Urban Ecosystems (2022) 25:1199–1206
https://doi.org/10.1007/s11252-022-01224-9

Rescue data as an alternative for assessing trends and phenological changes in two invasive parakeet species

Eleonora Ciprari[1] · Leonardo Ancillotto[2] · Emiliano Mori[3] · Valentina Studer[4] · Chiara Chessa[5]

Accepted: 24 February 2022 / Published online: 15 March 2022

Abstract

Monitoring population trends of alien species is pivotal to design effective management plans to preserve native biodiversity, particularly urban areas, where most populations of alien birds are established. Urban wildlife rescue centers, with personnel trained to record species, age and sex of each individual brought by the public, may represent a reliable citizen-science based method to estimate both local changes in alien species phenology and population trends. In this work, we analysed records of monk and ring-necked parakeets by comparing rescue records in the urban area of Rome from the last 15 years. We also tested whether breeding phenology of alien parakeets showed any changes since the start of the invasion processes.

We recorded a strong correlation between the number of rescued parakeets and their population trends, thus confirming the importance of wildlife rescue centers in monitoring populations of alien species in urban areas. We also observed a shift in the breeding phenology of these parakeet species. The hatching peak for ring-necked parakeet occurred in early spring, in line with previous studies on the reproduction of this species, but with a slight increase in the number of months with evidence of breeding in the last years. As to the monk parakeet, our findings support the expansion of its reproductive season between 2006 and 2020 in Rome, with chicks currently being observed for seven months a year. Therefore, data collected through wildlife rescue centers may help improving models of population growth of alien species established in urban areas.

Keywords Alien species · *Myiopsitta monachus* · Population increase · *Psittacula krameri* · Reproductive season · Urban parks

Introduction

Amongst conservation scientists, global consensus highlights that alien species represent one of the main causes of the worldwide current biodiversity crisis (Blackburn et al. 2019; Liu et al. 2020; Pyšek et al. 2020). Following a parsimony principle, all alien species may exert impacts on native ecosystems (Kumschick and Nentwig 2010; Blackburn et al. 2014; Evans et al. 2018), and these effects should be limited through addressed management actions (Hulme 2006; Mazzamuto et al. 2020; Saavedra and Medina 2020), often involving high economic costs (Bacher et al. 2018; Diagne et al. 2020). Early detection and surveillance programs of new invasions (or newly invaded areas) by alien

✉ Emiliano Mori
emiliano.mori@cnr.it

[1] Dipartimento di Biologia, Università di Pisa, Via Volta 4 bis, 56126 Pisa, Italy

[2] Wildlife Research Unit, Dipartimento di Agraria, Università degli Studi di Napoli Federico II, Napoli, Italy

[3] Consiglio Nazionale delle Ricerche – Istituto di Ricerca sugli Ecosistemi Terrestri, Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy

[4] Centro Recupero Fauna Selvatica, Lipu, Roma, Italy

[5] Dipartimento di Biologia e Biotecnologie Charles Darwin, Università di Roma La Sapienza, Viale dell'Università 32, 00161 Roma, Italy

species are therefore recommended by policy makers and field conservationists (Vall-Llosera et al. 2017; Kalandarishvili and Heltai 2019; Larson et al. 2020; Fierro-Calderòn and Fierro-Calderòn 2020; Rocha et al. 2020). Conversely, monitoring dynamics of established populations of invasive species is far more challenging and expensive in the long term, as it usually involves intensive field efforts (Daume 2016; Luna et al. 2016; Shivambu et al. 2020), or technologies requiring expertise and research practice (Le Louarn et al. 2017). Yet, established populations, particularly when not managed, need to be carefully monitored, as their increase in size and range might eventually result in further or worse impacts (Engeman et al. 2006; Martinoli et al. 2010; Berthier et al. 2017; Boscherini et al. 2020; Mazzamuto et al. 2020). Monitoring large populations is challenging and may require a high number of field operators, particularly in the case of invasive species with high mobility such as birds, with increasing difficulties when surveillance is required in urban areas, where most populations of introduced birds thrive (Rodríguez-Pastor et al. 2012; Sol et al. 2017). Monitoring urban animal populations is also hindered by the difficulties in applying several methods for census counts (including direct captures for marking), e.g. due to restricted access to private properties, or conflict with the general public opinion and animal-rights groups (cf. La Morgia et al. 2017; Archibald et al. 2020).

The ring-necked parakeet *Psittacula krameri* and the monk parakeet *Myiopsitta monachus* are the most widespread alien parakeets (Aves: Psittaciformes) in Europe (e.g. Strubbe and Matthysen 2009a; Pârâu et al. 2016; Postigo et al. 2019). Their impacts on ecosystems have been assessed in several countries where they've been introduced (e.g. Menchetti and Mori 2014; White et al. 2019; Mori and Menchetti 2021, for reviews), although they are not yet included amongst alien species of European concern (European Union 2020). Impacts by introduced parakeets might be locally important: for instance, a growing population of ring-necked parakeets is considered responsible for the dramatic decline of the threatened giant noctule *Nyctalus lasiopterus* in Sevilla, Spain (Hernández-Brito et al. 2018). In other countries, this alien species is responsible for the decline of hole-nesting birds (e.g. Strubbe and Matthysen 2009b; Yosef et al. 2016; Covas et al. 2017; Mori et al. 2017; Grandi et al. 2018; Ivanova and Symes 2019). Ecological impacts by monk parakeets are still poorly known (Mori and Menchetti 2021), although this species is responsible for crop damages (Senar et al. 2016; Battisti 2019) and possibly parasite spread to native species (Mori et al. 2019), and its nest may help the spread of other invasive species (e.g. the sacred ibis *Threskiornis aethiopicus*: Castiglioni et al. 2015; Hernández-Brito et al. 2021). Populations of both parakeet species are currently growing, particularly in Mediterranean countries (e.g. Domènech et al. 2003; Postigo et al. 2017; Grandi et al. 2018; Per 2018; Viviano and Mori 2021) and thus their impacts may become manifest or increase in the near future (White et al. 2019; Mori et al. 2020). In Southern Europe, breeding phenology of the ring-necked parakeet may have helped its invasion success, as it occupies tree cavities earlier than native birds for breeding purposes (Luna et al. 2017). Similarly, introduced populations of monk parakeets show a higher reproductive capacity, i.e. with double fledging success and triple the number of couples attempting second broods, compared to populations in the species' native range (Senar et al. 2019).

Given the times of economic crisis that research and conservation biology are facing (Cagnacci et al. 2012), methods and platforms of citizen science have been developed to monitor population expansion of alien species, including parrots, by fostering the general public attention and participation (Symes 2014; Ancillotto et al. 2016; Per 2017; Diamond and Ross 2019). However, citizen scientists may incorrectly identify species and local experts have to review data, with some possibilities of misidentifications, particularly where several species of non-native parrots occur (Uehling et al. 2019). Moreover, counts by different citizen-scientists might be unreliable due to different observer errors, thus making results incomparable with previous studies. The staff of Wildlife Rescue Centers (hereafter, WRCs) in urban areas is usually trained to record species, age and sex of each individual brought by the public, i.e. representing an invaluable source of wildlife data, particularly in urban environments (Ancillotto et al. 2013; Shine and Koenig 2001). Animals rescued by the public may thus provide researchers reliable data on their ecology, distribution and epidemiology, otherwise difficult to obtain (Reeve and Huijser 1999; Molony et al. 2006; Aaziz et al. 2015; Ancillotto et al. 2018). Therefore, WRCs may act as a reliable citizen-science based method to estimate both local changes in species phenology and population trends.

Here we aimed at testing whether wildlife rescue centers may act as monitoring centers for alien parakeet population trends. Thus, we analysed records of two introduced parakeet species from a wildlife rescue center in Rome, where the two largest parakeet populations of Italy occur. We compared rescue records with census data across 15 years, and assessed whether rescue records may be used as a proxy of local population trends. Moreover, we tested whether the breeding phenology of the two species showed any change since the start of the invasion process.

Methods

Rescue data

We compiled all records of rescued parakeets admitted at the LIPU (Italian partner of BirdLife International) wildlife rescue center in Rome, between 2006 and 2019. At each admission, center's staff records date of rescue, species, sex (if possible) and age class. Age classes were assigned following Eberhard (1998) and Butler and Gosler (2004) for monk and rose-ringed parakeets, respectively, as follows:

- Nestling: a young bird with body extensively covered with down feathers; not able to crawl or fly; estimated age between 1 and 40 days;
- Fledgling: a young bird with almost full plumage; able to crawl and fly short distances; estimated age between 41 and 60 days;
- Juvenile (yearling): a young bird with full plumage, able to crawl and fly properly; may or may not be still dependent from parents; estimated age between 61 and 100. Non-yearlings were distinguished by differently coloured iris (darker in yearlings).

Age class assignments was conducted by the center's staff ad admission, also with the aid of published photographic key to ageing nestling RNP (Braun & Wink 2013).

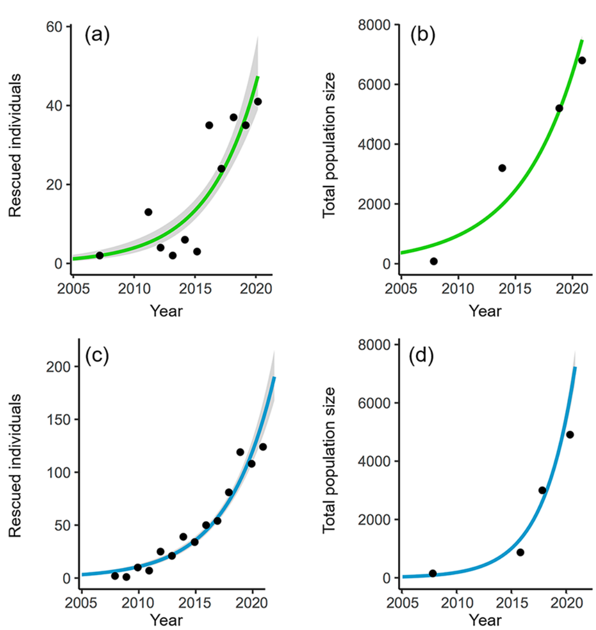

Fig. 1 Trends in numbers of rescued parakeets (a,c) and total population size (b,d) of MP (*Myiopsitta monachus*) – lower panels – and RNP (*Psittacula krameri*) – upper panels – in the city of Rome (Italy) between 2006 and 2020. Trend lines estimated by Poisson linear regression (shaded areas: 95% confidence intervals)

We assigned each non-adult bird to its month of presumed hatch, by assigning nestlings, fledglings and juveniles to 1, 2 and 3 months before admission date, to test for changes in the reproductive phenology.

Rescues as a proxy of population size

Trends in the numbers of rescued birds and population growth were assessed by running log-linear Poisson regressions on the numbers of rescued birds per year across the study period, using year as explaining variable; the relationship between numbers of rescued birds and estimated population size was then assessed by running a Pearson's correlation test with Bonferroni correction for the estimation of p-values. Population size was available for 5 (*P. krameri*: 1996, 2007, 2011, 2018 and 2020) and 4 (*M. monachus*: 1996, 2008, 2016 and 2018) time intervals. At each population size assessment, parakeets were counted using standard count methods, i.e. winter roosts surveys for RNP, and nest counts for MP (for a detailed description of methods see: Pârâu et al. 2016; Postigo et al. 2019; Chessa 2020).

Changes in reproductive phenology

We performed a Hermans-Rasson (HR) test for circular data for assessing whether the numbers of hatchlings followed a uniform distribution over the year and eventually identify peak months of births (Landler et al. 2019). The Hermans–Rasson test was computed through the R package *circMLE* (Fitak 2020). We also tested whether the numbers of months with evidence of hatching activity increased over the years between 2006 and 2019 by running a linear regression. All tests were performed with R 3.3.3 (R Core Team 2013), considering significant results when $p < 0.05$.

Results

Rescues as a proxy of population size

In total, 548 RNPs and 860 MPs were admitted at Rome WRC between 2006 and 2020; among rescued parakeets, 45.4% and 24.1% of RNPs and MPs, respectively, were admitted as adults; of the remaining immature birds, 74.4, 10.3 and 15.2% were classified juveniles, fledglings and nestlings respectively, in the case of RNP; in the case of MP, the same classes respectively represented 75.9, 15.1 and 9.0% of the immature birds. Both parakeet species showed strongly significant exponential trends in numbers of rescued birds as well as in estimated population sizes (Fig. 1). For the RNP, the first rescued bird occurred in 2005, and the rescue trend followed an exponential slope of 0.24 ± 0.03

($p < 0.001$); the first population count dates back to 1996 (10 birds), and followed a slope of 0.19 ± 0.00 ($p < 0.001$), reaching an estimated number of at least 6,800 birds in 2019. For the MP, first census (in 1996) reports 15 birds as total population, which exponentially increased up to 5,500 in 2019 (slope: 0.35 ± 0.01, $p < 0.001$); similarly, rescued MP were first recorded in 2007, also following an exponential growth (slope: 0.29 ± 0.02, $p < 0.001$).

The numbers of rescued birds and population counts showed a strongly positive significant linear relationship for both species: RRP: Estimate ± SE = 148.72 ± 24.84, t = 5.99, $p < 0.01$, adjusted $R^2 = 0.90$; MP: Estimate ± SE = 132.50 ± 36.08, t = 3.67, $p < 0.05$, adjusted $R^2 = 0.82$.

Changes in reproductive phenology

For MP, the HR test evidenced an uneven distribution of breeding events in all years (n = 10, out of 14 years with available data) except for 2006–2008, when too few rescues were recorded (between 0 and 1); in all other years, events were significantly biased, and a progressive advance of the breeding peak was evidenced. In the first years (2009–2013) breeding events peaked in June, while they were more frequent in May during the 2014–2018 interval, and in April in 2019. Moreover, the numbers of months with evidence of breeding also significantly increased with time (linear regression slope: 0.38 ± 0.03, t = 11.04, $p < 0.001$; $R^2 = 0.84$), rising from 1 to 4 months (2006–2011) up to 7 (2017–2019), indicating a concurrent expansion of the reproductive season (Fig. 2).

The HR test for RRP revealed significant results for most years (n = 7, out of 10 years with available data), evidencing a biased distribution of breeding events throughout the year, with a peak in March-April; no evidence of phenological shift was found for this species. A slight but non-significant increase in the number of months with evidence of breeding was also found along the study period (linear regression slope: 0.10 ± 0.04, t = 2.87, p: n.s., R^2: 0.56).

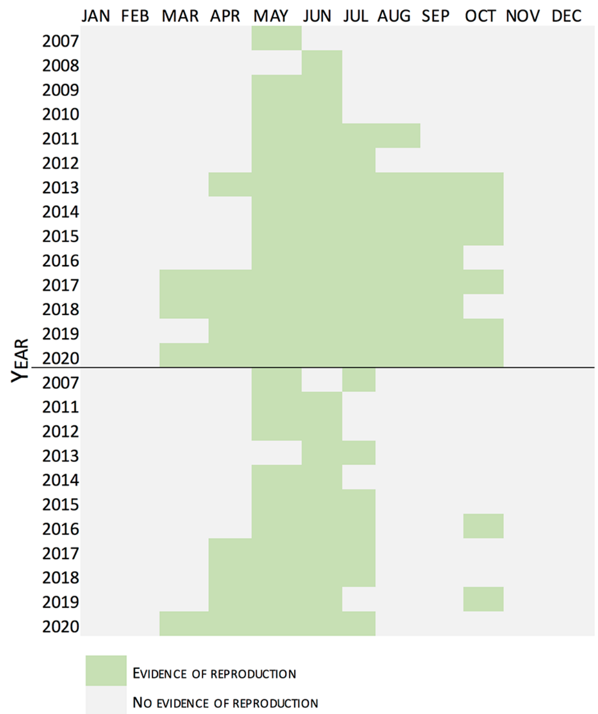

Fig. 2 Monthly distribution of reproductive evidence in Monk (upper panel) and Ring-necked (lower panel) parakeets, assessed as admittance of dependent young at the Wildlife Rescue Center of Rome, between 2007 and 2020

Discussion

Our findings confirmed the importance of WRCs in monitoring the population increase of alien species in urban and suburban ecosystems. Accordingly, a strong correlation occurred between the number of rescued parakeets belonging to two species and their population increase in an European metropolitan area. RNPs are present in Rome since the end of the 1980s, whereas first records of MP date back to early 1990s, but their populations have been limited both in distribution and individual numbers until early 2000s (e.g. Zocchi 1982; Cignini et al. 1996; Zocchi et al. 2009; Fraticelli and Molajoli 2002; Fraticelli 2014; Pârâu et al. 2016; Mori et al. 2020). However, before 2005, no parakeet was rescued in Rome. Currently, about 7,000 RNPs and nearly 6,000 MPs are suggested to occur in Rome. The sharp population increase of both parakeet species was shown to be clearly mirrored by the number of rescued individuals at WRCs.

The analysis of data from WRCs also showed an expansion in the breeding phenology of these parakeets, and predictive models suggest further increases in the number of parakeets (Pitzalis et al. 2005; Strubbe and Matthysen 2009c; Di Febbraro and Mori 2015; Le Gros et al. 2016). Lag phases in biological invasions can postpone important management interventions (Crooks 2005); as long-lived species, parrots usually reach sexual maturity several years after their birth (i.e. 3 years for both the RNP and the MP: Pithon and Dytham 1999; Postigo et al. 2017), so they are a good example of lag phase effects on population dynamics. Therefore, these species offer excellent conditions to rapidly manage their populations at the beginning of their invasion process; as such, the small breeding colony of Alexandrine parakeets *Psittacula eupatria* in Rome (Ancillotto et al. 2016) should be rapidly removed before any further population increase. Since it is important to monitor both new invasions and to keep those already present under monitoring and control even in a period of economic crisis (Nentwig et al. 2018), WRCs may provide researchers not only with health data (Ancillotto et al. 2018), but also genuine and low-cost proxies of population trends. Besides, assessing population dynamics, including data on productivity and recruitment, is pivotal for the control of introduced species (Pruett-Jones et al. 2007; Conroy and Senar 2009). Determining population recruitment and reproductive timing requires addressed and long-lasting monitoring projects (Viana et al. 2016; Luna et al. 2017; Senar et al. 2019).

The breeding period of the RNP in the native range is reported to be limited to spring, with increasing hatching success at lower latitudes (Shwartz et al. 2009; Luna et al. 2017). Pithon and Dytham (1999) suggested a low reproductive output in small populations of RNPs in UK, which may be linked to the low RNP densities recorded for these populations. Accordingly, in early 2000s, i.e. at the start of the invasion process in Europe, the reproductive season was similar between the native and the invasive ranges (Simwat and Sidhu 1973; Butler et al. 2013), with the mean day of first laid egg occurring in late March. However, differently from the native range (Hossain et al. 1993), Butler et al. (2013) were not able to detect any second brood by this species in England. Fledging inflight success was also similar to that recorded in the native range (i.e. about 1.5 young fledged / nest: Shivanarayan et al. 1981). Reproductive phenology of the RNP has been reported as a factor limiting the establishment at northern latitudes (Luna et al. 2017). RNPs are able to adapt to suitable areas by reproducing earlier (starting from late February) than native birds in relatively warm areas (Luna et al. 2017). In our work, we observed that RNP births peak in early spring, which is in line with previous studies on the reproduction of this species (Shivanarayan et al. 1981; Hossain et al. 1993; Butler et al. 2013; Luna et al. 2017), but a slight increase in the number of months with evidence of breeding was detected in the last years (i.e. up to June-July).

As to MPs, Senar et al. (2019) reported that fledgling success was higher in Europe than in the native range (Peris and Aramburú 1995). Although potentially recorded also in Argentina, presumably as a replacement brood (Navarro et al. 1992), the presence of a second brood has been recorded to be more common in the invasive range than in the native one (Peris and Aramburú 1995; Senar et al. 2019). This may also be due to the high environmental temperature and low predation pressure in European cities, which allow MPs to produce a higher number of offspring and for a longer period (7 months) with respect to the native range (5 months: Navarro et al. 1992; Peris and Aramburú 1995; Senar et al. 2019). Furthermore, Senar et al. (2019) reported that, in the invasive range, MPs reach the sexual maturity earlier their conspecifics in the native range, and also yearling birds are able to reproduce, increasing their invasion success. Our findings supported the expansion of the reproductive season of the MP in the last 15 years also in Italy, with chicks currently rescued at the WRC for seven months a year.

The impacts of introduced parakeets have been reviewed in a number of studies (e.g. Mori and Menchetti 2014, 2021; White et al. 2019). The ongoing exponential expansion of Mediterranean populations (see Pârâu et al. 2016; Postigo et al. 2019) is unlikely to be due to continuous releases, but it is possibly linked to increased reproductive outputs (Butler et al. 2013). Particularly, fast expanding populations require continuous monitoring or management actions, to limit impacts on native biodiversity and human wellness (e.g. Luna et al. 2016; Per 2018; Postigo et al. 2017,2019; Saavedra and Medina 2020). Monitoring large and widespread populations of alien species requires a good surveillance system, possibly involving a high amount of personnel (Vall-llosera et al. 2017). We have now shown that WRCs may provide reliable data on population trends, therefore helping to improve models of population growth of invasive species and to design effective management plans.

Acknowledgements Authors would like to thank Mattia Menchetti who helped in data collection on parakeet populations in Rome, and all staff members and volunteers from Rome's wildlife rescue center. The Co-Editor in Chief Charlie Nilon and two anonymous reviewers kindly took the time to provide us with comments on our manuscript.

Author contribution EC and LA conceived the research; EC, VS and CC collected most data on the field; LA ran the analyses; LA and EM wrote the first draft of the manuscript. All authors contributed to and approved the final draft.

Funding The study was supported by no external fund.

Data Availability All data are available via the corresponding author.

Declarations

Ethics approval and consent to participate This study did not involve human subjects. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Consent for publication All authors agree and consent with the publication of the study.

Conflict of interest Authors declare that they have no competing interest.

References

Aaziz R, Gourlay P, Vorimore F, Sachse K, Siarkou VI, Laroucau K (2015) Chlamydiaceae in North Atlantic seabirds admitted to a wildlife rescue center in western France. Appl Envir Microbiol 81:4581–4590

Ancillotto L, Serangeli MT, Russo D (2013) Curiosity killed the bat: domestic cats as bat predators. Mammal Biol 78:369–373

Ancillotto L, Strubbe D, Menchetti M, Mori E (2016) An overlooked invader? Ecological niche, invasion success and range dynamics of the Alexandrine parakeet in the invaded range. Biol Invasions 18:583–595

Ancillotto L, Studer V, Howard T, Smith VS, McAlister E, Beccaloni J, Manzia F, Renzopaoli F, Bosso L, Russo D, Mori E (2018) Environmental drivers of parasite load and species richness in introduced parakeets in an urban landscape. Parasit Res 117:3591–3599

Archibald JL, Anderson CB, Dicenta M, Roulier C, Slutz K, Nielsen EA (2020) The relevance of social imaginaries to understand and manage biological invasions in southern Patagonia. Biol Invasions 22:3307–3323

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Jan Pergl, Pysek P, Rabitsch W, Richardson DM, Roy HE, Saul WC, Scalera R, Vilà M, Wilson JRU, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). Methods Ecol Evol 9:159–168

Battisti C (2019) Impact of monk parakeet *Myiopsitta monachus* on commercial orchards: evidence of persimmon *Diospyros kaki* fruits (Rome, Central Italy). Alula 26:139–142

Berthier A, Clergeau P, Raymond R (2017) De la belle exotique à la belle invasive: Perceptions et appréciations de la Perruche à collier (*Psittacula krameri*) dans la métropole parisienne. Ann de Geographie 4:408–434

Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Markovà Z, Mrugala A, Nentwig W, Pergl J, Pyšek P, Rabistsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Wilson JRU, Winter M, Genovesi P, Bacher S (2014) A unified classification of alien species based on the magnitude of their environmental impacts. Plos Biol 17:203–207

Blackburn TM, Bellard C, Ricciardi A (2019) Alien versus native species as drivers of recent extinctions. Front Ecol Environm 17:203–207

Boscherini A, Mazza G, Menchetti M, Laurenzi A, Mori E (2020) Time is running out! Rapid range expansion of the invasive northern raccoon in central Italy. Mammalia 84:98–101

Braun MP, Wink M (2013) Nestling development of ring-necked parakeets (*Psittacula krameri*) in a nest box population.The Open Ornithology Journal, *6*(1)

Butler CJ, Gosler A (2004) Sexing and ageing Rose-ringed Parakeets *Psittacula krameri* in Britain. Ringing Migrat 22:7–12

Butler C, Cresswell W, Gosler A, Perrins C (2013) The breeding biology of rose-ringed parakeets *Psittacula krameri* in England during a period of rapid population expansion. Bird Study 60:527–532

Cagnacci F, Cardini A, Ciucci P, Ferrari N, Mortelliti A, Preatoni DG, Russo D, Scandura M, Wauters LA, Amori G (2012) Less is more: researcher survival guide in times of economic crisis. Hystrix 23:1–7

Castiglioni R, Azzola C, Capelli F, Biancardi C (2015) Aspetti ecologici e riproduttivi del parrocchetto monaco (*Myiopsitta monachus* Boddaert, 1783) in una colonia in provincia di Bergamo. XVIII Congresso Italiano di Ornitologia – Caramanico Terme (Pescara)–17–20September 2015: 17.

Chessa C (2020) Parrocchetto dal collare e parrocchetto monaco in Italia: aggiornamento dello stato attuale delle popolazioni. BSc Dissertation in Scienze Naturali, Università degli Studi di Roma "La Sapienza", Roma, Italy

Cignini B, Buscemi A, Isotti R, Tuccinardi P (1996) Tentativo di nidificazione di parrocchetto monaco *Myiopsitta monachus* a Roma. Alula 3:131–132

Conroy MJ, Senar JC (2009) Integration of demographic analyses and decision modeling in support of management of invasive Monk parakeets, an urban and agricultural pest. Environ Ecol Stat 3:491–510

Covas L, Senar JC, Roquè L, Quesada J (2017) Records of fatal attacks by rose-ringed parakeets *Psittacula krameri* to native avifauna. Rev Cat Ornit 33:45–49

Crooks JA (2005) Lag times and exotic species: The ecology and management of biological invasions in slow-motion. Ecoscience 12:316–329

Daume S (2016) Mining Twitter to monitor invasive alien species- an analytical framework and sample information topologies. Ecol Inf 31:70–82

Diagne C, Leroy B, Gozlan RE, Vaissière AC, Assailly C, Nuninger L, Roiz D, Jourdain F, Jaric I, Courchamp F (2020) InvaCost, a public database of the economic costs of biological invasions worldwide. Sci Data 7:1–12

Diamond JM, Ross MS (2019) Exotic parrots breeding in urban tree cavities: nesting requirements, geographic distribution, and potential impacts on cavity nesting birds in southeast Florida. Avian Res 10:39

Di Febbraro M, Mori E (2015) Potential distribution of feral parakeets in Tuscany (Central Italy): a bioclimatic model approach. Ethol Ecol Evol 27:116–128

Domènech J, Carrillo J, Senar JC (2003) Population size of the monk parakeet *Myiopsitta monachus* in Catalonia. Rev Cat Ornit 20:1–9

Eberhard JR (1998) Breeding biology of the Monk Parakeet. Wilson Bull 110:463–473

Engeman R, Whisson D, Quinn J, Cano F, Quiñones P, White TH Jr (2006) Monitoring invasive mammalian predator populations sharing habitats with the Critically Endangered Puerto Rican parrot *Amazona vittata*. Oryx 40:95–102

European Union (2020) Invasive Alien Species of Union Concern. Available at: https://op.europa.eu/en/publication-detail/-/publication/047cee1a-077b-11eb-a511-01aa75ed71a1. Accessed on 15.10.2021

Evans T, Kumschick S, Şekercioğlu ÇH, Blackburn TM (2018) Identifying the factors that determine the severity and type of alien bird impacts. Divers Distrib 24:800–810

Fierro-Calderòn E, Fierro-Calderòn K (2020) First record of *Psittacara erythrogenis* (Psittacidae) in Colombia. Caldasia 42:347–349

Fitak R (2020) Package "CircMLE". Maximum Likelihood Anaylsis of Circular Data. Available at https://cran.r-project.org/web/packages/CircMLE/CircMLE.pdf. Accessed on 15.10.2021

Fraticelli F, Molajoli R (2002) Nidificazione del parrocchetto dal collare *Psittacula krameri* a Roma. Alula 9:110–111

Fraticelli F (2014) The rose-ringed parakeet *Psittacula krameri* in a urban park: demographic trend, interspecific relationships and feeding preferences (Rome, central Italy). Avocetta 38:23–28

Grandi G, Menchetti M, Mori E (2018) Vertical segregation by ring-necked parakeets *Psittacula krameri* in northern Italy. Urban Ecosyst 21:1011–1017

Hernández-Brito D, Carrete M, Ibáñez C, Juste J, Tella JL (2018) Nest-site competition and killing by invasive parakeets cause the decline of a threatened bat population. Royal Soc Open Sci 5:172477

Hernandez-Brito D, Carrete M, Blanco G, Romero-Vidal P, Senar JC, Mori E, White TH, Luna A, Tella JT (2021) The role of monk parakeets as nest-site facilitators in their native and invaded areas. Biology 10:683

Hossain MT, Husain KZ, Rahman MK (1993) Some aspects of the breeding biology of the rose-ringed parakeet, *Psittacula krameri borealis* (Neumann). Bangladesh J Zool 21:77–85

Hulme PE (2006) Beyond control: wider implications for the management of biological invasions. J Appl Ecol 43:835–847

Ivanova IM, Symes CT (2019) Invasion of *Psittacula krameri* in Gauteng, South Africa: are other birds impacted? Biodiv Conserv 28:3633–3656

Kalandarishvili A, Heltai M (2019) The colonization of raccoon (*Procyon lotor* L. 1758) in Georgia–The beginning of the invasion? Columella. J Agric Environm Sci 6:17–28

Kumschick S, Nentwig W (2010) Some alien birds have as severe an impact as the most effectual alien mammals in Europe. Biol Cons 143:2757–2762

La Morgia V, Paoloni D, Genovesi P (2017) Eradicating the grey squirrel *Sciurus carolinensis* from urban areas: an innovative decision-making approach based on lessons learnt in Italy. Pest Manage Sci 73:354–363

Landler L, Ruxton GD, Malkemper EP (2019) The Hermans–Rasson test as a powerful alternative to the Rayleigh test for circular statistics in biology. BMC Ecol 19:1–8

Larson ER, Graham BM, Achury R, Coon JJ, Daniels MK, Gambrell DK, Jonasen KL, King GD, LaRacuente N, Perrin-Stowe TI, Reed EM, Rice CJ, Ruzi SA, Thairu MW, Wilson JC, Suarez AV (2020) From eDNA to citizen science: emerging tools for the early detection of invasive species. Front Ecol Environm 18:194–202

Le Gros A, Samadi S, Zuccon D, Cornette R, Braun MP, Senar JC, Clergeau P (2016) Rapid morphological changes, admixture and invasive success in populations of Ring-necked parakeets (*Psittacula krameri*) established in Europe. Biol Invasions 18:1581–1598

Le Louarn M, Clergeau P, Briche E, Deschamps-Cottin M (2017) "Kill two birds with one stone": Urban tree species classification using bi-temporal Pléiades images to study nesting preferences of an invasive bird. Remote Sens 9:916

Liu X, Blackburn TM, Song T, Wang X, Huang C, Li Y (2020) Animal invaders threaten protected areas worldwide. Nat Comm 11:1–9

Luna A, Monteiro M, Asenzio-Cenzano E, Reino L (2016) Status of the rose-ringed parakeet *Psittacula krameri* in Lisbon, Portugal. Biologia 71:717–720

Luna A, Franz D, Strubbe D, Shwartz A, Braun MP, Hernàndez-Brito D, Malihi Y, Kaplan A, Mori E, Menchetti M, van Turnhout CAM, Parrott D, Chmielewski FM, Edelaar P (2017) Reproductive timing as a constraint on invasion success in the ring-necked parakeet (*Psittacula krameri*). Biol Invasions 19:2247–2259

Martinoli A, Bertolino S, Preatoni DG, Balduzzi A, Marsan A, Genovesi P, Tosi G, Wauters LA (2010) Headcount 2010: the multiplication of the grey squirrel introduced in Italy. Hystrix 21:127–136

Mazzamuto MV, Panzeri M, Bisi F, Wauters LA, Preatoni D, Martinoli A (2020) When management meets science: adaptive analysis for the optimization of the eradication of the Northern raccoon (*Procyon lotor*). Biol Invasions 22:3119–3130

Menchetti M, Mori E (2014) Worldwide impact of alien parrots (Aves Psittaciformes) on native biodiversity and environment: a review. Ethol Ecol Evol 26:172–194

Molony SE, Dowding CV, Baker PJ, Cuthill IC, Harris S (2006) The effect of translocation and temporary captivity on wildlife rehabilitation success: an experimental study using European hedgehogs (*Erinaceus europaeus*). Biol Cons 130:530–537

Mori E, Ancillotto L, Menchetti M, Strubbe D (2017) 'The early bird catches the nest': possible competition between scops owls and ring-necked parakeets. Anim Cons 20:463–470

Mori E, Sala JP, Fattorini N, Menchetti M, Montalvo T, Senar JC (2019) Ectoparasite sharing among native and invasive birds in a metropolitan area. Paras Res 118:399–409

Mori E, Onorati G, Giuntini S (2020) Loud callings limit human tolerance towards invasive parakeets in urban areas. Urban Ecosyst 23:755–760

Mori E, Menchetti M (2021) The Ecological Impacts of introduced parrots. In: Pruett-Jones S (ed) Naturalized parrots of the world. Distribution, ecology, and impacts of the world's most colorful colonizers. Princeton University Press, New Jersey, USA, pp 87–101

Navarro JL, Martella MB, Bucher EH (1992) Breeding season and productivity of Monk parakeets in Cordoba, Argentina. Wilson Bull 104:413–424

Nentwig W, Bacher S, Kumschick S, Pyšek P, Vilà M (2018) More than "100 worst" alien species in Europe. Biol Invasions 20:1611–1621

Pârâu LG, Strubbe D, Mori E, Menchetti M, Ancillotto L, van Kleunen A, White RL, Hernàndez-Brito D, Le Louarn M, Clergeau P, Albayrak T, Franz D, Braun MP, Schroeder J, Wink M (2016) Rose-ringed parakeet *Psittacula krameri* populations and numbers in Europe: a complete overview. Open Ornith J 9:1–13

Per E (2017) The first report and preliminary observations on escaped parrot species (Psittaciformes) in Turkey through citizen science. Bird Census News 30:47–52

Per E (2018) The spread of the Rose-ringed Parakeet, *Psittacula krameri*, in Turkey between 1975 and 2015 (Aves: Psittacidae). Zool Middle East 64:297–303

Peris SJ, Aramburú RM (1995) Reproductive phenology and breeding success of the Monk Parakeet (*Myiopsitta monachus monachus*) in Argentina. Stud Neotr Fauna Environm 30:115–119

Pithon JA, Dytham C (1999) Breeding performance of ring-necked parakeet *Psittacula krameri* in small introduced populations in southeast England. Bird Study 46:342–347

Pitzalis M, Marangoni C, Bologna M (2005) Analisi di processi di dispersione e colonizzazione tramite un GIS in tre specie di uccelli alloctoni nella fauna di Roma (Italia centrale). Alula 12:193–205

Postigo JL, Shwartz A, Strubbe D, Muñoz AR (2017) Unrelenting spread of the alien monk parakeet *Myiopsitta monachus* in Israel. Is it time to sound the alarm? Pest Manage Sci 73:349–353

Postigo JL, Strubbe D, Mori E, Ancillotto L, Carneiro I, Latsoudis P, Menchetti M, Pârâu LG, Parrott D, Reino L, Weiserbs A, Senar JC (2019) Mediterranean versus Atlantic monk parakeets *Myiopsitta monachus*: towards differentiated management at the European scale. Pest Manage Sci 75:915–922

Pruett-Jones S, Newman JR, Newman CM, Avery ML, Lindsay JR (2007) Population viability analysis of Monk parakeets in the United States and examination of alternative management strategies. Human-Wildl Confl 1:35–44

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P, Jeschke JM, Kühn I, Liebhold AM, Mandrak NE, Meyerson LA, Pauchard A, Pergl J, Roy HE, Seebens H, van Kleunen M, Vilà M, Wingfield MJ, Richardson DM (2020) Scientists' warning on invasive alien species. Biol Rev 95:1511–1534

R Core Team (2013) R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing ISBN 3-900051-07-0. http://www.Rproject.org/ Accessed on 25.06.2021

Reeve NJ, Huijser MP (1999) Mortality factors affecting wild hedgehogs: a study of records from wildlife rescue centers. Lutra 42:7–24

Rodríguez-Pastor R, Senar JC, Ortega A, Faus J, Uribe F, Montalvo T (2012) Distribution patterns of invasive monk parakeets (*Myiopsitta monachus*) in an urban habitat. Anim Biodiv Conserv 35:107–117

Rocha R, Reino L, Sepúlveda P, Ribeiro J (2020) Introduced population of ring-necked parakeets *Psittacula krameri* in Madeira Island, Portugal – call for early action. Manage Biol Invasions 11:576–587

Saavedra S, Medina FM (2020) Control of invasive ring-necked parakeet (*Psittacula krameri*) in an island Biosphere Reserve (La Palma, Canary Islands): combining methods and social engagement. Biol Invasions 22:3653–3667

Senar JC, Domènech J, Arroyo L, Torre I, Gordo O (2016) An evaluation of monk parakeet damage to crops in the metropolitan area of Barcelona. Anim Biodiv Conserv 39:141–145

Senar JC, Carrillo-Ortiz JG, Ortega-Segalerva A, Dawson Pell FSE, Pascual J, Arroyo L, Mazzoni D, Montalvo T, Hatchwell BJ (2019) The reproductive capacity of monk parakeets *Myiopsitta monachus* is higher in their invasive range. Bird Study 66:136–140

Shine R, Koenig J (2001) Snakes in the garden: an analysis of reptiles "rescued" by community-based wildlife carers. Biol Cons 102:71–283

Shivambu TC, Shivambu N, Downs CT (2020) Population estimates of non-native rose-ringed parakeets *Psittacula krameri* (Scopoli, 1769) in the Durban Metropole, KwaZulu-Natal Province, South Africa. https://doi.org/10.1007/s11252-020-01066-3. Urban Ecosyst

Shivanarayan N, Babu KS, Ali MH (1981) Breeding biology of roseringed parakeet *Psittacula krameri* at Maruferu. Pavo 19:92–96

Shwartz A, Butler CJ, Kark S, Matthysen E, Strubbe D (2009) The effect of enemy-release and climate conditions on invasive birds: a regional test using the rose-ringed parakeet (*Psittacula krameri*) as a case study. Divers Distrib 15:310–318

Simwat GS, Sidhu AS (1973) Nidification of rose-ringed parakeet, *Psittacula krameri* (Scopoli), in Punjab. Indian J Agric Sci 43:648–652

Sol D, Gonzàlez-Lagos C, Lapiedra O, Dìaz M (2017) Why are exotic birds so successful in urbanized environments? In: Murgui E, Hedblom M (eds) Ecology and Conservation of Birds in Urban Environments. Springer Editions, London, UK, pp 75–89

Strubbe D, Matthysen E (2009a) Establishment success of invasive ring-necked and monk parakeets in Europe. J Biogeogr 36:2264–2278

Strubbe D, Matthysen E (2009b) Experimental evidence for nest-site competition between invasive ring-necked parakeets (*Psittacula krameri*) and native nuthatches (*Sitta europaea*). Biol Cons 142:1588–1594

Strubbe D, Matthysen E (2009c) Predicting the potential distribution of invasive ring-necked parakeets *Psittacula krameri* in northern Belgium using an ecological niche modelling approach. Biol Invasions 11:497–513

Symes CT (2014) Founder populations and the current status of exotic parrots in South Africa. Ostrich 85:235–244

Uehling JJ, Tallant J, Pruett-Jones S (2019) Status of naturalized parrots in the United States. J Ornithol 160:907–921

Vall-llosera M, Woolnough AP, Anderson D, Cassey P (2017) Improved surveillance for early detection of a potential invasive species: the alien rose-ringed parakeet *Psittacula krameri* in Australia. Biol Invasions 19:1273–1284

Viana IR, Strubbe D, Zocche JJ (2016) Monk parakeet invasion success: a role for nest thermoregulation and bactericidal potential of plant nest material? Biol Invasions 18:1305–1315

Viviano A, Mori E (2021) Population counts and potential impact of two successful invaders in a town of Northern Italy: the case of ring-necked parakeet and Alexandrine parakeet in Reggio Emilia. Nat Hist Sci 8:35–40

White R, Strubbe D, Dallimer M, Davies ZG, Davis AJS, Edelaar P, Groombridge J, Jackson HA, Menchetti M, Mori E, Nikolov BP, Pârâu LG, Pečnikar ŽF, Pett TJ, Reino L, Tollington S, Turbè A, Shwartz A (2019) Assessing the ecological and societal impacts of alien parrots in Europe using a transparent and inclusive evidence-mapping scheme. Neobiota 48:45

Yosef R, Zduniak P, Żmihorski M (2016) Invasive ring-necked parakeet negatively affects indigenous Eurasian hoopoe. Ann Zool Fennici 53:281–287

Zocchi A (1982) Un cacatua delle Molucche nel Parco di Villa Doria Pamphilii a Roma. Boll Centro Studi Conservazione Psittaciformi 2:54–56

Zocchi A, Battisti C, Santoro R (2009) Note sul pappagallo monaco, *Myiopsitta monachus*, a Roma (Villa Pamphilii). Riv Ital Ornit Milano 78:135–137