

Unrelenting spread of the alien monk parakeet *Myiopsitta monachus* in Israel. Is it time to sound the alarm?

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Abstract

BACKGROUND: Monk parakeets, *Myiopsitta monachus* Boddaert, are native to South America but have established populations in North America, Europe, Africa and Asia. They are claimed to act as agricultural pests in their native range, and their communal stick nests may damage human infrastructure. Although several monk parakeet populations are present in the Mediterranean Basin and temperate Europe, little empirical data are available on their population size and growth, distribution and potential impact. We investigated the temporal and spatial dynamics of monk parakeets in Israel to assess their invasion success and potential impact on agriculture.

RESULTS: Monk parakeet populations are growing exponentially at a higher rate than that reported elsewhere. The current Israeli population of monk parakeets comprises approximately 1500 individuals. The distribution of the species has increased and shifted from predominantly urban areas to agricultural landscapes.

CONCLUSIONS: In Israel, monk parakeet populations are growing fast and have dispersed rapidly from cities to agricultural areas. At present, reports of agricultural damage are scarce. A complete assessment of possible management strategies is urgently needed before the population becomes too large and widespread to allow for cost-effective mitigation campaigns to be implemented.

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Keywords: growth rate; invasive parrot; Israel; population dynamics; range expansion

1 INTRODUCTION

Information on the distribution and population growth of invasive alien species can be difficult to obtain, especially during the early stages of the invasion process, when invading species typically occur at low densities.^{1–3} However, alien birds are frequently attractive to humans and conspicuous, and consequently their introduction history has often been (reasonably) well documented. There is a generally good historical record of introduced birds worldwide, and thus avian invasions have strongly contributed to a better understanding of biological invasions.^{4–6} Parrots are well-known, widespread and charismatic alien birds, but some of them are considered to be pests in their native range and may also cause damage in non-native habitats.^{3,7} The most outstanding alien species of the Psittacidae are the ring-necked parakeet, *Psittacula krameri* Scopoli, and the monk parakeet, *Myiopsitta monachus* Boddaert. Both species are known to be able to cause extensive agricultural damage in their native ranges.^{8,9}

The monk parakeet is a highly social and vociferous parrot that is capable of acting as a pest species in its natural range of South America.^{10,11} It is unique among parrots in that it builds a communal nest, which contains a variable number of chambers that are used for breeding and also for roosting throughout the

year.¹² Monk parakeets were trapped on a massive scale for export to other countries as pets, and there is a growing number of new populations worldwide owing to intentional releases or accidental escapes.^{7,13–16} Most of the new alien populations appear in large cities,¹⁷ where they may not only cause damage in parks, gardens and orchards but can also damage human infrastructure (e.g. by

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building their bulky communal nests on utility poles).¹⁸ They are also sometimes perceived as a new source of noise pollution.^{19,20}

Once they are established in cities, urban colonies can act as propagules for their spread to suburban and neighbouring rural areas. Evidence from the United States suggests that their capacity for spread outside urbanised areas may be associated with climate and may be limited to warmer areas,²¹ such as the Mediterranean Basin where food is available all year in large cities and during part of the year in agricultural land. In any case, population estimates are essential to draw definite conclusions about the population dynamics of an invasive species and to guide management planning. Therefore, we assessed the current population size of monk parakeets in Israel and analysed the population and range dynamics of the species over the last two decades. We also determined its population growth rate in urban and agricultural areas. Finally, we identified and estimated the agricultural areas potentially exposed to damage.

2 METHODS

2.1 Study area

The study area comprised two locations in the Israeli low-altitude coastal plain, where the parakeets were first introduced: the Tel-Aviv District and Central District. These areas have the highest human population densities in the country, with 7784 and 1527 inhabitants per square kilometre respectively, and hold over 40% of the total population of Israel. The Tel-Aviv District and Central District comprise urban land (87 and 46% respectively) and farmland (6 and 26% respectively).²² Monk parakeets were first detected in 1995 in Yarkon Park, which is the largest park in Israel and is located in the northern part of the Tel-Aviv District.²³ Breeding monk parakeets were first recorded in 1998 (Shwartz A, unpublished). Although the initial population size in the Tel-Aviv District is unknown, four birds were released in the mid-1990s in the Central District in the same area where nests were first observed (Hatsofe O, private communication, 2004).

2.2 Population estimates and distribution

Monk parakeet population censuses were based on surveys of the number of nests, number of chambers per nest and estimates of 'occupancy' (i.e. the number of birds inhabiting a chamber). Historical survey data were available from anecdotal observations of birdwatchers and officials of the Israeli Nature and Park Authority (Shwartz A, unpublished). Five systematic surveys of nests and chambers were conducted in the period 2004–2007 and 2015 prior to the breeding season, which starts around April in the Mediterranean Basin.²⁴ The same methodology for detecting nests was used in each survey. Before conducting the censuses, birdwatchers, researchers, zookeepers and government and non-governmental officials were asked via online bird forums, mailing lists and websites to provide as much information as possible about the presence of monk parakeets in their areas. We then visited all the reported locations to confirm their presence and identify nests by locating calling birds.^{25–27} This is a feasible and efficient method to locate colonies, because monk parakeets are noisy and conspicuous birds that spend a large amount of time in the vicinity of their nests.^{26,27} We recorded the geographical coordinates and the nesting substrate (i.e. tree species) of each nest. Damaged chambers were considered to be abandoned and were not taken into account because monk parakeets use and repair their nests continually.^{13,28} In the case of nests in palm

trees (typically *Phoenix* palms), monk parakeets normally build individual nests around the base of the leaves until they finally merge and form a ring. For this reason, nests in palm trees were always counted as one nest, even if they had not yet merged.

From across the current Israeli distribution range, we selected a number of nests ($n = 34$) including 67 chambers, where visibility allowed extensive and detailed monitoring of monk parakeet activity, to estimate chamber occupancy. We conducted the survey in March before the breeding period to determine total population size. Monk parakeets reach sexual maturity in their third calendar year (around 50% of birds breed for the first time 2 years after fledging).²⁹ During the breeding period, breeding pairs defend the nest and prevent non-breeders from roosting inside. Therefore, if the occupancy survey is conducted at this time, the total population size could be seriously underestimated. The number of roosting parakeets per chamber was estimated by counting the number of birds moving in and out and calculating the number of those remaining in the nest at night. The survey was conducted from the ground, using binoculars between 1 h before sunset to the cessation of activity in the colony.²⁴ We counted the number of nests and the number of chambers, even though there is a strong correlation between these parameters that can be used as an indirect indicator of population size.²⁴ Population trends for the period 1998–2015 were determined using the number of nests, as no information was available about the number of chambers per nest during the first years (i.e. 1998, 2000) they were observed. We used the number of chambers and estimates of occupancy to estimate the monk parakeet population in 2015.

2.3 Data analysis

Following the methodology proposed by Van Bael and Pruett-Jones,³⁰ we used the number of nests detected in the period 1998–2015 to estimate monk parakeet population growth trends. The rate of population growth (r) was obtained by fitting the census data to the model using the equation $N_{t+1} = N_t e^{rt}$, where N_{t+1} is the population size at time $t + 1$, N_t is the population at time t , e is the natural logarithm base, r is the intrinsic rate of population growth and t is the time interval.

In order to determine whether the monk parakeet population growth rates differed between urban and rural habitats, we assigned nests to three habitat classes according to the amount of farmland in the vicinity of the nests. Given the lack of empirical data on invasive monk parakeet home ranges, based on our own observations, we considered a distance of 1 km from the nests to be the regular feeding distance (RFD) and 2 km to be the extreme feeding distance (EFD). Monk parakeets were considered to inhabit three habitats: agricultural habitats, when farmland was included in their RFD; semi-agricultural habitats, when farmland was included in their EFD but not in their RFD; urban habitats, when no farmland was included in their EFD. Population growth curves were fitted separately for monk parakeets living in these three habitats. We used the RFD and EFD to estimate the area potentially at risk of monk parakeet crop damage. As a proxy of potential damage, we calculated the farmland area within a circle centred on the location of each reported (1998, 2000) or recorded nest (2004–2007 and 2015). These calculations were performed using the QGIS 2.8.3 Wien[®] software program. Spatially explicit GIS data on land use was obtained from the Israeli Nature and Park Authority.

To explore the differences in population growth rates between the three habitats, we built a linear model with $\log(\text{number of nests} + 1)$ as a dependent variable and the interaction between

year and habitat (urban, semi-agriculture and agriculture) as explanatory variables. We tested model assumptions for normality and non-constant error in variance using Shapiro–Wilk and Breusch–Pagan tests respectively. We used a linear model to test whether the amount of agricultural land within monk parakeet home ranges increased over time.

3 RESULTS

3.1 Monk parakeet population size and trends

Monk parakeet nest censuses showed that the population grew exponentially in Israel in the period 1998–2015 at a rate (r) of 0.303 (model $R^2 = 0.962$) (Fig. 1). In 2015, 1213 chambers were detected. During the 2004–2007 period, there were between 1 and 4 chambers per nest (average 2.23 ± 0.65), whereas in 2015 there were between 1 and 20 chambers per nest (average 2.37 ± 2.24). There was an average of 1.3 ± 1.3 monk parakeets per chamber (range 1–6), which corresponded to an estimated average of 1556 (95% confidence interval 1162–1943) monk parakeets in 2015.

3.2 Spatiotemporal patterns of monk parakeet distribution

According to RFD and EFD, in 2015 there were 92 monk parakeet nests (18.0%) in urban habitat, 326 (63.8%) in agricultural habitat and 93 (18.2%) in semi-agricultural habitat. The majority of the urban nests (87) were located in Yarkon Park (Tel Aviv District). In the Israeli Central District, only six monk parakeet nests were found in urban habitat, whereas the rest (413) were located in agricultural and semi-agricultural habitats.

Urban populations grew more slowly than agricultural populations ($r = 0.207$ versus $r = 0.421$ respectively; $P = 0.03$, $R^2 = 0.88$), while there was no difference in growth rates between populations in either habitat compared with semi-agricultural populations ($r = 0.489$) (Fig. 2). The population doubling times were 1.5, 3.1 and 1.7 years in semi-agricultural, urban and agricultural habitats respectively. Based on the RFD, the area of farmland at risk increased from 0.58 km² in 2004 to about 20.7 km² in 2015. However, when based on the EFD, the farmland at risk increased from 1.66 km² in 2004 to 72.3 km² in 2015. Thus, there was a significant increase in agricultural land at risk of crop damage over the study period ($P = 0.003$, $R^2 = 0.87$) (supporting information Fig. S1).

3.3 Nest substrate

In 2015, monk parakeet nests were found in five tree species. The majority of the nests were built in Aleppo pines, *Pinus halepensis* M. (65.9%), followed by date palms, *Phoenix* spp. (16.8%), *Eucalyptus* spp. (10.8%), Canary pines, *Pinus canariensis* C. SM. (4.3%), fan palms, *Washingtonia* spp. (2.0%), and one unidentified species of tree (0.2%). The tree species differed between habitats; the majority of monk parakeet nests in urban areas were built in *Eucalyptus* trees (59.8%), followed by Aleppo pines and date palms (30.4 and 9.8% respectively), whereas in semi-agricultural and agricultural areas the vast majority of nests were built in Aleppo pines (>78.5%).

4 DISCUSSION

Since its introduction in Israel in 1995, the monk parakeet population has undergone striking growth. We estimate that the current population is about 1500 individuals, and therefore the Israeli population is the second largest in Europe and the Mediterranean Basin after the Spanish population of around 20 000 individuals.³¹

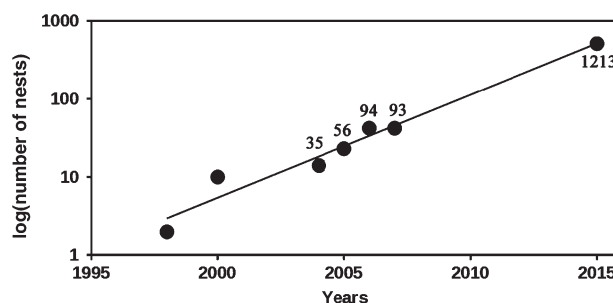


Figure 1. Population growth (1998–2015): population growth of *M. monachus* during the period 1998–2015; the labels represent the number of chambers in every year (2004–2015).

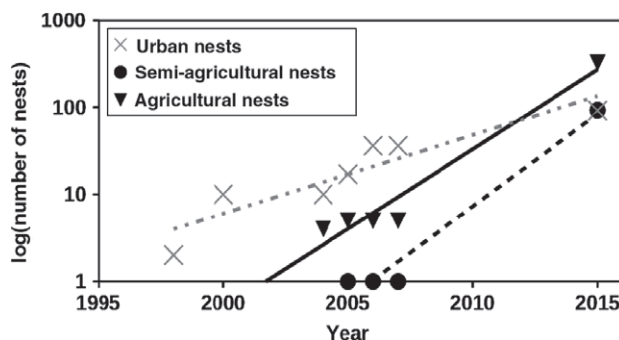


Figure 2. Population growth according to habitat: *M. monachus* population growth rates according to habitat.

Furthermore, since their introduction in Israel, monk parakeets have not only expanded their distribution from cities to agricultural areas but also established a growing number of breeding colonies in the vicinity of farmland.

In Israel, the monk parakeet population growth is exponential, as in other non-native areas, but it is noteworthy that the intrinsic rate of population growth in the Israeli population is about 3 times higher than the reported rate for alien monk parakeets in the United States ($r = 0.303$ versus 0.119 respectively).³² This information should be considered to be a warning of future population increase and range expansion, and probably of increased conflict with farmers in agricultural land. Israel produced about 5000 tons of sunflower seeds in 2014,³³ which is precisely the type of crop that is targeted by the monk parakeet in its native range.³⁴ Furthermore, climate has been commonly considered to be a primary factor that affects the distribution of alien species,³⁵ and so environmental conditions in the invaded area could explain the relative success of monk parakeets in Israel.³⁶ In Chicago (IL), monk parakeets are completely dependent on anthropogenic foods during the winter months.³⁷ The species is more likely to become extinct in colder and less densely populated invaded areas.¹⁵ A recent study showed that monk parakeets are unlikely to spread from urban habitats in cold areas of the United States owing to climate mismatch between the locations of origin and introduction.²¹ In Israel, however, monk parakeets do not face the energetic constraints of surviving and breeding at cold temperatures. Similarly to the case of ringed-necked parakeets in Israel,³⁸ we suggest that the temperate Mediterranean climate may facilitate higher reproductive and/or survival rates among monk parakeets.

Alien monk parakeets are thought to pose a relatively minor threat to agriculture not only because of their reliance on anthropogenic food³⁹ but also because there is no evidence that they

travel great distances,²⁹ even though agroecosystems are prone to invasions.⁴⁰ However, our study shows that, in contrast to other invaded areas, monk parakeets in Israel have spread from their urban strongholds to agricultural areas in a short period of time. A similar situation occurred in Spain, where monk parakeets spread from Barcelona to farmlands outside the city and caused damage to different crops (0.4% for tomatoes *Solanum lycopersicum* L., 7% for quinces *Cydonia oblonga* M., 17% for persimmons *Dyospiros kaki* L. f., 28% for corn *Zea mays* L., 9–36% for different varieties of round plums *Prunus domestica* L. and 37% for pears *Pyrus communis* L.⁴¹ Very recently, the Agriculture Damage Section of the Israeli Nature and Park Authority (Kaplan A, private communication, 2015) reported the first flock of monk parakeets feeding on wheat *Triticum* spp., which is common behaviour in its native range.⁴² Further studies could investigate the effect of land use changes and crop rotation on the expansion of monk parakeets in agricultural land.

In their native range, and especially in the Argentinian pampa grasslands, monk parakeets have strongly benefited from the conversion of natural grasslands to crops and urban areas. They have also benefited from the introduction of eucalyptus trees, in which they commonly breed both in South America and in invaded areas^{43,44} such as Israel and other parts of the Mediterranean Basin. If the rapid increase in population size in invaded areas such as the United States and Spain^{30,31} is taken into account, and also the fact that this parakeet can easily adapt to urban,^{30,31} suburban and agricultural habitats, it is reasonable to assume that the monk parakeet population will continue to spread and increase in Israel. This possibility is also supported by its nearly omnivorous diet,¹² its capacity to build its own nests, its large reproductive output⁸ and the generally favourable environmental conditions in the Israeli host area. Given these aspects, important farmland areas may be highly susceptible to invasion by the monk parakeet.

The potential risk of monk parakeet crop damage needs to be assessed in Israel and other Mediterranean areas where the species is firmly established. Such an assessment should include population viability analyses following Conroy and Senar²⁰ and Pruett-Jones *et al.*³² and also studies related to diet and feeding habits as important aspects of the biology of this species in non-native areas.^{20,32} The potential impact on crops could be assessed by identifying and quantifying food resources and by determining whether they are consumed in a selective way in relation to their availability.

However, the need for a more rigorous evaluation of possible monk parakeet impacts and mitigation strategies should not preclude rapid management actions, especially in Israel, where short-term monk parakeet damage to crops is not unexpected. Conflicts between farmers and parakeets, if not managed properly, are likely to result in (unplanned, unauthorised) cullings of monk parakeets (e.g. through poisoning), risking indirect negative consequences on the environment. Building on the expertise gained from monk parakeet management programmes such as the ones carried out in the United States,³² we advocate that, especially in agricultural areas, cautious mitigation actions be urgently implemented in order to reduce population growth and range expansion rates. Such actions can include the sterilisation of eggs to prevent them from hatching, or capturing monk parakeets where feasible. Environmental agencies should take action to reduce conflicts in a responsible manner and monitor ecological, agriculture and other social impacts to establish whether and which action is needed. In countries where the species is not yet established, or where only small localised populations are present, it

may be prudent to follow the precautionary principle and implement rapid-action eradication campaigns to prevent damage, as currently being undertaken in the United Kingdom, where parakeets are captured and taken to zoological parks (Robertson P, private communication, 2015). However, prior to implementing such campaigns, we would recommend conducting a feasibility study of the current situation that takes different aspects of biological invasions into account, including a cost-benefit analysis, an assessment of the feasibility of the measures proposed and a strategy for consulting and engaging public opinion, given that monk parakeets are often positively regarded by the citizens.⁴⁵

As suggested by Strubbe *et al.*⁴⁶ with regard to alien birds, a comprehensive study would be essential to identify the most appropriate long-term management policies and the most cost-effective way to manage the risk posed by monk parakeets in urban and agricultural ecosystems. If no action is taken until the problems have become severe, the effort needed to reduce damage could be too large to be practically implemented.

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SUPPORTING INFORMATION

Supporting information may be found in the online version of this article.

REFERENCES

- Hulme PE, Trade, transport and trouble: managing invasive species pathways in an era of globalization. *J Appl Ecol* **46**: 10–18 (2009).
- Hulme PE, Beyond control: wider implications for the management of biological invasions. *J Appl Ecol* **43**:835–847 (2006).
- Crook JA, Lag times, in *Encyclopedia of Biological Invasions*, ed. by Simberloff D and Rejmánek M. University of California Press, London, UK, pp. 404–409 (2011).
- Blackburn TM and Duncan RP, Determinants of establishment success in introduced birds. *Nature* **414**:195–197 (2001).
- Blackburn T, Lockwood J and Cassey P, *Avian Invasions: the Ecology and Evolution of Exotic Birds*. Oxford University Press, Oxford, UK (2009).
- Sol D, Maspons J, Vall-Llosera M, Bartomeus I, García-Peña GE, Piñol J *et al.*, Unraveling the life history of successful invaders. *Science* **337**:580–583 (2012).
- Cassey P, Blackburn TM, Sol D, Duncan RP and Lockwood JL, Global patterns of introduction effort and establishment success in birds. *Proc R Soc Lond B* **271**:405–408 (2004).
- Navarro JL, Martella MB and Bucher EH, Breeding season and productivity of monk parakeets in Cordoba, Argentina. *Wilson Bull* **104**:413–424 (1992).
- Dhindsa MS and Saini HK, Agricultural ornithology: an Indian perspective. *J Biosci (New Delhi, India)* **19**:391–402 (1994).

- 10 Bucher EH and Bedano PE, Bird damage problems in Argentina. *Int Stud Sparrows* **9**:3–16 (1976).
- 11 Forshaw JM, *Parrots of the World*, ed by Cooper WT. Blandford, London, UK (1989).
- 12 Hyman J and Pruett-Jones S, Natural history of the monk parakeet in Hyde Park, Chicago. *Wilson Bull* **3**:510–517 (1995).
- 13 Bucher EH, Martin LF, Martella MB and Navarro JL, Social behaviour and population dynamics of the monk parakeet, in *Acta XX Congressus Internationalis Ornithologici*, ed. by Bell BD, Cossee RO, Flux JEC, Heather BD, Hitchmough RA, Robertson CJR *et al.*, *Ornithological Trust Board*, Christchurch, New Zealand, pp. 681–689 (1990).
- 14 Lever C, *Naturalised Birds of the World*. T & AD Poyser, London, UK (2005).
- 15 Strubbe D and Matthysen E, Establishment success of invasive ring-necked and monk parakeets in Europe. *J Biogeogr* **36**:2264–2278 (2009).
- 16 Edelaar P, Roques S, Hobson EA, Gonçalves da Silva A, Avery ML, Rus-sello MA *et al.*, Shared genetic diversity across the global invasive range of the monk parakeet suggests a common restricted geographic origin and the possibility of convergent selection. *Mol Ecol* **24**:2164–2176 (2015).
- 17 Muñoz AR and Real R, Assessing the potential range expansion of the exotic monk parakeet in Spain. *Divers Distrib* **12**:656–665 (2006).
- 18 Avery M, Tillman E, Keacher K, Arnett J and Lundy K, Biology of invasive monk parakeets in South Florida. *Wilson J Ornithol* **124**:581–588 (2012).
- 19 Temple SA, Exotic birds: a growing problem with no easy solution. *Auk* **109**:395–397 (1992).
- 20 Conroy MJ and Senar JC, Integration of demographic analyses and decision modelling in support of management of invasive monk parakeets, an urban and agricultural pest, in *Modeling Demographic Processes in Marked Populations*, ed. by Thomson DL, Cooch DG and Conroy MJ. Springer, New York, NY, pp. 491–510 (2009).
- 21 Davis AY, Malas N and Minor ES, Substitutable habitats? The biophysical and anthropogenic drivers of an exotic bird's distribution. *Biol Invasions* **16**:415–427 (2014).
- 22 2008Census Data. [Online]. CBS (2014). Available: http://www.cbs.gov.il/census/?Mival=%2Fcensus%2Fpnimi_sub2_tables_e.html&id_topic=11&id_subtopic=2&id_subtopic2=2&Geog=7 [10 December 2015].
- 23 Shwartz A, Shirley S and Kark S, How do habitat variability and management regime shape the spatial heterogeneity of birds within a large Mediterranean urban park? *Landsc Urban Plan* **84**:219–229 (2008).
- 24 Domènech J, Carrillo J and Senar JC, Population size of the monk parakeet (*Myiopsitta monachus*) in Catalonia. *Rev Catalana Ornitol* **20**:1–9 (2003).
- 25 Martella MB and Bucher EH, Vocalizations of the monk parakeet. *Bird Behav* **8**:101–110 (1990).
- 26 Bucher EH, *Aves plaga de Argentina y Uruguay: dinámica de poblaciones. Unpublished report, Food and Agriculture Organization of the United Nations*, Rome, Italy (1991).
- 27 Eberhard JR, Breeding biology of the monk parakeet. *Wilson Bull* **110**:463–473 (1998).
- 28 Sol D, Santos DM, Feria E and Clavell J, Habitat selection by the monk parakeet during colonization of a new area in Spain. *Condor* **99**:39–46 (1997).
- 29 Bucher EH, Natal dispersal and first breeding age in monk parakeets. *Auk* **110**:930–933 (1993).
- 30 Van Bael S and Pruett-Jones S, Exponential population growth of monk parakeets in the United States. *Wilson Bull* **108**:584–588 (1996).
- 31 Molina B, Postigo JL, Muñoz AR and Del Moral JC, La cotorra argentina en España. Población reproductora en 2015 y método de censo. SEO/BirdLife, Madrid, Spain (2016).
- 32 Pruett-Jones S, Newman JR, Newman CM, Avery ML and Lindsay JR, Population viability analysis of monk parakeets in the United States and examination of alternative management strategies. *Human–Wildlife Conflicts* **1**:35–44 (2007).
- 33 FAOSTAT. [Online]. FAO (2014). Available: <http://faostat3.fao.org/browse/Q/QC/E> [10 December 2015].
- 34 Spreyer MF and Bucher EH, Monk parakeet (*Myiopsitta monachus*). *Birds N Am* **322**:24 (1998).
- 35 Thuiller W, Richardson DM, Pysek P, Midgley GF, Hughes GO and Rouget M, Niche based modelling as a tool for predicting the risk of alien plant invasions at a global scale. *GCB Bioenergy* **11**:2234–2250 (2005).
- 36 Real R, Márquez AL, Estrada A, Muñoz AR and Vargas JM, Modelling chorotypes of invasive vertebrates in mainland Spain. *Divers Distrib* **14**:364–373 (2008).
- 37 South JM and Pruett-Jones S, Patterns of flock size, diet, and vigilance of naturalized monk parakeets in Hyde Park, Chicago. *Condor* **102**:848–854 (2000).
- 38 Shwartz A, Strubbe D, Butler CJ, Matthysen E and Kark S, 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 (2009).
- 39 Pruett-Jones S, Appelt CW, Sarfaty A, Van Vossen B, Leibold MA and Minor ES, Urban parakeets in Northern Illinois: a 40-year perspective. *Urban Ecosyst* **15**:709–719 (2012).
- 40 Chytrý M, Maskell LC, Pino J, Pyšek P, Vilà M, Font X *et al.*, Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. *J Appl Ecol* **45**:448–458 (2008).
- 41 Senar JC, Domènech J, Arroyo L, Torre I and Gordo O, An evaluation of monk parakeet damage to crops in the metropolitan area of Barcelona. *Anim Biodivers Conserv* **39**:141–145 (2016).
- 42 Bruggers RL and Zaccagnini ME, Vertebrate pest problems related to agricultural production and applied research in Argentina. *Vida Silvestre Neotrop* **3**:71–83 (1994).
- 43 Muñoz AR, Cotorra argentina, *Myiopsitta monachus*, in *Atlas de las Aves Reproductoras de España*, ed. by Martí R and del Moral JC. Ministerio de Medio Ambiente-Sociedad Española de Ornitología, Madrid, Spain, pp. 638–639 (2003).
- 44 Aramburú RM, Cicchino A and Bucher EH, Material vegetal fresco en cámaras de cría de la cotorra argentina *Myiopsitta monachus* (Psittacidae). *Ornitol Neotrop* **13**:433–436 (2002).
- 45 Burger J and Gochfeld M, Exotic monk parakeets (*Myiopsitta monachus*) in New Jersey: nest site selection, rebuilding following removal, and their urban wildlife appeal. *Urban Ecosyst* **12**:185–196 (2009).
- 46 Strubbe D, Shwartz A and Chiron F, Concerns regarding the scientific evidence informing impact risk assessment and management recommendations for invasive birds. *Biol Conserv* **144**:2112–2118 (2011).