JOURNAL OF
AVIAN BIOLOGY

Article

Local use of landfills by a yellow-legged gull population suggests distance-dependent resource exploitation

Alexandra Egunez, Nere Zorrozua, Asier Aldalur, Alfredo Herrero and Juan Arizaga

A. Egunez (http://orcid.org/0000-0002-3288-8935) (aegunez@aranzadi.eus), N. Zorrozua, A. Aldalur, A. Herrero and J. Arizaga, Aranzadi Sciences Society, Donostia, Spain.

Journal of Avian Biology
2018: e01455
doi: 10.1111/jav.01455

Subject Editor: Yutaka Watanuki
Editor-in-Chief: Thomas Alerstam
Accepted 27 November 2017

Understanding the use of feeding sources at the local scale is crucial in comprehending the factors driving population dynamics, dispersal and territory use. Many gull (*Larus* spp.) populations have increased sharply, which is partly promoted by their use of landfills as a food resource. Although at the large scale it is known that birds from mainland colonies feed more on landfills than those from offshore colonies, at the local scale, this distance-dependent exploitation has been little studied. Here, then, we study whether the extent of gulls' use of landfill is distance-dependent through the study of 3 different gull colonies and five separate landfill sites within a relatively small geographical area. After controlling for bird numbers by both age cohort and colony, we observed that the number of gulls found at each landfill was colony dependent and that it decreased non-linearly with increased distance to place of birth.

Keywords: bird counts, colour-ring, feeding ecology, landfills, Gipuzkoa

Introduction

Generalist animal foragers adapt to exploit food resources generated by human activity, such as taking garbage from landfills, and this may promote changes in demography (Newton 2013), dispersal and migration (Newton 2008), trophic ecology (Ramos et al. 2009) and spread of disease (Monaghan et al. 1985). This phenomenon is well known in gulls (*Larus* spp.), for instance yellow-legged gull, *L. michahellis*, populations in both southern France (Duhem et al. 2008) and Poland (Skorka et al. 2005) have increased sharply due to the opening of landfills, and Such population changes often generate socio-economic (Belant 1997, Raven and Coulson 1997, Rock 2005), sanitary (Monaghan et al. 1985, Ramos et al. 2010), and ecological problems (Rusticali et al. 1999, Vidal et al. 2000, Oro et al. 2005).

The yellow-legged gull is one of the most abundant gull species in Europe (Olsen and Larsson 2004), with a population of some 200 000 breeding pairs. In the last decade, the population of the species had increased rapidly, which has been, at least

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partly, promoted by the bird's use of landfills as a principal food source across its complete distribution range (Arizaga et al. 2013a). On the continent, breeding colonies of yellow-legged gulls which are near landfills feed more in landfills than those from offshore colonies (Schmutz and Hobson 1998, Ramos et al. 2009). At a more local scale, however, the distance-dependent exploitation of landfills has been little studied (Arizaga et al. 2013a), though with some notable exceptions such as the works by Hunt (1972 and Ramos et al. (2009)). A number of studies have, though, shown there are significant differences in type of prey consumed by yellow-legged gull between colonies, even those located just a few kilometers apart (Moreno et al. 2009, Ramos et al. 2009, 2011), suggesting that the use of the landfills may well vary locally. It is thus reasonable to assume that there may well be similar preferences with respect to feeding at landfills, although this may well be influenced by the presence of alternative, and preferred, food resources (e.g. a fishing harbour) even for colonies situated close to landfill sites.

There is some evidence to support the notion that use of landfills may also vary across seasons with gulls making greater use of landfills during the non-breeding period (July–March) when availabilities of alternative food resources, such as marine prey or terrestrial prey, decreases. For example winter storms can result in a decrease of availability of marine prey (Schreiber 2001) and low and freezing temperatures result in the decreased availabilty of terrestrial prey, mostly invertebrates such as earthworms and slugs (Moreno et al. 2009, Arizaga et al. 2013b).

In the southeast area of the Bay of Biscay (Gipuzkoa province, north of Spain), the yellow-legged gull population increased from ca 500 pairs during the 1980s to > 1000 pairs in the 2000s (Arizaga et al. 2009), a figure that has remained stable (albeit with a slight non-significant decrease) (Arizaga et al. 2013a). The development of landfills in this area has been found to have strongly correlated with this population increase (Arizaga et al. 2010) as well as influencing gulls to move and take up residence within this area (Munilla 1997). With three colonies and five landfills in a relatively small (4000 km^2) area, Gipuzkoa presents a suitable location in which to study variation in the extent of landfill use by yellow-legged gulls from different colonies. Specifically, we aimed to examine whether landfill use is distance-dependent; hypothesizing that a higher proportion of birds from colonies close to the landfills would use them than from colonies located further away. Additionally, we also explored the effect of possible confounding factors on landfill use, i.e. seasonal (breeding, post-breeding, pre-breeding) and age-dependent fluctuations in the use of landfills.

Material and methods

Study area and data collection

Our study was carried out across three yellow-legged gull colonies in Gipuzkoa: in Ulia (43°20′N, 01°57′W), Santa Clara (43°19′N, 01°59′W), Getaria (43°18′N, 02°12′W) (Fig. 1) where colony sizes were 520, 85 and 92 breeding

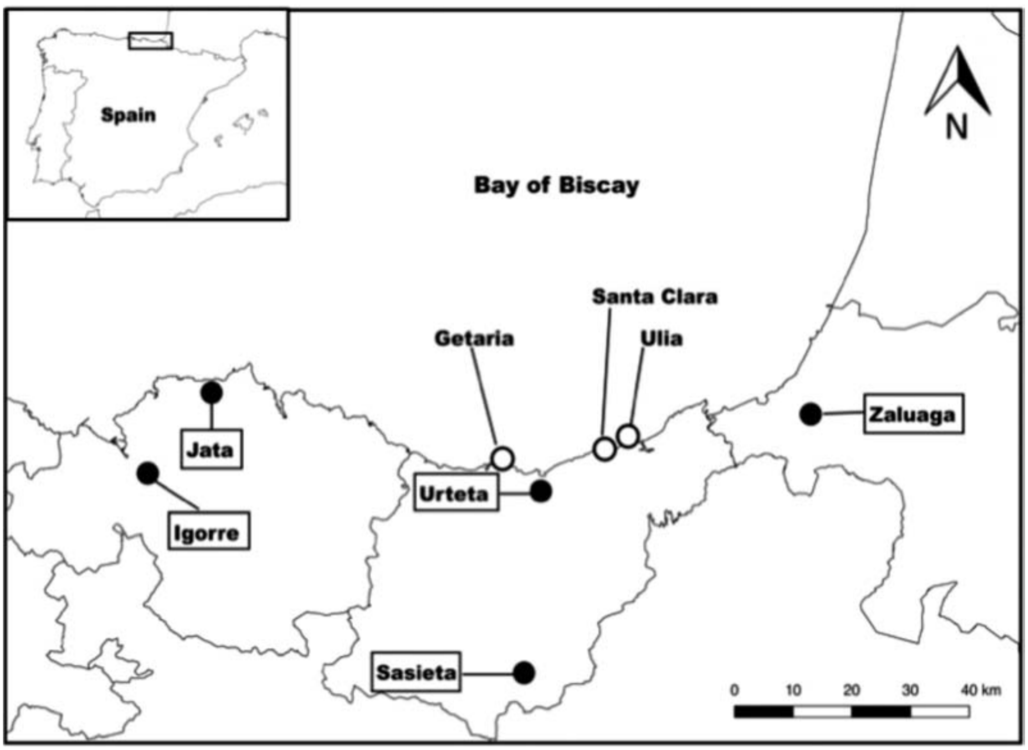

Figure 1. Location of the landfills studied (dark dots), all situated within 80 km of the three study colonies (open dots) in Gipuzkoa. Polygons represent the boundaries of provinces.

pairs, respectively (Arizaga et al. 2009), these three colonies accounting for 92% of the yellow-legged gull breeding population in Gipuzkoa, and ca 15% of that of the southeastern area of the Bay of Biscay (Arizaga et al. 2009). There are five landfills (Igorre, Jata, Urteta, Sasieta and Zaluaga, Fig. 1) within 80 km of the study sites, this radius being chosen because most yellow-legged gulls remain within 80 km of their natal colonies throughout their life (Jordi et al. 2014).

Ringing of chicks at the age of ca 20–25 d was carried out over a number of consecutive days at each colony. In total 3054 chicks (Ulia: 1962; Santa Clara: 636; Getaria: 457) were caught and ringed on days when it was neither raining nor windy in late-June and early July (to minimize handling effects on nestling survival) each year from 2006 to 2016. Ringing involved attaching a metal ring with the bird's individual data, and a plastic ring which was colour coded, thus enabling easy visual identification of the natal colony of individual gulls during the surveys at the landfill sites.

From 2006 to 2016 birds feeding at the various landfills were periodically surveyed by ornithologist from our work group in order to identify colour-ringed gulls until such time as the landfill was closed or the exercise became logistically impossible (Supplementary material Appendix 2). The one-hour surveys were carried out at each landfill from the same observation site each time. Since the duration of each sampling event (1 h) was constant, even though number of sampling events was not the same for each landfill, comparisons between landfills and periods were made possible by using a ratio . Data collected on days when gulls were flying around the landfill or continuously moving from place to place due to the use of falconry or other dissuasive methods was omitted from the analysis. We conducted 315 observations in total during the study, at various times in the year (Supplementary material Appendix 1).

Data analyses

The number of colour-ringed individuals at each landfill during the one-hour observation on a given day was recorded, along with the colony and year each bird was banded as a chick, hence providing data on age. Since the number of chicks banded at each colony in each year was known, we were able to calculate the ratio between the number of observed cour-ringed birds of a given age and colony at each landfill and the number of chicks from that same age cohort ringed at that colony.

We considered five age groups: birds in their 1st-, 2nd-, 3rd- or 4th yr and those over 4 yr old. Birds were considered to be 1st yr from the July of the year when they fledged (i.e. when they were ringed) to the June of the following year. Furthermore, depending on the time in the year when each observation in the landfill was made it was allocated to one of three periods (period) for the subsequent analyses: post-breeding (July–December), pre-breeding (January–March), breeding (April–June).

We applied generalized linear models (GLMs) with the number of colour-ringed birds observed in landfills as a response variable, and landfill, period, colony of origin and age as factors, including two and three-way interactions between period, colony and landfill. The number of chicks of the same cohort ringed at each colony was included as an offset variable. Models were conducted using a log-linear link function with a Poisson error distribution. Using the above mentioned model as full model we ran all the possible models and compared them using the small-sample size corrected Akaike's information criterion (AICc) (Akaike 2011). The model with the lowest AICc value was regarded as the best compromise between model deviance and complexity. Models with an AICc below 2.00 units were all considered to be equally supported (Akaike 2011).

Finally, we examined the effects of distance from natal colony on the proportion of colour-ringed birds observed at each landfill.

Results

In total 1607 different colour-ringed individuals of yellow-legged gull were recorded across the five landfills. The majority of these birds came from Ulia ($n = 1112$, 69%), followed by Santa Clara ($n = 298$, 19%) and Getaria ($n = 197$, 12%). Fifty-three percent of the total number of colour-ringed birds were observed in landfills and when each colony was considered separately, results were of a similar magnitude, with no statistical differences between colonies ($p > 0.05$).

The total number of birds using each landfill varied, being higher at the Sasieta, Urteta and Zaluaga landfills than at Igorre and Jata (Supplementary material Appendix 1). There were also differences between colonies, with gulls from the Ulia colony using the Zaluaga landfill proportionally more than Sasieta and Urteta, while, gulls from the Santa Clara and Getaria colonies used Sasieta and Urteta landfills more than those from the Ulia colony (Fig. 2; Table 1; Supplementary material Appendix 2). The proportion of gulls of a specific age seen at each landfill tended to decrease with age, and these differences were statistically significant (Table 1). Specifically, 28, 22, 14, 13 and 23% of colour-ringed gulls observed at landfills were birds in their 1st-, 2nd-, 3rd- and 4th yr and over 4 yr old, respectively. Period and period-landfill interaction was associated with the number of gulls using landfills, specifically, fewer landfill visits during the breeding period and more during the post-breeding period, although the effect was far weaker for the Zaluaga and, to a lesser extent, the Igorre landfills (Fig. 3).

The proportion of gulls seen at each landfill tended to decrease with distance to natal colony (Fig. 4). Overall this relationship fitted better an exponential ($r^2 = 0.814$) rather than a linear function ($r^2 = 0.713$), and the relationship was slightly stronger for the colony of Santa Clara ($r^2 = 0.916$) as compared to the other two colonies (Ulia: $r^2 = 0.848$, Getaria: $r^2 = 0.830$) (Fig. 4).

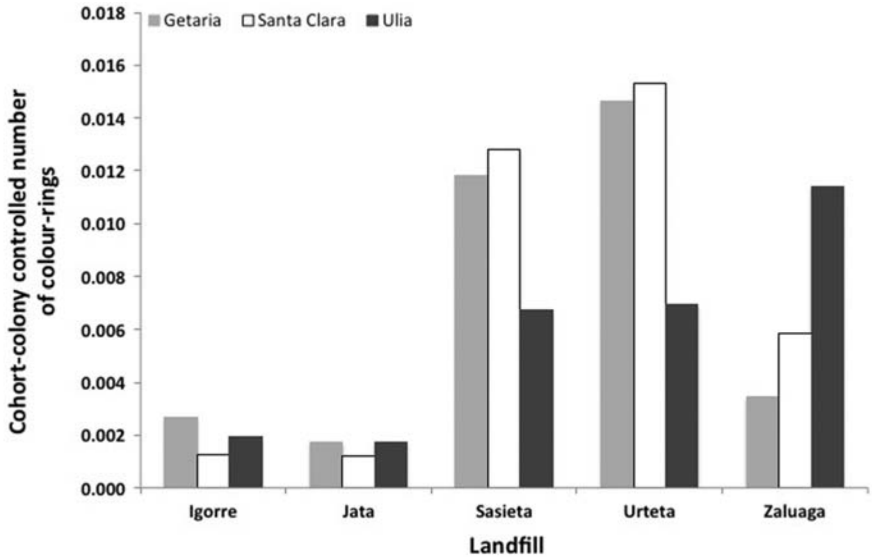

Figure 2. Standadized number of individuals observed in five landfill study sites in relation to the birth places (natal colony). Numbers have been controlled for the number of chicks ringed per cohort and colony.

Discussion

This study aimed to determine the local use of landfills by three different yellow-legged gull population all in the same geographical area. After controlling for the number of chicks ringed by age cohort and colony, we found that the number of gulls found at each landfill was colony-dependent, and that the number of gulls from a particular colony observed in a specific landfill tended to decrease with increased distance to that colony. Individual specialization in gulls is relatively common, and a few birds may stay in a landfill for a long period (Sanz-Aguilar et al. 2015). A priori, this may add bias to our results, and it should be noted that, within our models, each individual was considered only once per unit of analysis meaning that this model approach might be unable to separate individual- and colony effects.

Table 1. The beta-parameter estimates obtained from the best model of Supplementary material Appendix 3 (i.e. landfill × colony + landfill × period + age). Reference beta-parameter values (beta = 0): landfill = Igorre; colony = Getaria; Age = 1st yr; period = breeding.

Parameters	Beta ± SE of beta	p
(Intercept)	–4.119 ± 0.333	< 0.001
Landfill: Jata	+0.002 ± 0.002	0.382
Landfill: Sasieta	+0.009 ± 0.003	0.016
Landfill: Zaluaga	+0.005 ± 0.003	0.112
Landfill: Urteta	+0.010 ± 0.003	0.006
Colony: Santa Clara	+0.001 ± 0.002	0.844
Colony: Ulia	+0.001 ± 0.002	0.622
Age: 2nd yr	–0.215 ± 0.043	< 0.001
Age: 3rd yr	–0.493 ± 0.049	< 0.001
Age: 4th yr	–0.442 ± 0.050	< 0.001
Age: > 4 yr	–1.033 ± 0.043	< 0.001
Period: post-breeding	+0.941 ± 0.270	0.001
Period: pre-breeding	–0.179 ± 0.344	0.602
Landfill × colony interactions:		
Santa Clara × Sasieta	+1.184 ± 0.430	0.006
Santa Clara × Urteta	+1.475 ± 0.401	< 0.001
Santa Clara × Zaluaga	+0.907 ± 0.360	0.011
Ulia × Zaluaga	+1.848 ± 0.271	< 0.001
Landfill × period interactions:		
Jata × post-breeding	+0.598 ± 0.315	0.047
Urteta × post-breeding	+1.173 ± 0.338	0.001
Urteta × pre-breeding	+2.377 ± 0.406	< 0.001
Zaluaga × pre-breeding	+1.111 ± 0.349	0.002

These results replicate the pattern observed at larger spatial scales (Moreno et al. 2009, Ramos et al. 2009, Castège et al. 2016). Although the Getaria colony was the closest to Urteta landfill, a proportionally higher number of gulls from the Santa Clara colony was observed in the Urteta landfill. The Getaria colony is near the main fishing harbor (Getaria) in the region and birds from this colony have been found to feed on marine prey more than birds from the Santa Clara or Ulia colonies (Arizaga et al. 2013b). Thus our work supports the notion that local alternative food sources might influence the use of landfills.

Even though Santa Clara and Ulia are situated less than 4 km from each other, birds from Ulia tended to use the landfill of Zaluaga (situated to the east) more, while birds from Santa Clara used the Sasieta and Urteta landfills (situated to the south and west of the colony) more. This is in line with studies showing that birds from even very nearby colonies might travel in opposite directions to feed (Grémillet et al. 2006, Kralj et al. 2014). Our results also suggest such patterns, but the ultimate explaination for this behavior remains unknown. Future studies using telemetry could be very helpful to determine to what extent landfill use differs between colonies from a local spatial perspective (Kralj et al. 2014).

The use of the landfills also varied between periods. Landfills were frequented more during the non-breeding period (July–March). This supports other results reported in

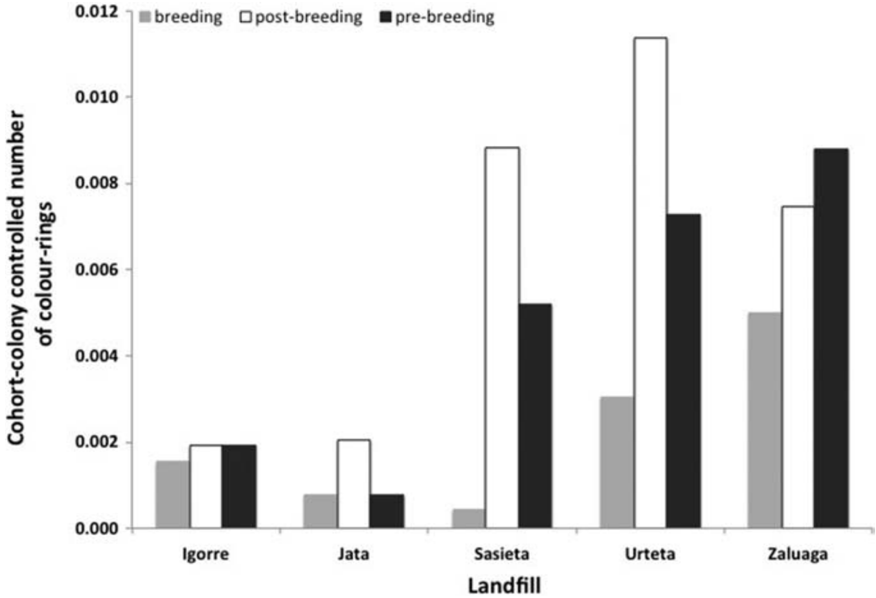

Figure 3. Standadized number of individuals observed in five landfill study sites in relation to period (breeding, post-breeding and pre-breeding). Numbers have been controlled for the number of chicks ringed per cohort and colony.

yellow-legged gulls in the Bay of Biscay: birds used landfills more during the winter than in summer (Jordi et al. 2014, Castège et al. 2016). The increased use of landfills in winter can be explained by two different processes. First, a decrease in other food resources in winter, such as marine prey (Spear 1988, Munilla 1997) or terrestrial prey. Preliminary data from stable isotope analyses in the Getaria, Santa Clara and Ulia colonies in Gipuzkoa reveal a slight increase in the use of garbage as well as marine prey in winter, together with a decrease in the use of terrestrial prey (Arizaga unpubl.). This result is compatible with both a decrease in the food resources that are used during the breeding period as well as an increase in landfill use during the post-breeding period. Second, gulls are not bound to their colonies for mating/parenting purposes during winter, allowing them to exploit different and more widely dispersed feeding resources. Thus during the post-breeding period, the number of gulls might increase in landfills that are located farther from the natal colony, as was the case for the Jata landfill.

We found that first-year birds were proportionally more abundant at landfills than older ages. This result may simply be due to a mortality-linked effect. An alternative (or complementary) explanation is that landfill sites might be proportionally more exploited by young gulls as compared

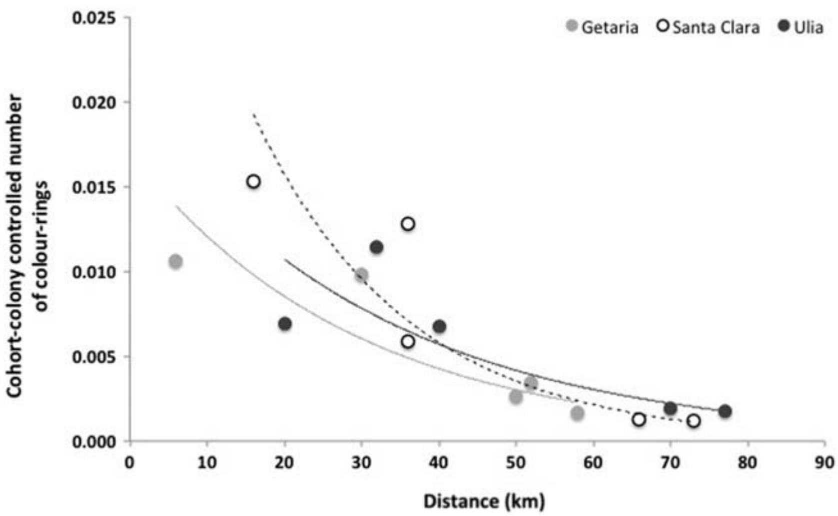

Figure 4. Non-linear relationship between the controlled numbers of individuals observed at the study landfills in relation to the number of chicks ringed per cohort and colony [Getaria (light grey line), Santa Clara (dashed line) and Ulia (dark grey line)] at Gipuzkoa and the colony-landfill distance (km).

to adults. However, previous research within the same study area has suggested that use of landfills was not age-dependent (Jordi et al. 2014), and GPS-tracked adult individuals showed a relatively frequent use of landfills (Arizaga et al. 2017). Further investigation is needed to throw more light on this question.

In conclusion, we found that yellow-legged gulls from colonies in the southeastern Bay of Biscay demonstrated differential use of landfills, with the distance from natal colony to a specific landfill largely explaining the presence of gulls at each landfill site. We also show that the number of gulls using landfills increased during the post-breeding period (July to December).

Acknowledgements – Many thanks to the people who provided the observation data and those who helped to ring chicks. Thanks to Syndicat Bizi Garbia for facilitating to take the data in Center of Stockage des Déchets Ultimes Zaluaga Bi. Two referees and the Editor Y. Watanuki provided very valuable comments that helped us to improve an earlier version of this work. Ronnie Lendrum provided editing support.
Funding – This research was funded by the Gipuzkoa Administration (Deputation of Gipuzkoa).

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Supplementary material (Appendix JAV-01455 at <www.avianbiology.org/appendix/jav-01455>). Appendix 1–3.