Importance of predictable anthropogenic food subsidies for an opportunistic gull inhabiting urban ecosystems

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Abstract

The provision of predictable anthropogenic food subsidies (PAFS) to urban wildlife has been recognized as an important trophic input in urban ecosystems. However, there is a lack of agreement about the benefits and harms of urban PAFS for avian species. While there are many studies about the impact of PAFS on birds, little information is available about the potential importance of PAFS on the ecology of urban gulls. In the present study, we aimed to evaluate the importance of human PAFS for the urban population of the yellow-legged gull (*Larus michahellis*) in the city of Barcelona, northeastern Spain. This opportunistic seabird is considered a pest species in urban areas. Specifically, by conducting a visual census in a location where PAFS were provided every week year-round, we examined the total number and age structure of gulls using this PAFS station. We identified the presence of yellow-legged gulls with some physical anomalies using the PAFS station. The results of this study suggest that PAFS may be an important artificial resource for urban yellow-legged gulls inhabiting Barcelona, used by either breeders or non-breeders, and also used by handicapped individuals. Based on these results, we suggest the regulation of this activity as a complement to other measures focused on the reduction of available food resources present in urban areas to manage this problematic species.

Keywords: supplementary food · trophic ecology · urban ecology · wildlife feeding · yellow-legged gull

Introduction

Urbanization is a clear and widespread example of human impact on natural environments, which leads to a loss of biodiversity (McKinney 2006; Goddard et al. 2010). However, for certain adaptable urban wildlife, such as some species of birds, urban areas can provide accessible and abundant trophic resources, temperate and stable microclimates and fewer natural predators than natural environments (McKinney and Lockwood 1999; Lim and Sodhi 2004; Palomino and Carrascal 2007; Schwartz et al. 2018; Castillo-Contreras et al. 2018). Among the different resources present in cities for these species, the provision of predictable anthropogenic food subsidies (PAFS) to urban wildlife has been recognized as an important trophic input in urban ecosystems (Jones and James Reynolds 2008; Jones 2011; Oro et al. 2013). Urban PAFS can have important effects on urban birds, such as the maintenance of urban populations, the attraction of new species to cities or changes in natural behavior (Griffin et al. 2017; Stofberg et al. 2019).

The provisioning of food to wild birds has become widespread, either by people that want to help birds or as a way to connect to nature (Cox et al. 2016). There is a lack of agreement about the benefits and harms of PAFS for urban birds. Some conservation organisations promote direct bird-feeding, and others are more cautious, especially regarding the potential effects of PAFS on physical condition, the spread of diseases or changes to natural behaviour of wildlife (Jones and James Reynolds 2008; Wilcoxon et al. 2015; Lawson et al. 2018).

Among the birds that have colonized urban environments, different species of opportunistic gulls have increased in urban areas and have even established breeding populations in cities around the world in the last few decades (Auman et al. 2008, 2011; Coulson and Coulson 2009; Washburn et al. 2013; Spelt et al. 2019; Méndez et al.

2020; Coccon and Fano 2020). These opportunistic predators are favored by the presence of diverse trophic resources in urban environments (Rock 2005; Washburn et al. 2013; Schwartz et al. 2018; Méndez et al. 2020; Coccon and Fano 2020). The yellow-legged gull (*Larus michahellis*) is one example of an opportunistic gull that has adapted to living in urban areas (Vidal et al. 1998; Sorace and Gustin 2009). However, by coexisting with humans, urban populations of this and other opportunistic gulls could interfere with human interests (Vidal et al. 1998; Vergara et al. 2017; Furst et al. 2018; Navarro et al. 2019), causing problems such as damage to urban structures, noise or the potential transmission of pathogens (Belant 1997; Vidal et al. 1998; Rock 2005; Vergara et al. 2017). For this reason, different management actions have been proposed to reduce the presence of gulls in urban habitats, such the use of particular structures to inhibit the installation of nests in the buildings or reducing access to food resources (Belant 1997). While there are many studies about the impact of PAFS on birds (Wilcoxon et al. 2015), little information is available about the ecology of urban gulls (Spelt et al. 2019; Méndez et al. 2020), especially in relation to the importance of PAFS for urban populations.

Here, we aimed to evaluate the importance of human PAFS for the urban population of the yellow-legged gull in the city of Barcelona, northeastern Spain. Although not very common, during the last decade there is evidence that in Barcelona the feeding of yellow-legged gulls by private residents occurs regularly. However, little is known about the importance of these PAFS for the urban populations of yellow-legged gulls. Specifically, by conducting a visual census in a location where PAFS were provided every week year-round we examined: (1) the seasonal abundance and age structure of the yellow-legged gulls exploiting this resource; (2) the degree of individuals that consistently used this resource throughout the year and (3) the importance of the use of

these artificial resources for yellow-legged gulls with physical anomalies. The results provide new insights into an understudied type of bird-feeding for opportunistic gulls inhabiting urban areas.

Material and methods

Study area

The study was carried out in the city of Barcelona (northeastern Spain, Figure 1), the second and eighth largest city of Spain and Europe in number of inhabitants, respectively (1.600.000 inhabitants; Eurostat database 2019). The yellow-legged gull breeding population of Barcelona has experienced a notable increase from a few pairs in the 1980s to ~300 pairs breeding today (García-Petit et al. 1986; Anton et al. 2017), with a total number of 1686 ± 273 breeders and non-breeders estimated in 2015 (Pascual et al. 2015). Barcelona has some characteristics that make it attractive to this species. For example, the presence of high and isolated buildings facilitates nesting in safe places without human disturbance. Additionally, the urban landscape of Barcelona surrounded by fishing ports, landfill installations, agricultural areas and freshwater habitats presents a diversity of trophic resources that can be exploited by gulls (Méndez et al. 2020). An important amount of fishing activity is associated with the fishing port of Barcelona, with around 3200 tons of annual catches (Idescat 2019), providing a large volume of fishing discards, one of the main trophic resources exploited by the yellow-legged gull (Lopezosa et al. 2019). Similarly, the availability of organic waste in the city and in nearby garbage processing plants and landfills also offer important subsidiary food sources for this species (Méndez et al. 2020). In addition to the exploitation of human-related resources randomly present in the city, PAFS provided by

people are also available as a resource for yellow-legged gulls (~500 persons regularly feed birds, mainly pigeons and invasive parrots, in the city; Montalvo 2010).

PAFS experiments

Between February and November 2018, we conducted 22 standardized censuses covering the breeding (February-April, n=8 census), post-breeding (May-July, n=7 census) and wintering period (September-November, n=7 census) of the yellow-legged gull at *Moll de la Fusta*, a dam situated between a touristic area and a fishing port of Barcelona (Figure 1). In this location, during the last 10 years, the same person provided PAFS composed of similar amount of discarded remains (~8 kg) of chicken, beef and pork to the yellow-legged gulls every Tuesday between 16:00-17:00h throughout the year.

The standardized censuses were conducted only when the PAFS were provided to gulls by this person by taking two standardized photographs. One photograph was taken when the maximum number of individuals was present and was used to estimate the total number of individuals. The second photograph was used to estimate the proportion of individuals by age based on their plumage color (juveniles = first year, immatures = second and third year, and adults = fourth year and older; Arizaga et al. 2019). All pictures were taken by the same person (M.C.) on a fixed point covering the same standardized area with digital cameras (Nikon Coolpix P510 and Nikon Coolpix B700) using the same sensor and view angle.

During the period when the gulls were exploiting the PAFS, we also read individual colored plastic rings of some of them to quantify the individuals using this resource. Always, the same person (M. C.) was the responsible to do this task, during ~1 hour. Since 2009, an ongoing project (BCN-Gulls) with yellow-legged gulls in Barcelona has

been developed, with more than 500 individuals ringed. We also recorded the presence of gulls with any kind of anomaly or physical alteration such as malformations, amputations, injuries, or plastics affixed to their bodies, to determine if handicapped yellow-legged gulls also exploit this artificial resource.

Data analysis

Differences in the(log-transformed) total abundance and the number of individuals with physical anomalies (log-transformed) between breeding, post-breeding and wintering periods were tested using one-way ANOVA tests. To evaluate the differences in the proportion (arcsin-transformed) of juveniles, immatures and adults between breeding, post-breeding and wintering periods, we used two-way ANOVA tests, including reproductive stage and age as fixed factors. In all cases, post-hoc comparisons were tested with a Tukey's test. The significance level for all tests was set at $p < 0.05$. IBM SPSS Statistics 26 (IBM SPSS Statistics, IBM Corporation, Chicago, IL) was used to perform statistical analyses.

Results

Phenological and ontogenetic changes in yellow-legged gulls using PAFS

The total number of yellow-legged gulls exploiting the PAFS ranged between 27 to 160 individuals, being higher during the post-breeding period than during breeding and wintering periods ($F_{2,20} = 4.21$, $p = 0.03$; Figure 2). Regarding the age structure, we found differences in the percentage of the different ages between breeding, post-breeding and wintering periods (Figure 2). Juveniles were found in greater proportions during the wintering period, followed by post-breeding and breeding periods ($F_{2,20} =$

17.38, $p < 0.001$). Immatures and adults were found in greater proportions during the breeding period, followed by post-breeding and wintering periods (immatures, $F_{2,20} = 10.51$, $p < 0.001$; adults $F_{2,20} = 5.96$, $p = 0.01$) (Figure 2).

Physical anomalies

One-hundred seventy-nine yellow-legged gulls with physical anomalies (adults=64.51%, immatures=24.26% and juveniles=11.23%) were found exploiting PAFS during all phenological stages, without differences in the abundance between breeding, post-breeding and wintering periods ($F_{2,23} = 1.31$, $p = 0.31$; Figure 3). These anomalies were leg/feet malformations/injuries (75%), malformations or fractures in the bill (9%), objects tied to their bodies (8%), alterations in the wings (4%) and damage to the eyes or head (3%, Figure 3).

Individual yellow-legged gulls exploiting PAFS

Eighty-four different yellow-legged gulls with unique numbering rings were detected exploiting the PAFS at the survey location. Of these individuals, most were recorded only one time ($n=39$ individuals), but others ($n=49$) were recorded from 2 ($n=18$) to 17 times ($n=2$) (Figure 4).

Discussion

The present study provides novel empirical information regarding the potential importance of PAFS delivery by humans. The results revealed that adult, juvenile and immature yellow-legged gulls consistently exploited this anthropogenic resource throughout the year. Therefore, between 2% and 10% of the estimated population of yellow-legged gulls in Barcelona used this PAFS station throughout the year (total

estimate of 1.686 ± 273 yellow-legged gulls in Barcelona; Pascual et al. 2015). However, it is important to mention that although adults were present throughout the year, the proportion of non-breeder (juveniles and immatures) gulls was always higher in this PAFS station, especially during the post-breeding period when we found an increase in the proportion of juveniles. This increase in the number of juveniles probably reflected the period of juvenile dispersal of yellow-legged gulls after the chick-rearing period and the tendency to aggregate to socialize and increase safety against potential predators (Kralj et al. 2014).

Why do non-breeders apparently use more PAFS than adults? A potential explanation could be the necessity of breeders/breeding gulls to obtain food of good nutritional quality to form eggs in the case of females or to feed the chicks in the case of females and males (Williams 2005; Santos et al. 2017; Sotillo et al. 2019). In general, marine fish represents a good quality food source in terms of energetic and nutritional quality (Albo-Puigserver et al. 2017; Santos et al. 2017). For this reason, adult gulls, constrained by their reproductive tasks, may avoid exploiting human food provided at the PAFS station, consuming marine resources at sea. In support of this hypothesis, in a recently published paper describing the diet of yellow-legged gulls breeding in Barcelona, Mendez et al. (2020) showed that breeding adults feed their offspring mainly with marine resources and urban pigeons (*Columba livia*), with a very residual importance of human-related resources such as pork, beef or chicken (garbage origin). Alternatively, due to the inferior foraging skills of juveniles and immatures compared to adults (Riotte-Lambert and Weimerskirch 2013), they avoid consuming the same prey as adults as a mechanism to reduce competition for similar food resources (Navarro et al. unpublished data; Ravasi et al. 2019). Also, social attraction could play an important role for immature and juveniles in relation to the use PAFS (Andersson et al. 1981).

At the individual level, we also found that different yellow-legged gulls visited the PAFS station consistently throughout the year, probably because they know this is an easily obtained trophic resource that is always available. The presence of specialized individuals within a population has been related to the success of different expanding species (Chapple et al. 2012; Cardador et al. 2012; Potier et al. 2015), including the yellow-legged gull (Ceia and Ramos 2015; Navarro et al. 2017; Lopezosa et al. 2019). Individual specialization may have management implications in some situations in relation to the implementation of effective actions to reduce impacts on species of human or conservation interest (Bowen and Lidgard 2013). For example, in the case of the yellow-legged gull, a drastic reduction in predation on an important colony of European storm petrels (*Hydrobates pelagicus*) in southeastern Spain was accomplished by removing specifically identified gulls specialized on the depredation of storm petrels (Sanz-Aguilar et al. 2009).

A potential problem related to urban wild bird-feeding is the effects on wildlife health and the maintenance of handicapped individuals of different ages that are unlikely to survive in natural conditions (Gil and Brumm 2014; Wilcoxon et al. 2015). We detected yellow-legged gulls, mainly adults but also immatures and juveniles, with evident physical anomalies at the PAFS station throughout the year. We found yellow-legged gulls with malformations and fractures in the legs, beaks, eyes and head, alterations to wings, and with attached objects such as fishing lines and plastics. Such physical alterations have been previously described in different species of gulls, with most of them due to entanglement with fishing gears, accidental collisions or developmental abnormalities (Smith and Kenneth 1971; Yorio et al. 2014; Greño et al. 2016). These malformations may make normal access to natural food difficult when

competing directly with individuals in good physical condition. Therefore, we suggest that PAFS may be maintaining individuals that would likely disappear from urban and also natural populations without the availability of this resource.

In conclusion, the results of this study suggest that PAFS could be an important artificial resource for urban yellow-legged gulls inhabiting Barcelona, used by breeders and non-breeders as well as handicapped individuals. Although our study was conducted only at one PAFS location, similar scenarios are expected in other parts of the city because the number of private residents feeding urban wildlife, mainly rock pigeons and invasive parrots, is relatively high in Barcelona (~500 residents regularly feed birds in the city; Montalvo 2010). For this reason, we encourage an evaluation of the impact of PAFS stations on this species in the city and other urban areas where yellow-legged gulls or similar species are present. In any case, as a precautionary measure, we recommend the regulation of this activity as a complement to other measures focused on the reduction of food availability in urban areas to control problematic urban species (Belant 1997; Senar et al. 2017).

Conflict of interest

The authors have no conflicts of interest to declare.

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Fig. 1 (A) General map showing the location of the study area. (B) Location where the predictable anthropogenic food subsidies (PAFS) experiments were conducted in Barcelona in 2018. (C) Picture showing yellow-legged gulls exploiting one PAFS event in Barcelona. Picture taken by Maria Carmona.

Fig. 2 (A) Mean and standard deviation of the abundance of yellow-legged gulls exploiting predictable anthropogenic food subsidies (PAFS) by phenological period. (B) Percentage by age of yellow-legged gulls exploiting PAFS.

Fig. 3 (A) Mean and standard deviation of number of yellow-legged gulls with some physical alteration exploiting predictable anthropogenic food subsidies (PAFS) by phenological period. (B) Percentage of each type of physical anomaly in relation to the total number of yellow-legged gulls with some physical anomaly.

Fig. 4 Frequency of the number of times that an individual yellow-legged gull was detected consuming predictable anthropogenic food subsidies (PAFS) in the survey location in Barcelona.