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Research article

Diet assessments as a tool to control invasive species: comparison between Monk and Rose-ringed parakeets with stable isotopes

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Abstract

Food is a main limiting factor for most populations. As a consequence, knowledge about the diet of invasive alien species determines the design of control measures. The Monk and Rose-ringed parakeets are two typical species of successful invasive parrots that are highly appreciated by people. Although some observations suggest that Monk parakeets rely on a higher percentage of anthropogenic food than Rose-ringed parakeets, no detailed quantitative data is available. The aim of this study was to compare the diet of the two parakeets using stable isotope analysis (SIA). We performed SIA of carbon and nitrogen in feathers collected in Barcelona, Spain. We also measured isotopic ratios for potential food sources. We reconstructed the diet of parakeets using Bayesian mixing models. The two species differed in the isotopic signatures of their feathers for both $\delta^{13}C$ and $\delta^{15}N$. Diet reconstruction showed that Monk parakeets feed mainly on anthropogenic food (41.7%), herbaceous plants (26.9%) and leaves/seeds (22.2%), while Rose-ringed parakeets feed mainly on flowers/fruits (44.1%), anthropogenic food provided in the trap located at the museum (32.4%) and leaves/seeds (23.1%). The more detailed information we can obtain from the diet of these species is useful to develop more effective control measures for their populations. The Monk parakeet may be more susceptible to control through education local residents, given the greater use of anthropogenic food in this species compared to Rose-ringed parakeet. Our conclusions also indicate that SIA is a powerful tool in providing crucial information about the diet and informing measures to control invasive species.

Key words: diet, stable isotopes, invasive species, *Myiopsitta monachus*, *Psittacula krameri*

Key message:

There was a knowledge gap regarding the ingested and assimilated diet of the Monk and the Rose-ringed parakeets. We used stable isotope and Bayesian methods to quantify their diet more accurately. This study is the first evidence of the resources used and assimilated by these two species. The dependence of Monk parakeets on the use of food resources provided by people provides an opportunity to educate the public to reduce the size of this pest population.

Introduction

Invasive alien species are those introduced by humans, deliberately or accidentally, outside of their natural geographic range into an area where they are not naturally present, and whose introduction and/or spread threatens biodiversity (Convention on Biological Diversity 2010). The main factors that promote the success of invasive species are deforestation, habitat fragmentation, climatic change, contamination, tourism and international trade (McNeely et al. 2001). These species may cause the spread of zoonotic diseases (Smith, Bukoski, and Siers 2012), can directly threaten biodiversity (Rosen and Smith 2010), can alter and disrupt ecosystem structure, functions and services (Gherardi 2007) and open the gateway for other biological invasions (Mollot, Pantel, and Romanuk 2017).

Birds are among the most successful invaders (Blackburn, Loockwood, and Cassey 2009). A large number of species have become naturalised in many countries, causing extensive damage to natural environments and agriculture (Mollot, Pantel, and Romanuk 2017), and hence threatening human well-being (Stearns 2009). Parrots (Psittaciformes), one of the most popular birds traded as pets, are known to be particularly successful in settling into new habitats after accidental escapes or deliberate releases (Cardador et al. 2017). The success of parrots as invaders may be due to their low predation risk within introduced ranges, their high synanthropy and their ability to exploit many anthropogenic resources (Butler 2003). Far from their native habitats, parrots may cause economic and ecological damage (Di Santo, Battisti, and Bologna 2016; Souviron-Priego et al. 2018) and are typically found in urban and suburban areas, suggesting that they can rapidly profit from anthropogenic resources in their new habitats, including ornamental non-native trees introduced in urban parks (Butler 2005; Di Santo, Bologna, and Battisti 2017).

The Monk parakeet *Myiopsitta monachus* (Boddaert 1783) native to South America, and the Rose-ringed parakeet *Psittacula krameri* (Scopoli 1769) native to Central Africa–Asia, are two well-known invasive birds, considered among the parrot species that have most successfully invaded several areas worldwide (Pârâu et al. 2016; Postigo et al. 2017). The first record of free-living Monk and Rose-ringed parakeets in Spain dates back to 1975 and 1976, respectively, in the city of Barcelona (Batllori and Nos 1985). Since then, both species have expanded their distribution throughout Spain, particularly in and around large cities, and have the potential to spread even more widely (Molina et al. 2016; Del Moral et al. 2017). The province of Barcelona holds one of the largest densities of Monk parakeet in Europe, with almost 7100 individuals (Molina et al. 2016), while the population of Rose-ringed parakeet is about 130 individuals, much less than other cities around Spain and Europe (Turbé et al. 2017; Del Moral et al. 2017). It has been demonstrated that the growing number of these invasive parrot species are causing both economic losses (Avery et al. 2002; Senar et al. 2016; Mentil, Battisti, and Carpaneto 2018; Mori, Menchetti, and Mazza 2018) and ecological concerns, negatively affecting biodiversity, such as native wildlife (Menchetti and Mori 2014). The negative impacts caused by these species will surely intensify in the near future, as climate change, augmented pathways of introduction and changes in land use generate greater opportunities for their expansion (Shiels, Bukoski, and Siers 2018).

The availability of food is, in natural habitats, one of the most important factors that can limit a population (Newton 1998). However, in urban habitats, the control of this limiting factor is hindered by the presence of garbage dumps, parks and gardens with trees that present new available niches for newly introduced foreign species (Adams and Lindsey 2010; Di Santo, Bologna, and Battisti 2017). Furthermore, a common and growing problem in urban areas is the large number of people who feed animals and the wide variety of plant resources (especially non-native species), which favours the expansion of some invasive species and represents an additional challenge to its control (Adams and Lindsey 2010). Both parakeets are now commonly using backyard feeders provided for other wild birds (Bull 1973; Freeland 1973; Hyman and Pruett-Jones 1995; Clergeau and Vergnes 2011). Monk parakeets have even been observed on the ground, feeding alongside pigeons on food provided by local residents (Weiserbs and Jacob 1999; Carrillo-Ortiz 2008). This is, however, not the case of the Rose-ringed parakeet, which has rarely been observed feeding on the ground, but rather on sources located in the treetops.

It is evident that the negative impact of these birds and the need for their control make it essential to improve our understanding of their biological and ecological patterns, such as their foraging ecology. Diet assessments of animals help to reveal their feeding habits, which could be a limiting factor to regulate the growth of populations of these species (Bruggers, Rodríguez, and Zaccagnini 1998; Shiels, Bukoski, and Siers 2018). This information can be used to determine whether we can reduce food availability, and hence limit their populations (Bruggers, Rodríguez, and Zaccagnini 1998). When an important percentage of the food ingested by an invasive species is provided by local human populations, educating the public to stop the provision of this additional food can greatly reduce the size of the pest population (Giunchi et al. 2012; Senar et al. 2017c). The difference in dietary preferences between the Monk and the Rose-ringed parakeets could convey information about their differential habits and would be useful to develop more effective and rigorous guidelines for preventing and mitigating the negative effects of these species (Shiels, Bukoski, and Siers 2018; Turbé et al. 2017).

Several studies have analysed, with traditional methods, the diet of the Monk and the Rose-ringed parakeets (Freeland 1973; Shields, Grubb, and Telis 1974; Hyman and Pruett-Jones 1995; Carrillo-Ortiz 2008; Di Santo et al. 2013; Victor and Victor 2013; Mentil, Battisti, and Carpaneto 2018). However, although direct observation could be considered one of the most reliable approaches to studying animal diet, it is subject to limitations such as the introduction of biases related to prey size or the visibility of the species when exploiting different food sources (Margalida, Bertran, and Boudet 2005). Traditional methods of diet analysis, such as the study of pellets, faeces or neck collars, are also constrained by several biases (Pagani-Núñez et al. 2017). These traditional approaches have progressively been combined with (Ramos et al. 2009; Shiels, Bukoski, and Siers 2018) and sometimes substituted by (Moreno et al. 2010) indirect methods involving intrinsic biogeochemical markers, such as stable isotope analysis (SIA). Carbon and nitrogen SIA is currently one of the most common and efficient methods to assess the diet of an animal since tissues provide quantitative information on the relative contributions of each source to the diet, which can supply a time-integrated depiction of consumer diet (Vander Zanden et al. 2015). Feathers are becoming the most commonly used tissue for the study of diet in birds (Torres, Farmer, and Bucher 2006). Since they are grown over an extended period of 2–3 months and isotopic composition analysis is done with the whole feather, the approach provides a picture of the diet integrated over the whole growing period of time and represents assimilated food by the consumer (not only a potentially biased, short-term picture of diet composition, as in the case of traditional dietary analysis which assesses ingested food, not assimilated food) (Inger and Bearhop 2008).

The aim of this study was to go a step further by taking advantage of recent advances in stable isotope analyses and Bayesian tracer mixing models (Stock et al. 2018) to compare the proportions of the food sources between the Monk and the Rose-ringed parakeets by reconstructing the diet, based on carbon and nitrogen stable isotope analyses. We focused on two resident invasive populations in Barcelona city and on individuals moulting within the same area, so that variations would be related to differences in diet and not to other factors.

Methods

Field material

Individuals of Monk parakeet (*M. monachus*) and Rose-ringed parakeet (*P. krameri*) were captured during the winter–spring season (from November 2016 to June 2017), with a modification of a Yunick platform trap (1971). The trap worked with a bait (peanuts and sunflower seeds). This trap is a metal mesh cage (1.5 cm light mesh) 200 cm long × 100 cm high and 100 cm wide, with two compartments: one large with food for the parakeets (bait) and another small one that worked as an extraction cage. The main compartment has one access door placed laterally and closed remotely operated by the researcher. The trap was located on a terrace on a first floor of the Museum of Natural Sciences of Barcelona, in the Parc de la Ciutadella (Barcelona, Spain), a typical urban area where both species maintain their larger densities (Senar et al. 2017a,b). The trap allowed us to capture both adult and juvenile parakeets. It is worth keeping in mind that this trap offers food throughout the year (peanuts and sunflower seeds) that can be used by birds at any time. To mark the birds, collars with numbered medals that are durable and do not cause damage to the bird were adapted (Senar, Carrillo-Ortiz, and Arroyo 2012). For the study of the diet composition, three feathers of each bird from the upper left side of the breast were collected and then the individuals were released. The moult in both species occurs between August and October, and therefore, the feathers contain the isotopic signature of the food consumed in the last 1–2 months before the moult (Jenni and Winkler 1994). Due to the fact that feathers are inert tissue, their composition does not change after the moult. Each individual was included only once (an integrated sample of three feathers) in the analyses to avoid pseudoreplication. Feathers were stored in dark and dry conditions until their use in the lab.

In addition, food samples of the main sources of the Monk and Rose-ringed parakeets were collected in the study area during spring and summer 2016 to establish their isotopic composition. Food samples mainly consisted of anthropogenic food such as peanuts (*Arachis hypogea*), sunflower seeds (*Helianthus annuus*), rice (*Oryza sativa*) and bread (*Tritticum* sp.); flowers (*Catalpa bignonioides*, *Jacaranda mimosifolia* and *Tipuana tipu*); fruits (*Celtis australis*, *Cercis siliquastrum*, *Gleditsia triacanthos* and *Melia azedarach*); herbaceous plants [Poaceae (grass) and *Trifolium* sp.]; leaves (*M. azedarach* and *Tilia cordata*) and seeds (*J. mimosifolia* and *Platanus* sp.). The food sources collected were based on previous knowledge of the diet of the species (Carrillo-Ortiz 2008). Three samples of each source were collected and frozen at −80°C until their use in the lab.

Stable isotope analysis

We performed treatment of feathers in the Natural History Museum of Barcelona. Feathers were cleaned in a 0.1 M NaOH solution, oven-dried at 50°C for 24 h and ground into a fine powder with scissors. As lipid component of diet can affect $\delta^{13}C$ values (Tarroux et al. 2010), flowers, fruits, seeds and anthropogenic food were previously washed of lipids using successive rinses in a 2:1 chloroform:methanol solvent, and were later oven-dried at 50°C for 24 h along with leaves and herbaceous plant samples.

We performed the stable isotope analyses at the *Serveis Científico-Tècnics* in the University of Barcelona. Stable carbon and nitrogen isotope assays for all samples were performed on 0.3 mg ± 0.03 subsamples (weighed using a micro-balance Mettler Toledo MX5) of homogenised materials by loading them into tin cups and crimping them for combustion, using elemental analysis–isotope ratio mass spectrometry. Relative isotopic abundances are expressed in δ notation in parts per thousand (‰) according to

$$\delta X = \left[\left(\frac{R_{sample}}{R_{standard}}\right) - 1\right] * 1000,$$

where X is ^{13}C or ^{15}N and R is the corresponding $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio. The standard values for ^{13}C and ^{15}N were Pee Dee Belemnite and atmospheric nitrogen (AIR), respectively. Measurement errors (standard deviation, SD) were ±0.15‰ for $\delta^{13}C$ and ±0.25‰ for $\delta^{15}N$. The laboratory of isotopic ratio mass spectrometry applies international standards run every 12 samples: IAEA CH_7 (86% of C), IAEA CH_6 (42.1% of C), IAEA N1, IAEA N2 (21.2% of N), IAEA NO_3 (13.9% of N), IAEA 600 (49.5% of C and 28.9% of N), USGS 40 (40.8% of C and 9.5% of N), UREA (20.2% of C and 46.8% of N) and ACETANILIDE (71.1% of C and 10.4% of N).

Data analysis

We compared the $\delta^{13}C$ and $\delta^{15}N$ values of feathers of the animals captured in the field with the Mann–Whitney U-test to determine if there were significant differences in their diets. We used a Bayesian mixing model analysis—MixSIAR (Stock et al. 2018) to reconstruct the diet using the isotopic ratios from feathers and prey items, which allowed us to quantify the percentage contribution of each dietary source to the consumer's overall diet. Isotopic values of food sources were corrected by TEF: $\Delta^{13}C = 3.97 \pm 0.16‰$ and $\Delta^{15}N = 3.67 \pm 0.13‰$ for the Monk parakeet and $\Delta^{13}C = 3.64 \pm 0.40‰$ and $\Delta^{15}N = 4.10 \pm 1.69‰$ for the Rose-ringed parakeet (Mazzoni et al. 2019). We ran Bayesian Mixing Models for each species with individual $\delta^{13}C$ and $\delta^{15}N$ values.

A mixing model with more than seven sources contributing to a mixture based on two tracers will have fairly wide and diffuse distributions of possible solutions for each source, while those for combined sources may be much narrower and lead to easier interpretation (Phillips et al. 2014). Furthermore, results will be more interpretable if the sources combined have a logical connection so that the combined source has some biological meaning (Stock et al. 2018). For these reasons, we combined food sources *a posteriori* based on the place where birds find the food (ground or treetops) and on their distribution in the isotopic space (pooling food sources with similar signatures). This resulted in five source groups: three groups of natural food—flowers/fruits, herbaceous plants and leaves/seeds; and two groups of anthropogenic food—peanuts/sunflower seeds (which are provided in the trap as bait to capture the birds, although some local residents may additionally provide this food source) and rice/bread (which are provided mainly by local residents). Mean $\delta^{13}C$ and $\delta^{15}N$ values, and their SDs, for these groups of food were input as sources.

We used 'weakly informative priors' with the Rose-ringed parakeet's model because we know that this species does not consume food on the ground, such as the food provided by local residents like rice and bread, or herbaceous plants (such as grass) (previous observations). Therefore, for food found on the ground (rice, bread and herbaceous plants), the prior value was 0.01, while for the rest of the sources (flowers/fruits, leaves/seeds and peanuts/sunflower seeds), prior values were 1.66 for each source. In this way, the sum of all prior diet proportions equals the number of sources, which is defined as 'weakly informative prior'. All statistical analyses were completed in R version 3.4.2. 'All applicable institutional and/or national guidelines for the care and use of animals were followed'.

Results

A total of 72 individuals of Monk parakeet and 21 Rose-ringed parakeets were captured. Monk parakeet feathers had $\delta^{13}C$ mean values of -23.98 ± 0.42 and $\delta^{15}N$ mean values of 7.40 ± 1.81 while Rose-ringed parakeets had $\delta^{13}C$ mean values of -22.84 ± 0.72 and $\delta^{15}N$ mean values of 9.16 ± 2.00. There were significant differences in the values of both $\delta^{13}C$ ($U = 137$; $z = -5.6832$; $P < 0.001$) and $\delta^{15}N$ ($U = 386$; $z = -3.3952$; $P < 0.001$) between the two species. The analysis of the stable isotope composition of the potential food sources of Monk and Rose-ringed parakeets showed that flowers and fruits displayed the highest values of $\delta^{13}C$ and $\delta^{15}N$, whereas herbaceous plants displayed the lowest values of $\delta^{13}C$ and $\delta^{15}N$ (Fig. 1).

The Bayesian mixing models implemented in MixSIAR produce posterior probabilities of the contribution of each food source to the diet of consumers. Our results showed the difference in the diet between the Monk and the Rose-ringed parakeets, in which flowers and fruits, herbaceous plants and rice and bread were the food sources that most differed in their proportions, while leaves and seeds and peanuts and sunflower seeds had the same importance in the diet of the two species (Fig. 2).

Monk and Rose-ringed parakeets exhibited a different diet, with anthropogenic food (peanuts and sunflower seeds and rice and bread) (41.7%), herbaceous plants (26.9%) and leaves and seeds (22.2%) being the most consumed food sources for the Monk parakeets, and flowers and fruits (44.1%), anthropogenic food provided in the trap located at the museum (peanuts and sunflower seeds) (32.4%) and leaves and seeds (23.1%) for the Rose-ringed parakeets (Table 1).

Discussion

Information about the dietary habits of introduced populations may be important for their management (Blackburn, Loockwood, and Cassey 2009). However, few studies have evaluated the assimilated diet of some of the most invasive birds in the world, such as parakeets. This study is a contribution to an increasingly comprehensive set of detailed assessments of the biology and ecology of introduced parakeets in Europe, showing the first evidence of the resources used and assimilated by the Monk and the Rose-ringed parakeets. The main results of this study are largely consistent with previous studies based on traditional methods (South and Pruett-Jones 2000; Pezzoni, Arambarri, and Aramburu 2009; Di Santo et al. 2013; Victor and Victor 2013; Fraticelli 2014; Molina et al. 2016; Del Moral et al. 2017). The diet of the Monk parakeet is more generalist, feeding on many sources in similar proportions, while the Rose-ringed parakeet feeds on more particular items. The key point however, is that although there is a high overlap in the use of vegetable material by both species, the Monk parakeet tends to consume a greater proportion of anthropogenic food than the Rose-ringed parakeet. Data also show that peanuts and sunflower seeds provided in the trap located at the museum seems to be important for both species, and supports the view that these are preferred food sources (Ahmad et al. 2011; Canavelli et al. 2014).

Findings from our study revealed that the sources most consumed by the Monk parakeet are anthropogenic food (peanuts and sunflower seeds and rice and bread), herbaceous plants (such as grass) and leaves and seeds (Table 1). These food sources are present in gardens and parks throughout Barcelona, which confirm our view that this species mainly (70%) consumes sources that can be found on the ground. In their native range, Monk parakeets spend a lot of time feeding on the grass and therefore the species consumes plant families that naturally occur there, such as Poaceae, Asteraceae and/or Fabaceae (Aramburú 1997; Di Santo et al. 2013). The use of grass and other herbaceous plants as a main food source has been recorded in Barcelona since the first phases of establishment and spread, along with the search for other food sources such as leaves, shoots, seeds, flowers, bark and roots of trees (Santos and Sol 1995; Carrillo-Ortiz 2008). However, 20 years ago observations of parakeets eating food directly provided by local residents, such as rice or bread, were rarely recorded (Santos and Sol 1995). In this study, this source accounts for 18% of the Monk parakeet diet (Table 1). We were surprised that the amount of these food sources is not as high as in previous observations, which have reached 30% (Carrillo-Ortiz 2008). This could be due to the fact that the consumption of these sources is overvalued by direct observations, since it is easier to observe the birds when they are eating on the ground compared to in the treetops. However, the proportion of herbaceous plants coincides with previous (direct) observations, even though this food sources is also on the ground and thus easily observable as with anthropogenic food. The difference seen between previous observational studies and this study with anthropogenic food but not with herbaceous plants suggests that the lower anthropogenic food proportion could be real and that direct observations are not very biased. This lower contribution of anthropogenic food to the diet could be due to the fact that analysed feathers were moulted between August and October and therefore, contained the isotopic signature of the food consumed between July and August (the last 1–2 months before the moult) (Jenni and Winkler 1994), which is when many local residents go on vacation and are therefore providing less food to the parrots. Therefore, we can safely conclude that >40% of food ingested by the Monk parakeet in Barcelona is provided by humans. In some localities this percentage could be even higher, since in the northern areas of the USA, for instance, Monk parakeet populations have been shown to be completely dependent on anthropogenic foods, such as sunflower seeds, during winter months (South and Pruett-Jones 2000).

On the other hand, for the Rose-ringed parakeet, flowers, fruits, leaves, seeds and anthropogenic food provided in the trap located at the museum (peanuts and sunflower seeds) were the main sources of food (Table 1), which confirms our view that sources in the treetops are the most consumed sources by this species, which eats natural food sources (not

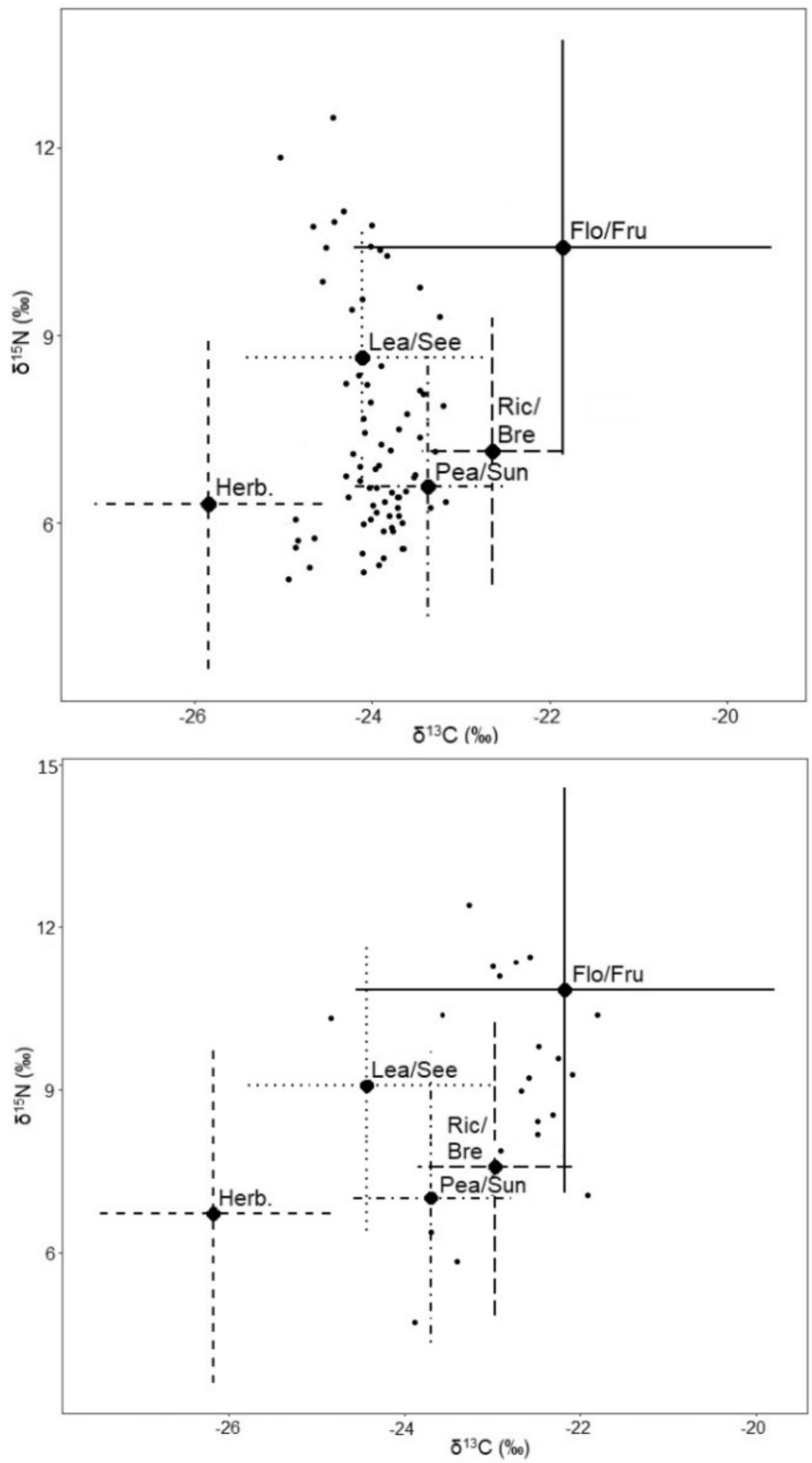

Figure 1: Isotopic values (δ^{13}C and δ^{15}N) in feathers of Monk (*M. monachus*) (up) and Rose-ringed parakeets (*P. krameri*) (down) and their main source types. Large dots represent food source mean values, and bars represent SD: flowers and fruits (Flo/Fru), herbaceous plants (Herb.), leaves and seeds (Lea/See) and anthropogenic food: peanuts and sunflower seeds (Pea/Sun) and rice and bread (Ric/Bre). Small dots represent individual values of Monk ($N = 72$) and Rose-ringed parakeets ($N = 21$)

provided by local residents) in a greater proportion than the Monk parakeet. Numerous references in the literature also report that the food of Rose-ringed parakeet consists of fruits, seeds and flowers (Victor and Victor 2013; Fraticelli 2014; Mentil, Battisti, and Carpaneto 2018).

Almost no observations in the literature have reported the Rose-ringed parakeet feeding on the ground, except for Fraticelli (2014). He observed in three cases birds drinking water from a puddle and another six cases in which they were feeding on holm oak *Quercus ilex* acorns (Fraticelli 2014). In spite of the fact

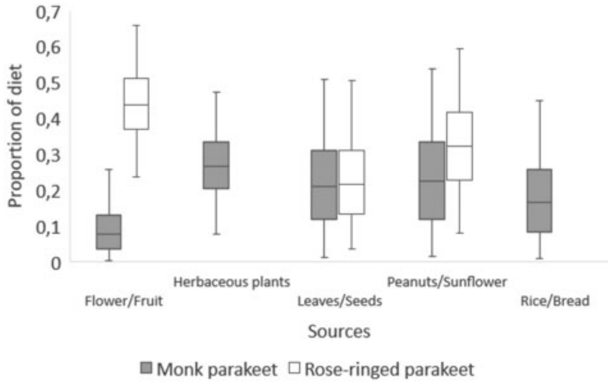

Figure 2: Diet reconstruction for all sampled individuals of Monk (*M. monachus*, N = 72, grey) and Rose-ringed parakeets (*P. krameri*, N = 21, white) estimated from SIA mixing models (MixSIAR): for each food source group, the central line represents the median value, the box shows 50% credibility interval and the whiskers represent the 95% credibility interval

that the Rose-ringed parakeet does not use the resources provided directly by local residents, such as rice and bread, its high consumption of peanuts and sunflower seeds offered in the trap was indicated. Although in our data it is logical that peanuts and sunflower seeds show high values since we captured them with that food in the trap, it is important to point out that in Central Europe and America the Rose-ringed parakeet, just like the Monk parakeet, has been seen feeding at bird feeders that people put in their gardens and in parks, in which the preponderant food is actually peanuts and sunflower seeds (Butler 2005; Strubbe and Matthysen 2007; Clergeau and Vergnes 2011; Shiels, Bukoski, and Siers 2018). Our work confirms their preference for this source when it is available and thus, that it is an important part of their diet in Barcelona and surely in other parts of the world.

The increase in anthropogenic food provided to the Monk parakeet, as occurs with other invasive species, contributes to its expansion and makes it more difficult to control its populations (Adams and Lindsey 2010). However, this dependence on the use of food resources provided by local human populations, provides an opportunity to implement public awareness and education measures to control populations. Previous work with feral pigeons (*Columba livia*) has shown how public education at a local scale, explaining the negative impacts of these species, can be effective in achieving an important reduction in the food provided by humans, and hence a reduction in pest population size. This method was successfully implemented in Basel, Switzerland, where the population of pigeons was reduced by 50% in 2 years, with the only measure being the education of the human population to not provide them with food (Haag-Wackernagel 1995). The method has also been used more recently in Venice (Italy) (Giunchi et al. 2012) and Barcelona (Spain) (Senar et al. 2017c) with similar success. Therefore, public education at a local scale on the negative impacts of Monk parakeets should play an important role in reducing the available food base and may be the most feasible way to exert selection pressure on the populations to reduce their abundances (Souviron-Priego et al. 2018). This approach could also be used in Rose-ringed parakeet populations in Central Europe, where peanut and sunflower seed feeders provided by people are responsible for the survival of many of these populations (Clergeau and Vergnes 2011). People feed parakeets because they are often positively regarded by the public, which in turn may explain why parakeets are more widespread in urban habitats than in natural environments (Butler 2005; Braun and Wegener 2008; Burger and Gochfeld 2009; Crowley, Hinchliffe, and McDonald 2019; Postigo et al. 2017). Because of the public appreciation of parakeets, effective control will require an interdisciplinary and multi-scale approach including education at a local scale, encouragement of local residents to value wildlife, and coordinated national and international regulations with a greater allocation of resources for the management of nature (Rosen and Smith 2010; Crowley, Hinchliffe, and McDonald 2017). This highlights the great importance of the human dimension in studies of ornithology and urban ecology, since humans can be as much a part of a solution as they are a part of the problem (Crowley, Hinchliffe, and McDonald 2017).

Table 1: Dietary proportion estimates for the Monk (*M. monachus*, N = 72) and the Rose-ringed parakeets (*P. krameri*, N = 21)

Source	Monk parakeet		Rose-ringed parakeet	
	Mean	SD	Mean	SD
Flowers/fruits	0.09	0.070	0.44	0.107
Herbaceous plants	0.27	0.100	0.00	0.004
Leaves/seeds	0.22	0.135	0.23	0.125
Peanuts/sunflower seeds	0.24	0.143	0.32	0.136
Rice/bread	0.18	0.121	0.00	0.031

Values were calculated using Bayesian Mixing Models (MixSIAR) and represent the mean proportion and SD for each food source in the posterior distributions.

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Conflict of interest statement. None of the authors declare any conflict of interests.

Ethical approval: All applicable international, national and/or institutional guidelines for the care and use of animals were followed.

We declare that data are not available because they are part of later publications.

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