsville, Harlingen, Weslaco, Anzalduas–Bentsen) in 2016 (www.forbes.com/sites/grrlscientist/2016/04/07/are-there-more-free-living-mexican-red-headed-parrots-in-us-cities-than-in-all-of-mexico/#12412ac4675a. Accessed on 25th April 2016; National Audobon Society, 2016). This species was reported since 1970 on the island of Oahu, Hawaii (Lever, 2005), where it reproduced until 1980s and then, possibly, disappeared (cf. Runde et al., 2007). A single individual of *A. finschi* was observed at El Paso, in Texas, in 2015 (National Audobon Society, 2016). Haphazard observations were reported of single individuals of *A. ochrocephala* in New York and small numbers (2–4) in Texas in the 1970s (Lever, 1987).

Puerto Rico and other Caribbean islands

Probably introduced in the late 1960s (Lever, 2005), *A. viridigenalis* was reported in Puerto Rico (T. Silva, pers. comm., 1985) and later confirmed by Raffaele et al. (1998), who recorded as many as 40 individuals, indicating an established population. Forshaw (1980) reported the presence of hundreds of *A. ventralis*, including hybrids with *A. aestiva*, breeding in Puerto Rico after releasing a shipment of traded birds. The Puerto Rican population is growing, unlike the native population in Hispaniola. Other established populations are reported from St. Croix and St. Thomas (Virgin Islands) (Lever, 2005). *Amazona amazonica* is also present with an established population in Puerto Rico since the late 1960s (Owre, 1973; currently about 130 individuals: T. White, pers. comm., 2015) and in Martinique (Raffaele et al., 1998). *A. oratrix* was probably introduced in Puerto Rico in the early 1970s, but data on its breeding success are lacking (Lever, 2005). Eleven records of *A. albifrons*, possibly breeding, in groups of 3–11 individuals, are reported from 2001 to 2013 by eBird.

South America

Alien populations of *A. aestiva* are recorded in some South American cities outside the native range of this species. For example, flocks of 6–10 individuals have been observed in São Paulo and Porto Alegre, Brazil (J. L. Tella, pers. obs.). In Argentina, an alien population occurs in Buenos Aires, where individuals have been observed since the late 1990s. In 1999, 16 individuals were present; in 2015, 40 animals were counted (T. Calatoso, pers. comm., 2015). A group of 5 *A. aestiva* was recorded in 2002 in Río Cuarto (Argentina), but no recent observations are available (T. Calatoso, pers. comm., 2015).

South Africa

Symes (2014) compiled information on *A. aestiva* (up to 6 individuals) observed in Pinetown since 1989, where two pairs seem to breed sporadically but most chicks are poached from their nests. Apart from this small population, only one other *Amazona* sp. individual is recorded in Johannesburg.

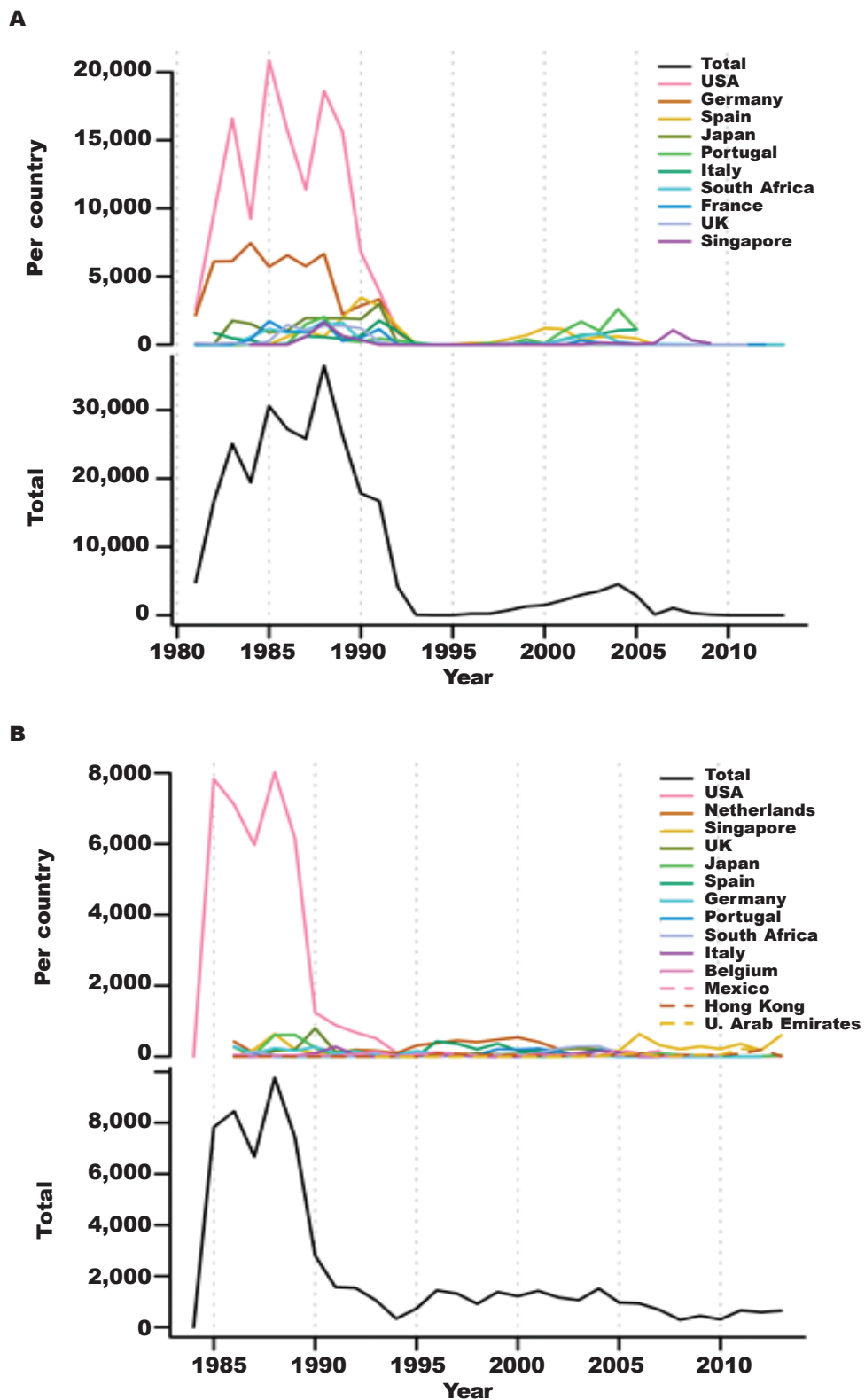


Fig. 3. Total of *Amazona* specimens imported globally per year, highlighting the two most traded species, *A. aestiva* (A) and *A. ochrocephala/A. oratrix* (B).

Fig. 3. Total de individuos de *Amazona* importados en todo el mundo por año; se destacan las dos especies más comercializadas: *A. aestiva* (A) y *A. ochrocephala/A. oratrix* (B).

Temporal trends in global trade of *Amazona* spp.

Between 1980 and 2013, a total of 372,988 traded wild Amazon birds were reported by CITES. *A. aestiva* was the most commonly traded species (288,112 individuals), followed by *A. ochrocephala* (68,401 individuals) (fig. 3). After the 1992 ban on wild-bird trade in CITES-listed species in USA, most (66%) of this trade was redirected to the European Union. A rapid increase in the number of globally traded *A. aestiva* individuals occurred from 37 birds in 1995 to over 5,000 individuals in 2004, at which point the number of recorded traded birds declined sharply to 374 in 2006. This sharp reduction coincided with the first European ban on trade in wild birds in 2005, which became permanent in 2007. Between 1981 and 2007, before the EU ban on wild bird trade was implemented (Commission Regulation (EC) No. 318/2007), the predominant importers of *A. aestiva* were Portugal (7,991), Spain (5,551) and Italy (3,681). Only small numbers (74) were recorded as imported into the USA (fig. 3). As to *A. ochrocephala*, approximately 1,500 imports per year were recorded between 1996 and 2004. Subsequently, yearly recorded imports decreased to approximately 500 birds, apart from in 2012 when over 1,000 importations were recorded, possibly after the release of an animated feature movie with parrots as main characters ('Rio', from 20th Century Fox). The predominant importers of *A. ochrocephala* between 1981 and 2007 were the Netherlands (3,717), Singapore (3,216) and Spain (2,066), with small numbers (789) being imported into the USA (fig. 3). Amazon parrots are listed within the CITES Appendices (several species in Appendix I, which includes species whose trade should be controlled to avoid an unsustainable withdrawal from the wild). The earliest countries to record the trade of Amazon parrots by subscribing CITES were the USA and South Africa (1975), followed by UK (1976), France (1978), Portugal (1981), Belgium and the Netherlands (1984), Spain (1986), Singapore (1987) and Mexico (1991). Trade of CITES-listed wild birds was banned in 1992 in the USA, after which the EU remained responsible for about 87% of worldwide trade. In the EU, the first ban of wild bird trade occurred in October 2005 and became permanent in 2007.

Discussion

Our review showed that at least 14 species of Amazon parrots have been reported to be free-living outside their native ranges, with nine species having established alien populations in Europe (*A. aestiva*, *A. oratrix* and *A. amazonica*), Africa (*A. aestiva*), South (*A. aestiva*) and North America (*A. aestiva*, *A. albifrons*, *A. amazonica*, *A. autumnalis*, *A. finschi*, *A. ochrocephala*, *A. oratrix*, *A. viridigenalis*), and the Caribbean islands (*A. ventralis*, *A. viridigenalis*, *A. amazonica* and *A. aestiva*). The most widespread of these is *A. aestiva*, with at least 8 known alien populations. Our work showed that although Amazon parrots were widely traded as pets, a small number of introduced populations occurs worldwide.

A species is defined as 'invasive' if, once introduced, it spreads and exerts negative ecological impacts on native biodiversity (Genovesi & Shine, 2004). Prior to the trade bans imposed by US and by the European Union in Europe, most of the traded Amazon parrots were wild-caught, a factor which may have favoured the establishment of non-native populations (Carrete & Tella, 2008, 2015, 2016; Cabezas et al., 2013). The European Union has banned the trade of wild-caught individuals since 2005, allowing only the sale of captive-born parrots, which usually show lower invasiveness potential than their wild-caught counterparts (Gismondi, 1991; Carrete & Tella, 2015).

Some illegal trade still occurs across the Mexico–USA boundary, although no information on the numbers of traded birds is available (Tella & Hiraldo, 2014). The illegal trade might have contributed to a much larger introduction and escape of birds and a higher establishment success and population growth in the most populated southern USA states (e.g., California, Florida and Texas). The establishment of non-native populations may be due to patterns of climate-matching between the native and introduced ranges (Ancillotto et al., 2015; Jackson et al., 2015; Cardador et al., 2016) and ecological niche expansion into colder climates (Strubbe et al., 2015). Our analysis showed that establishment success of Amazon parrots was not related to initial propagule pressure, although one cannot rule out the possibility that further releases/escapes after the first observations would have helped alien populations to establish. Therefore, niche suitability may be more important for establishment success than propagule pressure (Cardador et al., 2016) for Amazon parrots. Accordingly, the most widespread Amazon species outside their native range are not only those most traded (*A. aestiva*, *A. ochrocephala/oratrix* and *A. viridigenalis*, in this order), but also those showing the widest natural extent of occurrence (Forshaw, 1980). Although living mainly in densely forested areas, species with large extent of occurrence have evolved adaptations to cope with climatic conditions in their distribution ranges (Ancillotto et al., 2015; Menchetti et al., 2016). This may represent an adaptive feature in establishing alien populations outside the native range, i.e. where climatic conditions are different from those occurring within the core area of the extent of occurrence of the species (Duncan et al., 2003; Ancillotto et al., 2015). Main European introduced nuclei and isolated breeding instances occurred in warmest countries (e.g., Italy and Spain), while the only German population was first human-assisted (Bauer & Woog, 2008; Martens et al., 2013). In contrast, large populations of Amazon parrots are flourishing in southern USA and Puerto Rico, where climate is more similar to that of their native distributions (Hijmans et al., 2005; Toft & Wright, 2015). From a general perspective, the probability of establishing new populations is also related to propagule pressure, i.e. the number of individuals introduced, which is probably correlated to the number of traded animals, though this information is often lacking. As Amazon parrots are popular and expensive pets (Tella & Hiraldo, 2014), their presence

in natural environments outside the natural range is mainly due to unintentional escapes (Abellán et al., 2016). In Italy, an average of 3.4 Amazon parrots per year were recorded as lost or escaped over the last 10 years, with the largest numbers in the largest cities (fig. 1s in supplementary material).

Although new non-documented releases may play a pivotal role in determining local population increases even without reproduction (fig. 1s in supplementary material), the observation of fledglings or juvenile individuals suggests that breeding may have occurred also where observation of nesting sites lacks.

Alien populations of Amazon parrots grow up at very low rates, being long-lived, slow-reproducing species, suggesting that timely and successful control of these population is still feasible at the start of their establishment process (Edelaar & Tella, 2012). The population curve for *A. oratrix* in Germany showed a steeper trend than that of Italian populations, possibly because this population is still fed by humans in urban parks (Martens et al. 2013). Impact exerted by European populations seems to be negligible or nearly absent, possibly because these nuclei are composed of a few individuals (Andreotti & Piacentino, 2009; Martens et al., 2013). Nevertheless, even for the largest populations in the USA, studies on the impact are still lacking. Further investigations should be carried out on other, often overlooked, typologies of impact, e.g., on parasites and potential diseases carried by introduced Amazon parrots (Menchetti & Mori, 2014; Mori et al., 2015).

Despite these considerations, small and localized populations together with limited expansion rates prevent us from identifying the impact of Amazon parrots in Europe. Neither can we rule out the possibility that the impact of these parrots might be limited. Studies on feeding ecology in Genoa (Italy: Andreotti & Piacentino, 2009) and Stuttgart (Germany: Martens et al., 2013) show a wide trophic spectrum for these parrots, without any detectable impact on plants. Some food items containing poisonous compounds are only used by Amazon parrots, thus reducing competition for food resources with native birds (Martens et al., 2013). These alkaloid-rich, poisonous species (e.g., Taxaceae, Cupressaceae and *Robinia pseudoacacia*) may reach the 60% of the diet of *A. oratrix* in Stuttgart (Martens et al., 2013). In Europe, aggressive behaviour towards jackdaws and rats has been observed in the vicinity of the nests, when chicks were present (Andreotti & Piacentino, 2009). Similarly, harassment of starlings and American crows by Amazon parrots was observed in California (Mabb, 1997, 2002).

As to potential impact, Amazon parrots are considered agricultural pests. For instance, in its native range, *Amazona aestiva* may damage up to 100% individual fruit crop size (e.g., citrus orchards: Navarro et al., 1991). Other impacts by Amazon parrots included fungal and microbial infections in captive individuals, transmittable to humans and other animal species (De Freitas Raso et al., 2004; Romanov et al., 2006; Hannon et al., 2012). Observed harassment toward jackdaws and starlings in invaded regions seems to be the only certified impact of these parrots, although

no study has measured whether they affected the reproductive success of native species. Apart from any possible concerns due to invasion potential, introduced populations may have a conservation value (e.g., genetic pool) as reservoirs that could be used to rescue endangered populations in their native ranges (Bauer & Woog, 2008), e.g., *A. oratrix* in Stuttgart (Germany) and *A. ventralis* in Puerto Rico. It is important to note that due to the frequent hybridization found between species co-occurring in the invaded regions, care should be taken before considering these populations valuable for conservation (e.g., for captive breeding or translocations).

A growing body of global evidence recognizes biological invasions as one of the main drivers of the current biodiversity crisis (Wonham, 2006; Vilà et al., 2010; Scalera et al., 2012; Mazza et al., 2014). For instance, over 12,000 introduced species currently occur in Europe (DAISIE; www.europe-alien.org/aboutDAISIE.do [Accessed on 21st March 2016]). A total of 12 billion euros per year is required for damage caused by only 15% of introduced species in Europe (Kettunen et al., 2008). Genovesi & Shine (2004) proposed a 3-stage hierarchical approach to reduce the risks posed by introduced species, which includes: i) prevention of new introductions, ii) early detection of new establishments and iii) mitigation of impact through eradication or numerical control of populations. In contrast with other parrot species (e.g., *Myiopsitta monachus* and *Psittacula krameri*: Menchetti & Mori, 2014; Menchetti et al., 2016), Amazon parrots are alien non-invasive species as their spread and impact on native environments seem to be low even after more than 30 years after the first release. Only a few species, i.e. mainly those with wide native ranges, have thrived outside their native range, even if their population growth seems to be mainly helped by new releases or escapes from captivity, rather than by breeding success. The reduction of propagules entering invasive Amazon parrot populations, after trade bans and CITES agreement, has further reduced the survival of alien populations. Nevertheless, with a precautionary principle approach, a continuous trend-monitoring would be recommended for all the established populations in order to follow the recommendations for the reduction of impact by alien parrots postulated by Menchetti & Mori (2014).

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Supplementary material

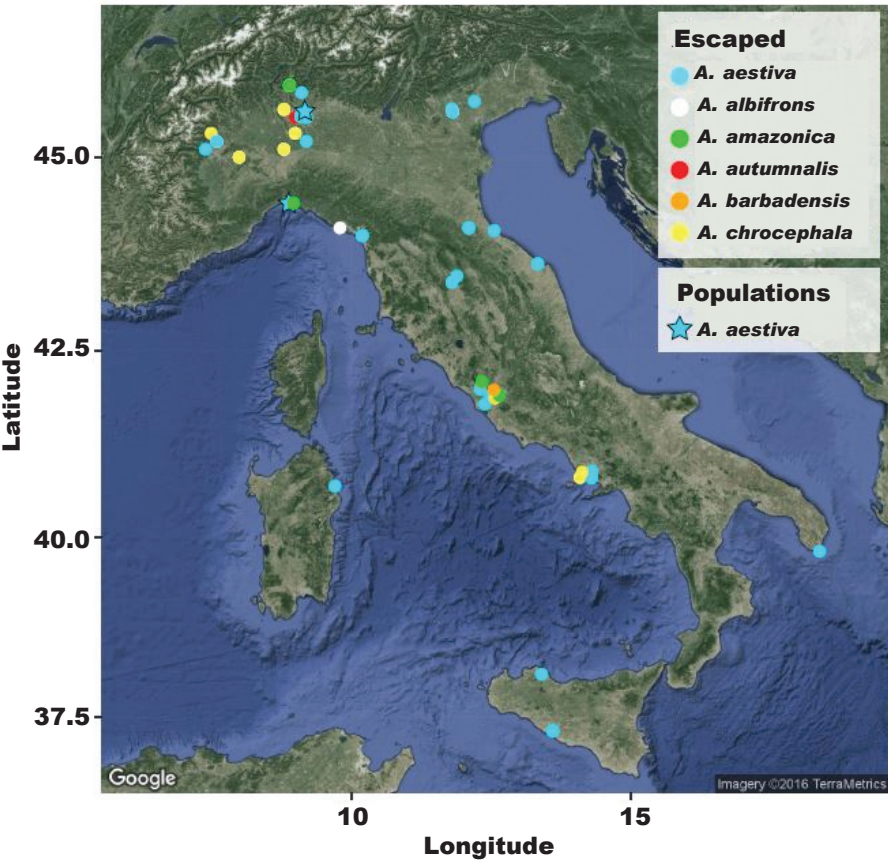


Fig. 1s. Distribution of reported escapes and free ranging populations of Amazon parrots in Italy.

Fig. 1s. Distribución de las fugas reportadas y de las poblaciones libres de loros del género Amazona en Italia.