Adapting to urban ecosystems: unravelling the foraging ecology of an opportunistic predator living in cities

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Abstract

The increasing urbanisation of the natural environment affects species differently. While most species cannot cope with these human impacts, others can persist or may even be favoured in these anthropogenic ecosystems. Among the different urban-adapted wildlife species, the populations of different species of opportunistic gulls have increased in urban areas and some have established breeding populations at a global scale. Although the ecology of these predators is relatively well-known in their natural environment, accurate knowledge about their urban ecology is very scarce. Here, we investigated the foraging ecology (habitat use, spatial movements and feeding) of an urban population of yellow-legged gulls (*Larus michahellis*) inhabiting the city of Barcelona (north-eastern Spain). We examined the diet of this urban population by analysing the stomach contents of chicks distributed throughout the urban area of Barcelona. The foraging movements of breeding gulls were investigated using GPS devices and habitat landscape information. The results show that this urban population of yellow-legged gull exploits different food resources, highlighting the consumption of urban birds and marine resources from fishery discards. In line with the diet results, GPS tracking data indicated that although yellow-legged gulls were able to use different types of habitats close to the city, they mainly foraged in urban and fishing port areas. In conclusion, yellow-legged gulls have adapted to exploit the food resources associated with urban environments. This study provides useful information to discuss management options measures to control the yellow-legged gull populations nesting in urban areas.

Keywords: foraging ecology · *Larus michahellis* · urban marine ecology · opportunistic predators · tracking devices · trophic ecology · yellow-legged gull

Introduction

Human impacts on the natural environment cause significant changes in the functioning of natural ecosystems worldwide (McKinney 2006; Worm et al. 2006). A clear and widespread example of human impact is the process of urbanisation of the natural environment, which has led to a loss of biodiversity (McKinney 2006; Goddard et al. 2010). However, urbanisation affects species differently—while most are not able to cope with these human impacts, others may persist or even be favoured by these new human environments (McKinney and Lockwood 1999). Urban ecosystems can provide accessible and abundant food resources for these adaptable species, including a more temperate and stable urban microclimate 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). Also, birds have a more stable food availability through the year in urban areas (see Leveau 2018).

Among the wildlife that has colonised urban environments, opportunistic gulls use urban habitats to breed and/or forage (Rock, 2005; Rock, Camphuysen, Shamoun-Baranes, Ross-Smith, & Vaughan, 2016; Spelt et al., 2019; Washburn, Bernhardt, Kutschbach-Brohl, Chipman, & Francoeur, 2013). Although gulls have long been considered to breed in remote islands or coastal natural areas, in the last few decades, some opportunistic gull species have become more common in urban areas and have even established breeding populations in cities around the world (Auman et al. 2008, 2011; Coulson and Coulson 2009; Washburn et al. 2013; Spelt et al. 2019). These opportunistic and generalist predators are favoured by several factors such as the presence of accessible and diverse trophic resources in urban environments, including prey of anthropogenic, terrestrial or freshwater origin (Belant et al. 1998; Rock 2005; Washburn et al. 2013; Schwartz et al. 2018). By exploiting the habitats and resources present in urban areas, urban populations of opportunistic gulls may come into conflict with human interests (Vidal et al. 1998; Vergara et al. 2017; Furst et al. 2018; Navarro et al. 2019), resulting in problems such as noise pollution, damage to urban infrastructure, transmission of pathogens and collisions with vehicles (Belant, 1997; Rock, 2005; Vergara et al., 2017; Vidal et al., 1998). For this reason, different management measures have been proposed to reduce the abundance of gulls in the cities such culling programs (of eggs and/or individuals), use of structures to impede nest installation on the rooves of the buildings, or reducing access to food resources (Belant 1997).

Although different aspects related to population dynamics, diet or spatial movements of opportunistic gulls are relatively well-known in their natural environment (Ceia et al., 2014; Navarro et al., 2017; Payo-Payo et al., 2015; Ramos, Ramírez, Sanpera, Jover, & Ruiz, 2009;

Ramírez et al. 2020), accurate knowledge about the urban ecology of these predators is very scarce (Monaghan 1979, 1982; Rock et al. 2016; Spelt et al. 2019). Knowing the trophic habits or spatial movements of urban gulls is essential to understanding how these species have adapted to urban environments and to designing effective management measures to mitigate potential conflicts with humans (Alm et al., 2018; Navarro et al., 2019; Spelt et al., 2019).

The yellow-legged gull is one clear example of an opportunistic gull that has adapted to living in urban areas (Vidal et al. 1998; Sorace and Gustin 2009). This predator has a highly plastic foraging behaviour, which allows efficient exploitation of a great diversity of marine and terrestrial food resources of both natural and human origin (Arizaga et al., 2014; Lopezosa, Forero, Ramírez, & Navarro, 2019; Matos et al., 2018; Navarro et al., 2017). Moreover, this species is considered problematic across its distribution, as it comes into conflict with a variety of human activities (Navarro et al., 2019; Vidal et al., 1998)

Barcelona has a number of characteristics that make it attractive to this species. The presence of high and isolated buildings facilitates the nesting of this species 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. An important amount of fishing activity is associated with the fishing port of Barcelona, with around 3,200 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 (Arcos, 2001; Lopezosa et al., 2019; Ramos, Ramírez, Sanpera, Jover, & Ruiz, 2008). 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 (Ramos et al., 2009).

In the present study, we aim to investigate the foraging ecology (habitat use, spatial movements and feeding habits) of the urban population of yellow-legged gulls (*Larus michahellis*) breeding in the city of Barcelona (north-eastern Spain). In addition to its ecological interest, this aim also could help to design effective management measures to mitigate potential conflicts with humans. We examined the diet of this urban population by analysing the stomach contents of chicks distributed throughout the urban area. To study the foraging movements, we equipped yellow-legged gull breeders with GPS devices and overlapped this spatial information with the type of habitat used. Based on the previous information about the feeding habits of this species and the presence of fishing activity close to the city, we expected that the diet of this population included prey from fishery discards. The use of human-related habitats that include urban areas and garbage dumps were also expected for these yellow-legged population.

Materials and methods

Study area and fieldwork procedures

The study was carried out in the city of Barcelona (north-eastern Spain, Figure 1), the second and eighth largest city of Spain and Europe in terms of the number of inhabitants, respectively (1.600.000 inhabitants; Eurostat). The yellow-legged gull breeding population of Barcelona has experienced a notable increase from a few pairs in the 1980s to around 375–611 pairs breeding today (García-Petit et al. 1986; Anton et al. 2017).

The fieldwork was conducted from May to June 2018, during the gulls' breeding season. To determine the trophic habits, we examined the stomach contents, a common method used with seabirds (see Barrett et al. 2007), of 101 chicks of yellow-legged gulls collected during one month in 101 different nests located throughout the city of Barcelona (Figure 1). These chicks were provided by the Public Health Agency of Barcelona after they were collected and sacrificed as part of the urban pest species management plan (Legislative Decree 2/2008 of April 15th, DOGC). We scored the age of each chick as 1st age (~ 1 week old), 2nd age (~ 2-3 weeks old) and 3rd age (~ 4-5 weeks old) based on the principal component analysis (PCA) scores that included 3 morphological variables (bill length, tarsus length and body mass), which increase linearly with the age of gulls (Ramos et al., 2008).

To investigate the spatial movements of the yellow-legged gulls, seven breeding adults were captured in a baited trap placed in an urban park in Barcelona and were equipped with two different GPS device models (4 with WIMBISF-25 from Wimbitek SL and 3 with CatLog from Perthold Engineering LLC; Table 1). To confirm that they were breeders, all tagged individuals presented incubation/brood patch. The incubation patch is a patch of featherless skin that is visible on the underside of birds during the breeding season. The two types of GPS devices differed in their frequency of position recording based on their original recording configuration (WIMBISF-25 every 30 minutes and CatLog-GPS every 15 minutes) and the method of retrieving the GPS information (WIMBISF-25 data is downloaded remotely through a SigFox network and the CatLog-GPS requires bird recapture in the same baited trap placed in the urban park two months after the deployment to download the data directly from the logger). GPS devices were attached using a wing harness fixed with a reef knot in the tracheal pit, an attachment method recommended for large gulls (Thaxter et al. 2014). The GPS logger and harness weighed less than 2% of the body mass of the birds (WIMBISF-25=21 g, CatLog=16 g; mean $\pm$ SD of tracked gulls= 1021.43 $\pm$ 165.77 g), less than the 3-5% body mass threshold suggested for seabirds (Phillips et al. 2003; Passos et al. 2010).

Stomach content analysis

To study the diet of chicks we analysed their stomach content. The contents of each stomach were separated and all prey items were identified to the lowest taxonomic level possible. Individuals of each identified taxon were counted. Whenever animal fragments were found, the

number of individuals was registered as the smallest number possible based on the number of identifiable body parts found. To assess the importance of different prey groups in the diet, we calculated two trophic metrics in relation to the total number of stomachs analysed: %FO (frequency of occurrence of each prey) and %N (contribution by number of each prey). All calculations were based on the entire stomachs since all of them had contents. In addition to prey, we recorded the presence of plastics in the stomachs and estimated it as %FO.

PERMANOVA tests (PRIMER-E v6 software, Anderson et al., 2008) based on a Bray-Curtis distance matrix were used to compare the diet (%N) between the three age classes. Prior to these analyses, data were square-root transformed to minimize the impact of outliers. The method calculates a pseudo-F statistic, analogue to the traditional F statistic used in ANOVA tests, using permutation procedures to obtain the p-values (Anderson et al. 2008). To analyse the average dissimilarity and to identify which prey made the greatest contribution to the observed differences in diet composition between ages, Similarity Percentage analysis (SIMPER) was applied (Clarke and Gorley 2006).

GPS data analysis

To study gulls' habitat use, we only considered the GPS locations associated with foraging activity. Thus, all GPS locations registered within a range of 100 m around each nest and those on flight displacement (speed > 4 m/s; Navarro et al. 2016) were removed. The location of each nest was obtained visually based on the aggregation of GPS locations at a specific place over several weeks. After filtering GPS locations, we calculated the percentage of habitat use by each yellow-legged gull as the number of specific habitat positions divided by the total number of GPS positions recorded during the entire tracking period for a particular individual. Habitat use was determined by overlapping all foraging GPS locations with land cover information (Urban Atlas of the European Environment Agency; Copernicus Land Monitoring Services 2016; <5 m resolution). This habitat classification was subsequently visually reviewed using the most recent satellite images offered by Google Earth at a 0.5 m spatial resolution. This double-check allowed us to detect particular habitats such as illegal landfills (Navarro et al. 2016). All GPS foraging locations were ultimately classified into eight categories: urban area, fishing port, marine environment, agricultural area, beach, industrial area, river, water pond and garbage dump (Figure S1 in Online Resource 1). The software QGIS 3.10. A Coruña (QGIS Development Team 2019) was used to perform spatial analysis.

Results

Stomach contents

The stomach contents of yellow-legged gull chicks were mainly composed of terrestrial birds (%FO= 72.28%, %N= 36.14%), followed by species present in demersal marine habitats – named demersal marine resources (%FO= 49.51%, %N= 26.24%), mammals (%FO = 30.69%, %N = 14.85%), species present in pelagic marine habitats - named pelagic marine resources (%FO = 9.90%, %N = 4.95%), terrestrial invertebrates (%FO = 10.89, %N = 5.45) and human garbage (%FO = 6.93, %N = 3.46) (Table 2, Figure 2, Figure S2 in Online Resource 1). Among birds, we mainly found rock pigeons (*Columba livia*) (%FO = 21.78%, %N = 10.89%) and monk parakeets (*Myiopsitta monachus*) (%FO = 11.88%, %N = 5.94%) (Table 2, Figure S2 in Online Resource 1). The bogue (*Boops boops*) was the main demersal species found in the stomachs (%FO = 16.83%, %N = 9.91%; Table 2). Half of the stomachs analysed contained plastic items (%FO=50.49; Table 2).

Differences in diet were found between chicks of different ages (PERMANOVA tests, $Pseudo-F_{2,89}=2.79$, $p=0.02$) (Tables 3, 4). No differences were found between 1st and 2nd age chicks (Pair-Wise tests, $T = 1.45$, $p=0.43$), but the diet of 2nd age chicks differed from the diet of 3rd age chicks ($T = 2.11$, $p = 0.008$), while a trend was only found for the comparison between 1st age and 3rd age chicks ($T = 1.63$, $p = 0.06$) (Tables 3, 4). Demersal marine resources and birds were the prey type that contributed to the differences between chicks of different ages were the demersal marine resources and the birds (Table 3): birds were more common in the stomachs of 1st and 2nd age chicks and demersal marine resources were more common in 3rd age (~ 2-3 weeks old) chicks (Tables 3, 4).

Spatial movements and habitat use

Based on the filtered GPS locations (Figure 1) the tracked gulls used (as a percentage of total locations) mainly urban areas (52% of total GPS locations), followed by fishing ports (30%) and, to a lesser extent, marine environments (6%), industrial areas (6%), garbage dumps (2%), agricultural areas (1%), river and water pond habitats (1%) and beaches (1%) (Figure 3).

Discussion

The results of the present study revealed that the urban population of yellow-legged gulls inhabiting Barcelona exploits different food resources, highlighting the consumption of urban birds and demersal prey items. In line with the diet results, GPS tracking data indicated that although yellow-legged gulls were able to use different types of habitats close to the city, they mainly foraged in urban and fishing port areas.

Similar to previous studies, we found that the urban population of yellow-legged gulls included in its diet a large quantity of fish discards, at least during the chick-rearing period (Arcos, 2001; Ramos et al., 2008). In particular, we found different demersal fish (e.g. *Boops*

boops, *Trisopterus capellanus* or *Micromesistius poutassou*), as well as demersal cephalopods and crustaceans in the stomach contents of the yellow-legged gull chicks (Lopezosa et al., 2019; Mendes et al., 2018; Oro, Genovart, Tavecchia, Fowler, & Martínez-Abraín, 2013; Ramos et al., 2008). Based on the GPS tracking data from adult gulls, these marine prey are only available to the gulls at the port, as a result of discards from fishery activity, and were obtained in the fishing ports and the open sea, two important habitats used by GPS-tracked adults.

While the marine resources were expected to be found in the diet of the yellow-legged gull, we found that the main prey present in the stomach contents of the chicks in Barcelona was urban birds, mainly rock pigeons and monk parakeets. These terrestrial prey found in the stomach content were probably captured by adult yellow-legged gulls in the city of Barcelona, as the urban area was the main habitat used by GPS-tracked gulls during their foraging trips. Although birds, such the rock pigeon, have been previously cited as prey for the yellow-legged gull (Vincent and Guiguen 1989; Canestrelli and Fraticelli 2016), the presence of the invasive monk parakeet in its diet had not previously been documented. The presence of pigeons and parakeets as important prey in the diet of the yellow-legged gull could be directly related to the high abundance of these two species in the city of Barcelona (Anton et al. 2017). Although we cannot rule out that some of these birds may have been consumed as carrion, field observations confirm that gulls capture living, and apparently healthy, individuals of rock pigeons and parakeets in Barcelona (see Fig. S2 in Online Resource 1). These findings, together with sporadic predation on the invasive rose-ringed parakeet (*Psittacula krameri*) in Barcelona by the yellow-legged gull (Senar et al. 2019), suggests that yellow-legged gulls could be acting as a natural predator of these problematic avian species. In fact, the consumption of pigeons and parrots overlaps with the trophic habits of the urban population of peregrine falcons (*Falco peregrinus*) breeding in Barcelona (Anton et al. 2017), a raptor introduced in Barcelona to increase the city's biodiversity and contribute to the control of the populations of problematic urban bird species (García and Durany 2005). It is important to mention that the consumption of rock pigeons and parrots exposes gulls to the pathogens such *Salmonella* spp., *Campylobacter* spp. and *Escherichia coli* of these species, which may explain the origin of some pathogens (Vincent and Guiguen 1989; Vázquez et al. 2010) frequently carried by yellow-legged gulls that potentially could be transmitted to humans via contaminated food (Migura-Garcia, Ramos, & Cerdà-Cuéllar, 2017; Navarro et al., 2019).

The importance of urban birds and marine resources in the diet of the chicks differs between ages classes. Specifically, larger chicks were fed mainly with demersal marine resources whereas smaller chicks were fed mainly with urban birds. These age-related differences could be associated to the fact that when the chicks are small, breeding adults need to be close to the nest to defend against potential predation by conspecifics or other mortality factors such corporal temperature regulation (Marin et al. 1995; Catry et al. 2009). Therefore, adults forage

close to the nests in the urban areas where terrestrial birds are abundant. This feeding strategy could help guarantee a food source during the first days of life of chicks (Marin et al. 1995). Once the chicks are larger, adults can move greater distances (more than 50 km) from the nests and exploit marine resources, a more nutritional resources for the growth of the chicks (Sotillo et al. 2019).

The consumption of organic resources present in garbage dumps is common in this and other similar opportunistic gull species (Arizaga et al. 2014; Ramos et al. 2008). Previous studies conducted during the nineties in areas close to Barcelona indicated that yellow-legged gull exploited extensively garbage dumps (Sol et al. 1993; Sol and Senar 1994). However, based on the stomach contents and GPS tracking data, in the present study we found that the importance of this resource in the diet of this urban population is very low during the breeding period. Probably, some of the landfill management measures (e.g. reduction in the number of landfills or measures to impede access by wildlife to these facilities; Landfill Directive 1999) conducted during the last few decades in the metropolitan area of Barcelona have likely reduced the accessibility of this human-related subsidiary resource to the yellow-legged gull. This situation could force that gulls consume more terrestrial prey items (Zorrozueta et al. 2020) that acquire relatively easy in the urban areas predating on urban birds. In fact, we could not rule out the possibility that some of the organic resources of human origin or mammals may be obtained inside the city in the urban parks or touristic beach areas (Navarro et al. 2016; Schwartz et al. 2018). The presence of plastics in birds has become common, and represents a serious danger to marine and terrestrial biodiversity (Derraik 2002). Plastic debris is often ingested by marine predators and can cause health disorders and even death (Egbeocha et al. 2018). Given the high presence of plastics detected in the stomach content, probably present in the stomach of marine fish (Bellas et al. 2016) or ingested directed by adults during the feeding events (Codina-García et al. 2013), and the potential detrimental effects of plastic ingestion in seabirds, there is necessity to assess the magnitude of the effects of plastics on these birds (Wilcox et al. 2015).

5. Conclusions

The results of this study enhance our understanding of how opportunistic and successful species such as the yellow-legged gull have adapted to exploit the trophic resources associated with urban environments, including human-related trophic resources and other bird species common in urban habitats. Subsidiary anthropogenic food resources have been described as the main cause for the increase in the populations of opportunistic gulls, and has been suggested to facilitate the colonisation of urban areas by opportunistic predators. For this reason, we suggest that the combined presence of abundant fishing resources from fishing discard close to the city and the high abundance of urban birds in Barcelona may have contributed to the establishment and growth of this urban population, by providing abundant food subsidies for this species. The

present study provides useful information to apply particular measures to control the yellow-legged gull populations nesting in urban areas. Among these measures, reducing the availability of the most important food resources on which this species relies is key in addressing the control of their populations. At an epidemiological level, it is important to highlight that the high consumption of terrestrial birds found in this study suggests that yellow-legged gulls may acquire pathogens, presenting new epidemiological scenarios for the transmission, dispersal and spillover of rock pigeon pathogens to humans. This should be evaluated in detail in future research.

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Conflict of interest

The authors have no conflicts of interest to declare.

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Table 1 Details of the GPS devices deployed on yellow-legged gulls during the 2018 breeding season in Barcelona (north-eastern Spain).

Individual	GPS model	Date of first GPS fix	Date of last GPS fix	Total duration (days)	Total locations
PBTP	WIMBISF-25	16 May 2018	30 June 2018	46	2036
PBWB	WIMBISF-25	16 May 2018	30 June 2018	46	1766
PXTZ	WIMBISF-25	16 May 2018	25 June 2018	41	1655
PXXT	WIMBISF-25	25 May 2018	31 May 2018	7	213
PXZS	CatLog	9 May 2018	25 June 2018	17	1518
PYAB	CatLog	1 May 2018	14 May 2018	14	1220
PBMM	CatLog	11 May 2018	13 June 2018	34	3130

Table 2 Diet of yellow-legged gull chicks from Barcelona during the 2018 breeding season. The diet was calculated with the stomach content analysis of 101 chicks sampled in 101 different nests from Barcelona. %FO = frequency of occurrence of each prey in the stomachs. %N = contribution by number of each prey in the stomachs. Unidentified Marine Resources are food remains (mainly bones or muscle of fish) that was not assigned to pelagic or demersal origin.

Prey	%FO	%N
DEMERSAL MARINE RESOURCES	49.51	26.24
Fish	37.62	20.29
<i>Boops boops</i>	16.83	9.91
<i>Trisopterus capellanus</i>	1.98	0.99
<i>Trisopterus</i> sp,	2.97	1.48
<i>Phycis phycis</i>	0.99	0.49
<i>Diplodus</i> sp,	1.98	0.99
<i>Coelorinchus coelorinchus</i>	1.98	0.99
<i>Nezumia</i> sp,	0.99	0.49
<i>Nezumia aequalis</i>	1.98	0.99
<i>Trachinotus ovatus</i>	0.99	0.49
<i>Pagellus acarne</i>	1.98	0.99
<i>Pagellus erythrinus</i>	0.99	0.49
<i>Micromesistius poutassou</i>	1.98	0.99
<i>Lesueurigobius</i> sp,	0.99	0.49
Gadiformes	0.99	0.49
Cephalopod	4.95	2.47
Crustacean	6.93	3.46
PELAGIC MARINE RESOURCES	9.90	4.95
Fish	9.90	4.95
<i>Trachurus trachurus</i>	0.99	0.49
<i>Trachurus</i> sp,	6.93	3.46
<i>Engraulis encrasicolus</i>	0.99	0.49
<i>Sardina pilchardus</i>	0.99	0.49
UNIDENTIFIED MARINE RESOURCES	17.82	8.91
BIRDS	72.28	36.14
<i>Columba livia</i>	21.78	10.89
<i>Myiopsitta monachus</i>	11.88	5.94
Passerine	3.96	1.98
Unidentified	34.65	17.32
MAMMALS	30.69	14.85
<i>Rattus</i> sp	1.98	0.49
<i>Mus musculus</i>	0.99	0.49
Rodents	8.91	4.45
Unidentified	18.32	9.32
TERRESTRIAL INVERTEBRATES	10.89	5.45
GARBAGE DUMP	6.93	3.46
<i>Gallus gallus domesticus</i>	5.94	2.97
Unidentified vegetables	0.99	0.47
PLASTIC ITEMS	50.49	

Table 3 Diet according to the age category of yellow-legged gull chicks from Barcelona during the 2018 breeding season. %FO = frequency of occurrence of each prey in the stomachs. %N = contribution by number of each prey in the stomachs.

Prey group	1st age (n=19)		2nd age (n=33)		3rd age (n=49)	
	%FO	%N	%FO	%N	%FO	%N
Demersal marine resources	31.57	16.67	39.39	20.83	63.26	34.04
Pelagic marine resources	0	0	6.06	2.77	16.32	8.51
Unidentified marine resources	21.05	11.11	33.33	15.27	6.12	3.19
Birds	78.94	41.67	81.81	37.50	63.26	32.97
Mammals	31.57	16.67	36.36	16.66	24.49	12.76
Terrestrial invertebrates	21.05	11.11	6.06	2.77	10.20	5.31
Garbage dump	5.263	2.78	9.09	4.16	6.12	3.19

Table 4 Results of SIMPER analysis comparing the %FO of the main prey items in stomachs according to chick age categories. Only prey groups that contributed more than 5% of the dissimilarity are reported.

Prey	Abundance 1	Abundance 2	Contribution dissimilarity (%)	Cumulative contribution (%)
(1) 2nd age – (2) 3rd age				
Demersal marine resources	0.35	0.61	26.46	26.46
Birds	0.79	0.70	21.24	47.70
Mammals	0.38	0.27	18.39	66.10
Unidentified marine resources	0.34	0.07	15.93	82.03
Pelagic marine resources	0.04	0.15	6.20	88.22
Garbage dump	0.09	0.07	5.93	94.16
(1) 1st age – (2) 3rd age				
Demersal marine resources	0.30	0.61	26.42	26.42
Birds	0.86	0.70	20.39	46.81
Mammals	0.38	0.27	18.76	65.57
Unidentified marine resources	0.25	0.07	13.23	78.80
Terrestrial invertebrates	0.21	0.10	10.84	89.64
Pelagic marine resources	0.00	0.15	5.32	94.96

Fig. 1. (A) General map showing the location of the study area. (B) GPS foraging positions (yellow circles) of 7 GPS-tracked yellow-legged gulls during the 2018 breeding season in Barcelona. (C) Distribution of the nests sampled in Barcelona during the 2018 breeding season to examine the stomach contents of the yellow-legged gull chicks.

Fig. 2. Prey categories found in the stomach contents of 101 yellow-legged gull chicks sampled during the 2018 breeding season in Barcelona calculated as the percentage of stomachs (%FO) (A) and the percentage of preys (%N) (B) for each category.

Fig. 3. Habitat use by seven yellow-legged gulls tracked during the 2018 breeding season in Barcelona. Each individual is represented by a vertical bar, subdivided by the proportion of locations in each habitat in relation to all GPS positions.