https://doi.org/10.61350/sbj.37.4

Variations of demographic parameters of a mixed-gull colony on French west Coast in relation to egg removal

Justin Chambrelin[1], Julien Gernigon[1], Jean-Christophe Lemesle[1], Amandine Delory[1], Paméla Lagrange[1]*

* *Correspondence author: pamela.lagrange@lpo.fr*

[1] *Ligue pour la Protection des Oiseaux, Fonderies Royales - 8-10 rue du Dr Pujos - CS 90263 - 17305 Rochefort, France*

PL ORCiD 0000-0001-8582-7741

Abstract:

Egg removal campaigns are a common practice in France and Europe, including in natural areas, to manage conflicts between large gulls and other species or humans. Few studies have evaluated the impact of this practice on the breeding site fidelity of targeted colonies. The Lilleau des Niges Nature Reserve hosts a mixed-species colony of gulls (Laridae), including European Herring Gull *Larus argentatus*, Lesser Black-backed Gull *L. fuscus*, and Great Black-backed Gull *L. marinus*. The gull colony was controlled between 1990 and 2017 using egg removal. A citizen-science led capture-recapture study began in 2010, and resighting of colour-marked individuals were obtained at the breeding colony between 2010 and 2022. By using a multi-event model, we assessed the colony fidelity and adult survival during the egg removal campaign (2010–17) and in the following years (2018–22). Breeding site fidelity was lower during the years of egg removal than in subsequent years for two species (a decrease of 0.07 for Herring Gull and 0.22 for Lesser Black-backed Gull). The probability of survival for all species declined during the study period but could not be directly linked to gull control measures. No difference between sexes was found for these two parameters. Moreover, colour ring resighting by citizen scientists showed that some individuals moved from natural colonies to urban colonies. These initial results suggest that the local population dynamics of gulls have changed over time, although a causal link to egg removal campaigns cannot be confirmed.

Introduction

Since the 1950s, population sizes of several gull (Laridae) species have increased in Europe. This development is often attributed to the increasing availability of anthropogenic food (Coulson 2015), for example, from open landfill development (Pons & Migot 1995) and discards from industrial fishing (Oro *et al.* 2004; Hudson & Furness 2008). Another contributing factor is the introduction of better legal protection of gulls in France in 1962 (Henry & Monnat 1981). The population growth in gulls encouraged the emergence of large colonies, which can impact rare flora (Vidal *et al.* 1998) or compete with other colonial birds (Salathé 1983; Cadiou & Fortin 2010). It has therefore been necessary for some conservation managers to control numbers of gulls, despite their protection status (Paulet & Bioret 2021). In addition to the growth in natural colonies, since the 1970s gull populations have also been urbanising. Observations of gull colonisation of urban areas were first made in England (Cramp 1971) and Bulgaria (Nankinov 1992), then in France in 1975 (Camberlein & Floté 1979; Vincent 1986), but no study quantified this tendency for urbanisation. The recent proximity to humans in urban areas has caused new conflicts to emerge (Paulet & Bioret 2021) and, consequently, control measures have been implemented to reduce nuisance behaviours in gulls. Many methods are available to control gulls, including: culling of adults, egg-oiling, replacing eggs with fake eggs, euthanasia, use of narcotics, contraception, sound deterrents, or even the introduction of predators (Calladine 2006).

The population trends of European Herring Gull *Larus argentatus* (hereafter 'Herring Gull'), Lesser Black-backed Gull *L. fuscus* and Great Black-backed Gull *L. marinus* in Europe have varied between 1950 and 2000, with increases reaching a plateau by the 1970s, followed largely by a declining trend. The British Herring Gull population deteriorated rapidly, with a decline of 60% between 1969 and 2015 (Eaton *et al.* 2015). In France, the breeding population of Herring Gulls declined moderately between 1999 and 2012 (Issa & Muller 2015), with the most recent estimate of 50,720 pairs of Herring Gulls made during the 2020–22 census (GISOM 2023). In Great Britain, the population of Lesser Black-backed Gulls declined between 2000 and 2013 (Ross-Smith *et al.* 2014), whereas in France, the breeding population trend was stable between 1989 and 2012 (Issa & Muller 2015), with the most recent census estimate at 13,705 pairs (GISOM 2023). European populations of Great Black-backed Gull declined by 28% between 1985 and 2021, with declines more pronounced in populations in northern Europe (Langlois Lopez *et al.* 2023). The French Great Black-backed Gull population increased strongly between 1989 and 2012 (Issa & Muller 2015) and was estimated to be 6,565 pairs during the most recent census (GISOM 2023). Although the three species are considered as 'Least concern 'on the IUCN's European Red List of Threatened Species (Birdlife International 2020), this status is uncertain. The Herring Gull has recently moved to the 'Least concern 'category of the Red List of the UK (Stanbury *et al.* 2024). Langlois Lopez *et al.* (2023) recommended the status of Great Black-backed Gull from 'Least Concern 'to 'Vulnerable 'on the world IUCN Red List categories. Over the last century, the reduction of available anthropogenic food resources is partly responsible for their decline (Pons 1992; Bicknell *et al.* 2013).

Few studies have investigated the importance of control measures on the population dynamics of gulls and the impacts these may have on breeding site fidelity or other demographic parameters (Coulson 2015). Due to the decline in European gull populations, non-urban colony management is being reconsidered to improve the conservation status of their population by stopping control measures such as egg removal or sterilisation campaigns (Paulet & Bioret 2021).

Gull control measures exert a similar pressure to predation by reducing adult survival (Coulson *et al.* 1982) or reproductive success (Parsons *et al.* 1976; Monaghan 2008). Predation disrupts colony dynamics by reducing reproductive success and increasing adult dispersal away from the colony (Craik 1997; Oro & Pradel 2000). High reproductive success and the presence of conspecifics are two factors promoting colony fidelity for individuals in colonial birds (Smith & Peacock 1990; Danchin *et al.* 1998; Cam *et al.* 2004). For larids, breeding sites that do not produce many young in a given year tend to cause individuals to disperse to more productive colonies in the next year(Oro & Pradel 2000), while the most productive sites recruit more easily the following year (Danchin *et al.* 1998; Cam *et al.* 2004). Disturbing the reproduction of an individual can therefore have an impact on its reproduction over several years, through causing dispersal to another colony or non-reproduction in subsequent years (Fairweather & Coulson 1995; Salas *et al.* 2020). In the Double-crested Cormorant *Nannopterum auritum*, one of the rare examples for which the impact of regulation campaigns was investigated and published, adults showed greater fidelity to the breeding site when colonies were not sterilised (Chastant *et al.* 2014).

The gull colony of the national nature reserve of Lilleau des Niges was established in 1984 (Robreau 1999). It is one of the few natural non-urban colonies in the centre of the French Atlantic coast. It is a multi-species colony where Herring Gulls, Lesser Black-backed Gulls, Great Black-backed Gulls, and Yellow-legged Gulls *L. michahellis* nest. Gull management was requested in 1992 by local authorities to reduce predation on eggs and chicks of Pied Avocet *Recurvirostra avosett* and Black-winged Stilt *Himantopus himantopus.* These operations targeted Herring Gulls and Yellow-legged Gulls, which were suspected of predating wader nests at a higher rate than Lesser Black-backed Gulls and Great Black-backed Gulls. To assess the impact of egg removal campaigns on gull colony dynamics, a capture-recapture programme was launched in 2010. Long-term breeding season monitoring on the reserve, including participation by many citizen scientists, has resulted in numerous resightings of marked individuals within the reserve and outside its borders. Gull management was stopped in 2018, with the authorisation of local authorities, due to the risk the colony might disappear. In total, nearly 17,000 nests were destroyed during the regulation period.

This study aims to compare adult gull survival and colony fidelity during the egg removal campaigns at Lilleau des Niges National Nature Reserve (2011–17) and after the operations were stopped (2018–22). We predicted that egg removal campaigns promote the dispersal of adults away from their original colony.

Methods

Study area and data collection

The study colony is located in the Lilleau des Niges National Nature Reserve, on the island Ile de Ré (46.13°N, 1.30°W), managed by the Ligue pour la Protection des Oiseaux (LPO). The reserve consists of both marine and terrestrial areas formerly used for salt production (Figure 1). Gulls nest on the dikes that divide the salt marshes.

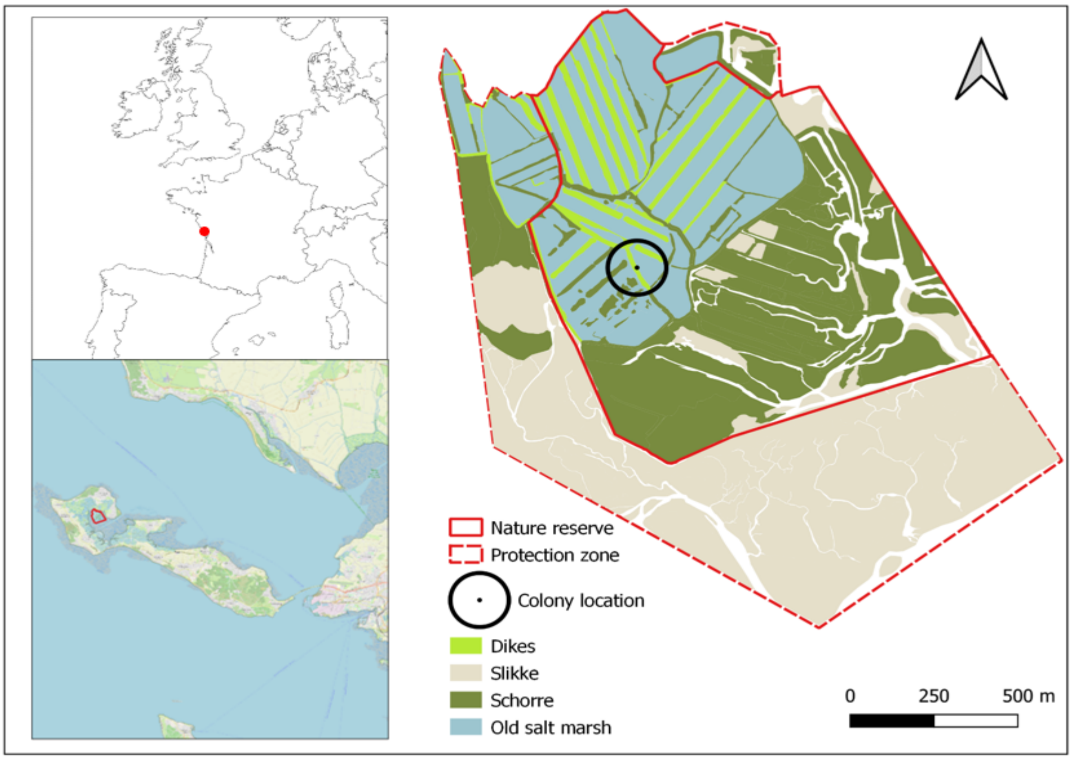

Figure 1: Location of the Lilleau de Niges National Nature Reserve in France (top left), Ré Island (bottom left), and the habitat composition of the study area (right).

The colony grew steadily until 2002, the year in which shredding of household waste was stopped at the island's landfill site. Herring Gull numbers peaked in 2002 at about 1,200 pairs. In 2010, a warehouse was built to transfer waste to the mainland, preventing the gulls from accessing large quantities of food. These two events are considered potential environmental changes that may have influenced the dynamics of the colony. Between 2002 and 2014, Herring Gull numbers fluctuated between 300 and 700 pairs, before falling sharply to about 100 pairs in 2017. The colony is divided into two sub-colonies, a mixed sub-colony of Herring, Lesser Black Backed and Yellow-legged Gull, and a separate sub-colony mainly composed of Great Black-backed Gull.

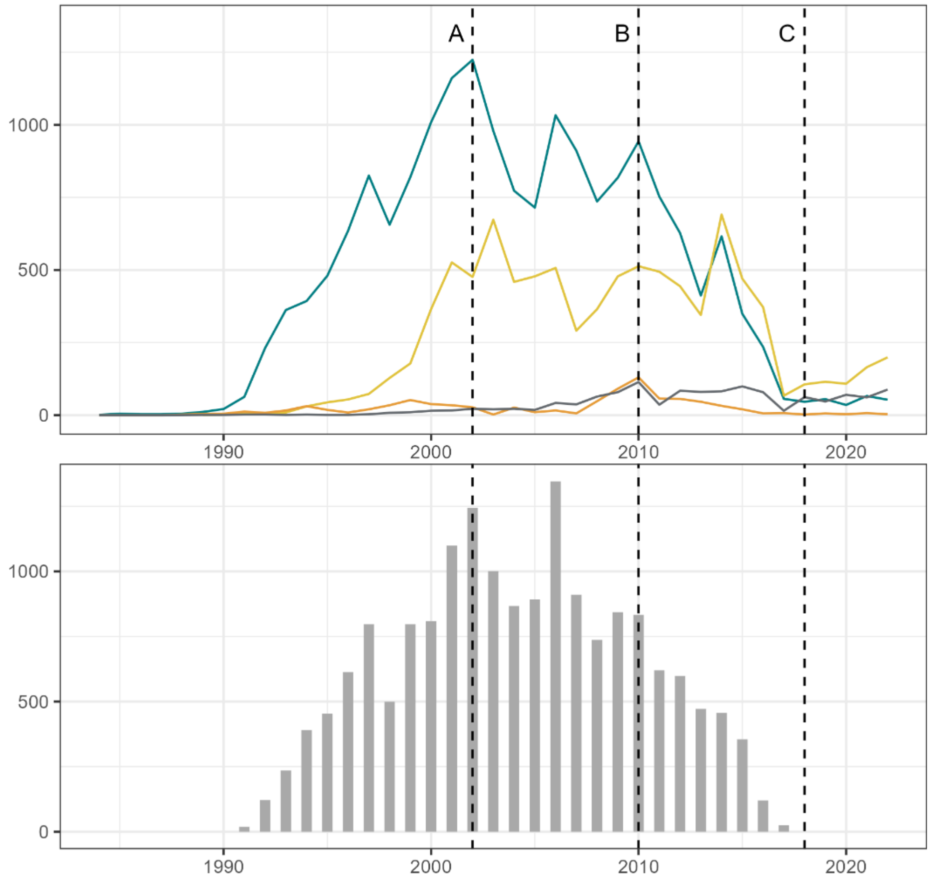

Figure 2: Top: Number of nests per year (blue = Herring Gull, yellow = Lesser Black-backed Gull, grey = Great Black-backed Gull, orange = Yellow-legged Gull). Bottom: The number of nests of Herring Gull sterilized by year. The dotted bars show the events that likely had an impact on the colony's demography: the halting of shredding waste at the site (A), landfill cover (B), and stopping egg removal campaign (C).

The percentage of sterilised nests varied from 21% in 1991, up to 100% of Herring Gull nests being sterilised in 2005 and 2006 (Figure 2). In 2011, the management team replaced chemical egg-oiling with the replacement of fake plaster eggs in nests. Between 2011 and 2016, 90 adults were directly destroyed. The control campaign stopped in 2018. Since then, the Herring Gull population has been observed to be stable, whereas Lesser Black-backed Gulls appear to be increasing.

Bird capture and colour-ring resighting

Ringing was carried out on adult Herring, Lesser Black-backed and Great Black-backed Gulls during the breeding season at Lilleau des Niges from 2010 to 2022. The individuals were captured adults (>4 years) during brooding, using a trap placed on the nest. Birds are identified using a white PVC ring (Darvic®), with a unique black alphanumeric code (R: letter/number/letter or R: number/letter/number). The first capture of an individual gull is an opportunity to record biometric measurements including: folded wing (LP), measured using a ruler with a stop (accuracy ±1mm), the size from the back of the skull to the tip of the beak (TB), the length of the total tarsus (LT_GBT), and the depth of the bill (EB). These last three measurements were taken using a digital calliper (accuracy ± 1mm), and all birds were measured by the same bird-ringer. To sex individual gulls, we used our biometric measurements in combination with a molecular sexing dataset based on the method of Fridolfsson and Ellegren (1999). To predict sex, we performed a linear discriminant analysis, using biometric measurements (LDA, Lequitte-Charransol *et al.* 2021). The formula was tested with a molecular dataset and verified on sexing data observed in the field (e.g. mating). It was then extended to individuals whose sex was unknown. The formula was based on two biometric measurements: the size from the back of the skull to the tip of the beak (TB) and the depth of the bill (EB). The accuracy of the LDA is 97.1% for the Herring Gull, 95.4% for Lesser Black-backed Gulls and 100% for Great Black-backed Gulls.

During the breeding season (April to July), two observational monitoring visits for resighting individuals were made per week by the nature reserve team. Resighting of colour-marked gulls were also made by observers outside of the reserve (http://www.bretagne-vivante-dev.org/goelands/). These include records from landfill sites in Spain, mainly of Great Black-backed Gulls, and in western France, mainly of Herring Gulls. Other observations were occasionally made on the coast, in agricultural areas, or on water bodies. The use of Darvic rings (colour rings) has considerably increased the chance of resighting outside the study area (Meissner & Bzoma 2011).

Capture-recapture analysis

The emergence of mathematical models such as capture-recapture models has made it possible to quantify demographic parameters such as breeding site fidelity (Pradel 2005). For this study, we used a capture-recapture dataset that categorised individuals into two states based on the location of their resighting (inside or outside the colony) and the period (breeding season or outside breeding season). This structure allowed us to construct a multi-event model (Pradel 2005) using the maximum number of resightings to enhance the precision estimates, particularly for evaluating breeding dispersion during egg removal campaigns and afterwards (2011–17 vs. 2018–22). The dataset comprises of 12 capture occasions (one year of ringing and resighting between two breeding seasons) from 2010–22. Adults ringed in 2010 were excluded from analysis because they lacked the biometric measurements necessary for sex determination.

For every capture occasion, three subsequent events were considered: not seen (0), seen at least once during the breeding season within the colony (1), and seen outside the colony or outside the breeding season(2). If an individual was seen during the breeding season within the colony and outside the colony in the same year, priority was given to the observation within the breeding colony (1). For each event, three states are associated: dead (D), alive within the colony during the breeding season (A), alive elsewhere; i.e. resighting made outside the breeding season, or outside the breeding colony (B).

In the matrices, the rows correspond to occasion *t*, and the columns to occasion *t*+1. The capture occasions in the model correspond to the annual observation of individuals.

In the initial state, which corresponds to the first capture (ringing) on Lilleau des Niges, all the individuals are necessarily alive and present in the nature reserve. Therefore, this parameter has was assigned a probability of 1 in the models.

$$\text{Initial state} = \begin{array}{cc} A & B \\ \left| 1 \right. & \left. 0 \right| \end{array}$$

The following matrix was used to calculate the resighting probability. Only individuals that are alive can be seen with a probability *b*, either on Lilleau des Niges (1) or outside of the colony (2), the probability of not being seen in a state being equal to 1-*b*. Dead individuals cannot be detected.

$$\text{Resighting (p)} = \begin{array}{c} \\ A \\ B \\ D \end{array} \begin{array}{ccc} 0 & 1 & 2 \\ \hline 1-b & b & - \\ 1-b & - & b \\ - & - & - \end{array}$$

The probability *s* of survival in a state is estimated between year *t* and *t*+1 for each condition. The probability of being dead in a state is the complement, which is equal to 1-*s*.

			A	B	D
		A	*s*	-	1-*s*
Survival (ϕ)	=	B	-	*s*	1-*s*
		D	-	-	1

Finally, the parameter of highest interest in the model was the fidelity to the breeding colony of the nature reserve. This probability of staying in the colony for two consecutive years (*t* and *t*+1) was denoted as *f*, whereas the probability of dispersing from the colony was equal to 1-*f*.

			A	B	D
		A	*f*	1-*f*	-
Fidelity (ψ)	=	B	1-*f*	*f*	-
		D	-	-	1-*f*

Several effects were tested on the resighting parameter: ʼtime ʼ(defined by the year), ʻsex ʼ(an individual variable), and the ʻstate ʼ(A or B). On survival and fidelity parameters, we added ʼperiodʼ, a temporal variable dividing the study time in two periods: during the egg removal campaign (2010–17) and after the egg removal campaign (2018–22), and a last environmental variable 'sterilisation' serving as a proxy for the sterilisation effort: the proportion of sterilised nests on the total number of counted nests of Herring Gulls (one value by year). We used a stepwise model selection starting with parameters that affected the resighting probability (p), then identified which parameters affected survival (ϕ), and finally the parameter of interest, fidelity (ψ), with the goal to reduce the numerous potential model structures. We thus defined a list of single effects on the resighting parameter, retained the effect with the highest impact and tested this effect in interaction with another effect until we identified the model structure for 'p' with the lowest Akaike's Information Criterion corrected for overdispersion and sample size (QAICc), and a good estimate of all parameters (excluding models that had interval confidence close to 0 and 1). We then used the same approach for both the survival and fidelity parameters to identify the best model structures.

The models were implemented in the E-SURGE software (Choquet *et al.* 2009). Model selection was based on the QAICc criterion, considering the coefficient of overdispersion and small sample sizes (Burnham *et al.* 2011). The results presented reflect those derived from the most parsimonious among the 'best' models.

Using this multievent model requires respecting the assumptions of the Arnason-Schwarz model (Pradel *et al.* 2003). Specifically, there should be no trap-dependent effect or transient individuals (i.e. ringed individuals with subsequent resighting) in the dataset (Pradel *et al.* 2003). The datasetʼs deviation from these assumptions was assessed using a goodness-of-fit test implemented in the U-CARE software (Choquet *et al.* 2009). Three tests were conducted: the 3G.SR (Groups Survival Structure) test to evaluate the presence of transient individuals, the M.ITEC (Memory Influence on Transition and Encounter Capture) test to examine trap-dependence and the JMV (JollyMove) test for the overall dataset quality. While the JMV test was not specifically developed for multi-event models, we chose this because it represents a special case of multi-site testing (Pradel *et al.* 2003). To address overdispersion and trap-dependence, we used the global c-hat ($\hat{c} = \chi^2/df$) to adjust the models ʼfit in E-SURGE (standard errors, confidence intervals and AIC were adjusted).

Results

Observations

A total of 35,833 observations were collected over the period 2010–22. Our dataset consisted of 16,087 observations collected during colony-based monitoring and 19,746 observations made by citizen scientists.

Goodness-of-fit

The goodness-of-fit test revealed a lack of fit for adult Herring Gulls (χ^2=103.96, df = 95, p <0.1), primarily attributed to trap-dependence effects (χ^2=36.00, df = 17, p <0.1). Similarly, for Lesser Black-backed Gulls, the test indicated an inadequate fit (χ^2=229.27, df = 118, p <0.1), primarily due to trap-dependence effects. To address this, the coefficient of overdispersion for the global test was applied, resulting in $\hat{c}$ = 1.09 for Herring Gulls and $\hat{c}$ = 1.93 for Lesser Black-backed Gulls.

The dataset for Great Black-backed Gulls showed a slight deviation from Arnason-Schwarz's assumptions (χ^2=58.46, df = 62, p >0.1). The coefficient of the global test was adjusted ($\hat{c}$ = 0.94), this under-dispersion as possibly influenced by sample size rather than a genuine data adjustment issues. Hence, the coefficient was set to 1 in our analysis (Cooch & White 2014).

Model results

Details of all tested models are available in the Supplementary Material. The results are presented by species and the estimates of the 'best' models were presented with their standard errors (SE) and summarised in Figure 3.

Herring Gulls

The Herring Gull capture-recapture dataset included 275 adults, comprising of 135 males and 140 females. The probabilities of survival and fidelity were influenced by the gull control/no gull control period, which combined years with and without egg removal campaigns (estimates of model 96, Supplementary Material Table S1). There was no observed effect of time (model 74) or sex (model 70) on the resighting probability.

The resighting probability within the colony during the breeding monitoring period was 0.97 ± 0.01, and it was 0.72 ± 0.02 for individuals observed alive and outside of the breeding season monitoring. Only the state was retained on this parameter among the tested variables (models 75 and 78 versus model 69).

The survival rate decreased between the gull control/no gull control periods, dropping from 0.92 ± 0.01 during the egg removal campaign to 0.85 ± 0.03 afterward within the colony (Figure 3). This decrease was also obvious for individuals alive and seen outside breeding monitoring, declining from 0.87 ± 0.02 to 0.72 ± 0.03 between the two periods. Time (model 80) or sex (model 87) had no impact on survival.

Breeding individuals' fidelity to the colony increased after the cessation of the egg removal campaign, rising from 0.49 ± 0.02 to 0.63 ± 0.04. Similarly, the fidelity of individuals observed alive and outside the breeding season monitoring, whether living outside the colony or observed outside the breeding period in the colony, increased from 0.63 ± 0.02 to 0.88 ± 0.02. As for survival, sex was not retained when modelling the fidelity parameter (model 97), nor sterilisation (model 98).

Exchanges between the two events (seen at least once during the breeding season within the colony and seen at least once during the year outside the breeding season monitoring) decreased between the period of colony sterilisation and afterwards. The probability of dispersing from the colony during the breeding season decreased from 0.43 ± 0.02 during sterilisation to 0.36 ± 0.04 afterwards. The probability of returning to the colony during the breeding season after dispersing decreased from 0.36 ± 0.02 to 0.11 ± 0.02, regardless of sex.

Lesser Black-backed Gull

The Lesser Black-backed Gull capture-recapture dataset included 417 individuals, comprising 209 males and 208 females. The probabilities of survival and fidelity were influenced by the gull control/no gull control period, combining years with and without egg removal campaigns (estimates of model 7, Supplementary Material, Table S2). There was no observed effect of time or sex on the resighting probability (models 34, 35, 38).

The resighting probability within the colony during the breeding season monitoring was 1, while it was 0.55 ± 0.02 for individuals observed alive outside of the breeding season monitoring. Time seemed to have an impact on resighting probability in interaction with the state (model 36), but parameters were not well estimated and hence we did not retain this interaction effect in the model structure.

The survival rate declined between the two periods, dropping from 0.92 ± 0.01 during the egg removal campaign to 0.88 ± 0.02 afterwards within the colony (Figure 3). This decline was also obvious outside the colony, decreasing from 0.90 ± 0.01 during the campaign to 0.73 ± 0.04 afterwards. None of the other variables seemed to impact the survival probability (models 42, 43, 47, 48). Time may have an impact on survival probability in interaction with the state (model 41) but estimated parameters were not precise (large standard errors) to retain this model parameterisation.

Breeding individuals' fidelity to the colony increased after egg removal campaigns, rising from 0.49 ± 0.02 to 0.70 ± 0.03. Similarly, the fidelity of individuals observed alive and outside the breeding season monitoring increased from 0.59 ± 0.03 to 0.76 ± 0.03.

Exchanges between the two events (seen at least once during the breeding season within the colony and seen at least once during the year outside the breeding season monitoring) decreased between the period of colony sterilisation and afterwards. The probability of dispersal from the colony during the breeding season decreased from 0.50 ± 0.02 during sterilisation to 0.29 ± 0.03 afterwards. The probability of returning to the colony during the breeding season after dispersing decreased from 0.40 ± 0.02 to 0.23 ± 0.03, irrespective of sex (model 11), sterilisation (model 56) or time (model 51).

Great Black-backed Gull

For the Great Black-backed Gull, the dataset comprised 92 adults, with 43 males and 49 females. The model with the best fit indicated that the survival rate was influenced by the gull control/no gull control period and fidelity by the birds' state, i.e. either 'within the colony during the breeding monitoring' or 'individuals observed alive outside of breeding monitoring.' Sex influenced the resighting probability (model 58, Supplementary Material, Table S3), but this probability did not vary over time (model 54) or the state (model 27). The resighting probability was lower for males compared to females, with an average difference of 15.5%, ranging from 0.78 ± 0.03 for males to 0.93 ± 0.02 for females.

The survival rate decreased between the gull control/no gull control periods, declining from 0.90 ± 0.02 during the egg removal campaign to 0.84 ± 0.03 afterwards (Figure 3). There was some support for an interaction of time with period (model 35), but parameters were not well estimated and hence we did not retain this interaction in the model structure. None of the other variables seemed to impact the survival probability (models 40, 36, 37). The fidelity of breeding individuals to the colony was 0.68 ± 0.03, and for individuals observed alive outside of breeding colony, it was 0.44 ± 0.05 (model 58). Gull control/no gull control period did not have an impact on the fidelity parameter (model 60 or 63), not even the proxy of sterilisation effort (model 67), nor sex (model 59). Time may have had an impact on this parameter (model 61) but estimated parameters were not precise (large standard errors) to retain this model parameterisation.

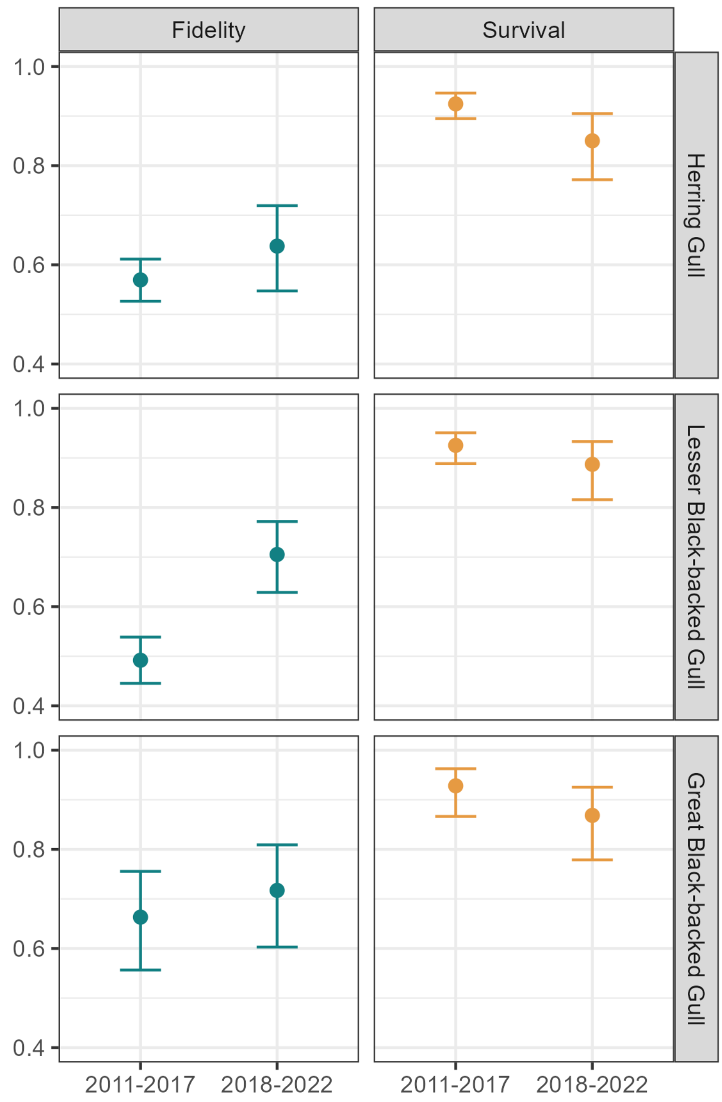

Figure 3: Fidelity (blue; left) and survival (yellow, right) of the three gull species banded Lilleau des Niges Nature Reserve during (2011–17) and after (2018–22) an egg removal campaign. Error bars represent standard errors. Estimates come from the models 96 (European Herring Gull *Larus argentatus*), 7 (Lesser Black-backed Gull *L. fuscus*), and 58 (Great Black-backed Gull *L. marinus*), see Supplementary Materials.

Discussion

Volunteer citizen scientists submitted resightings across an extensive geographical area, spanning from northern Germany to southern Mauritania. This data enabled the utilisation of a multi-event model to calculate colony fidelity and survival probabilities with greater precision than could be attained using colony monitoring effort alone. Resighting probabilities were consistent between sexes but varied based on the state for Herring Gulls and Lesser Black-backed Gulls. For Great Black-backed Gulls, males were 15.5 % less likely to be detected than females. The resighting probability generally tended to be lower outside the colony than within for Herring and Lesser Black-backed Gulls.

The probability of colony fidelity increased after the cessation of the egg removal campaign (2018–22) for Herring and Lesser Black-backed Gulls. For Great Black-backed Gulls, we found no effect of gull control/no gull control period on fidelity, thus fidelity was not affected by the egg-removal campaigns. This could be explained by the fact that the Great Black-backed Gull colony was located further away from the centre of the mixed colony of Herring Gulls and Lesser Black-backed Gulls. It may have been less impacted by the effects of conspecific presence and breeding success (Smith & Peacock 1990; Danchin *et al.* 1998; Cam *et al.* 2004). This could explain why there was no effect of the period on site fidelity in Great Black-backed Gulls compared to the other two species. Our results further suggest that the management goal of reducing the Herring Gull colony in the reserve through sterilisation may have encouraged birds to disperse away from the controlled colony, promoting colonisation of nearby urban areas. This dispersal may have led to issues such as noise pollution and droppings in the urban areas, as well as colony fragmentation. Resightings of ringed individuals in urban colonies support this hypothesis. Several colour ringed birds were confirmed breeding on rooftops in Ré Island's villages and in a colony located at Pallice port about 20 km away (46°09'42.6"N, 1°13'36.7"W). Some individuals from these colonies had not been resighted since they were ringed, suggesting a low resighting effort or a very distant dispersal for this long-lived species. It reflects the difficulty of observing colour-ringed birds on rooftops or away from natural sites, where the observation pressure is higher, and the viewing conditions are more favourable.

For all three study species, the survival probability decreased after the end of the egg removal campaign compared to during the campaign period itself. As adults are not directly affected by egg removal campaigns, the survival probability should not vary between the two periods. For Herring Gulls, the survival probability varied from 0.87 to 0.98 in other European and Canadian colonies (Coulson & Butterfield 1986; Pons & Migot 1995; Allard *et al.* 2006; Breton *et al.* 2008; Rock & Vaughan 2013; Kentie *et al.* 2023). Herring Gull survival in our study was therefore within the range found in other colonies during the egg removal campaign (0.92 ± 0.01) but fell below this after the end of the campaign (0.85 ± 0.03). For Lesser Black-backed Gulls, the survival probability varied between 0.88 in England and 0.91 in Scotland (Wanless *et al.* 1996; Rock & Vaughan 2013). The estimate of survival in our study was therefore within the upper range during the egg removal campaign (0.92 ± 0.01), and at a similar level as in England after the egg removal campaign (0.88 ± 0.02). For Great Black-backed Gulls, the survival probability in our study was lower (0.90 ± 0.02 during the egg removal campaign and 0.84 ± 0.03 afterwards) than estimates found in the literature, which varied between 0.93 in Germany and 0.95 in France (Glutz Von Blotzheim *et al.* 1982; Linard & Monnat 1990). In these gull studies, survival decreased over time. However, it is not possible to make a direct link between the decreased survival probability and egg removal campaigns, suggesting possibly a large-scale effect.

In population dynamics, survival is the most relevant parameter in long-lived species that contributes to population conservation (Lebreton & Clobert 1991). Thus, declining survival estimates observed in this study are likely to limit the growth of Herring, Lesser Black-backed and Great Black-backed Gull colony size at Lilleau des Niges Nature Reserve. Survival can be influenced by the availability of anthropogenically sourced food; for example, the closure of landfill sites has been shown to increase foraging times and distances (Langley *et al.* 2021) and therefore daily energy expenditure. This can then lead to a decrease in body mass (a proxy for body condition) in breeding individuals (Steigerwald *et al.* 2015), as well as a reduction in reproductive success (Pons 1992). Compared to variability in foraging resources, other factors that drive gull population dynamics are less discussed in the literature. The survival probability for seabirds is negatively correlated with the presence of pollutants in some individuals of Glaucous Gull *L. hyperboreus* and Black-legged Kittiwakes *Rissa tridactyla* (Erikstad *et al.* 2013; Goutte *et al.* 2015). However, the decline in gull survival is global and our results corroborate this trend. The three species studied on the Ré Island are significantly exposed to mercury and PFAS (per- and poly-fluoroalkyl substances) (Jouanneau *et al.* 2022; Sebastiano *et al.* 2021, 2023). Further research on pollutant exposure and capture-recapture data for the colony would be required to understand whether pollutants are contributing to the decline in survival of gulls at this colony.

The impact of control measures on gull populations is rarely mentioned in the literature, but in Great Britain, between 1972 and 1987, 48% of the gull population decline can be attributed to the regulation of 100,000 individuals over the same period (Coulson 2015). In France, the total scale of egg removal campaigns has not been quantified, making it difficult to assess impacts on the decline of breeding gulls in France. This study demonstrates that control measures in natural areas may have unintended consequences, such as dispersal to other breeding sites, particularly to urban areas. To mitigate conflicts between humans and gulls in cities, management strategies that promote fidelity to natural colonies should be prioritised. From a conservation perspective, it is crucial to investigate the impact of targeted egg removal campaigns on gull population declines, in addition to other factors that may be driving declines more broadly, such as the reduction of anthropogenic food resources. Observed declines in gull survival could not be directly attributed to egg removal campaigns by this study, and further investigations into ecotoxicology or the availability of food resources may offer insights into this trend.

Acknowledgments:

We extend our gratitude to all contributors to this programme, including numerous ornithologists, volunteers, and professionals involved in resighting efforts. Special thanks go to Frédéric Robin for his initial involvement in the programme. The programme, titled "Long-term monitoring of demographic parameters of breeding larids in the Nature Reserve of Lilleau des Niges and the Charentais Shoals," has been authorised by the Centre de Recherche sur la Biologie des Populations d'Oiseaux (CRBPO) under the project name PP533. We also acknowledge the team at the Centre d'études biologiques de Chizé (CEBC - UMR 7372 CNRS Univ. La Rochelle) for their assistance with molecular sexing and their research on the presence of contaminants in gulls, which may help explain variation in mortality over time. This programme has been made possible through the financial support of DREAL Nouvelle Aquitaine, CDC Île de Ré, and the French Ministry of the Environment. And we extend an acknowledgement to the editorial team of Seabird for manuscript support.

References:

Allard, K. A., Breton, A. R., Gilchrist, H. G. & Diamond, A. W. 2006. Adult survival of herring gulls breeding in the Canadian Arctic. *Waterbirds* 29: 163–168. https://doi.org/10.1675/1524-4695(2006)29[163:ASOHGB]2.0.CO;2

Bicknell, A. W. J., Oro, D., Camphuysen, K. C. J. & Votier, S. C. 2013. Potential consequences of discard reform for seabird communities. *Journal of Applied Ecology* 50: 649–658. https://doi.org/10.1111/1365-2664.12072

Birdlife International. 2020. European Red List of Birds. Office for *Official Publications of the European Communities.* Luxembourg.

Breton, A. R., Fox, G. A. & Chardine, J. W. 2008. Survival of Adult Herring Gulls (*Larus argentatus*) from a Lake Ontario Colony Over Two Decades of Environmental Change. *Waterbirds* 31: 15–23. https://doi.org/10.1675/1524-4695(2008)31[15:SOAHGL]2.0.CO;2

Burnham, K. P., Anderson, D. R. & Huyvaert, K. P. 2011. AIC model selection and multimodel inference in behavioral ecology: Some background, observations, and comparisons. *Behavioral Ecology and Sociobiology* 65: 23–35. http://dx.doi.org/10.1007/s00265-010-1084-z

Cadiou, B. & Fortin, M. 2010. Bilan des mesures de gestion des goélands sur les sites à sternes. *Penn Ar Bed* 208: 24–29.

Calladine, J. R., Park, K. J., Thompson, K. & Wernham, C. V. 2006. Review of urban gulls and their management in Scotland: *A report to the Scottish Executive*. Scottish Executive. Edinburgh, Scotland.

Cam, E., Oro, D., Pradel, R. & Jimenez, J. 2004. Assessment of hypotheses about dispersal in a long-lived seabird using multistate capture–recapture models. *Journal of Animal Ecology* 73: 723–736. https://doi.org/10.1111/j.0021-8790.2004.00848.x

Camberlein, G. & Floté, D. 1979. Le goéland argenté en Bretagne: Étude démographique et gestion de population. *Penn Ar Bed* 98: 89–115.

Chastant, J. E., King, D. T., Weseloh, D. V. C. & Moore, D. J. 2014. Population dynamics of double-crested cormorants in two interior breeding areas: Demographics of Interior Cormorants. *The Journal of Wildlife Management* 78: 3–11. https://doi.org/10.1002/jwmg.628

Choquet, R., Rouan, L. & Pradel, R. 2009. Program E-Surge: A Software Application for Fitting Multievent Models. In: Thomson, D. L., Cooch, E. G. & Conroy M. J. (eds.) *Modeling Demographic Processes In Marked Populations*: 845–865. Springer, USA. https://doi.org/10.1007/978-0-387-78151-8_39

Cooch, E. G. & White, G. C. 2014. *Program MARK - "A Gentle Introduction."* www.phidot.org/software/mark/docs/book

Coulson, J. C. 2015. Re-Evaluation of the Role of Landfills and Culling in the Historic Changes in the Herring Gull (*Larus argentatus*) Population in Great Britain. *Waterbirds* 38: 339–354. https://doi.org/10.1675/063.038.0411

Coulson, J. C. & Butterfield, J. 1986. Studies on a colony of colour-ringed Herring Gulls *Larus argentatus:* I. Adult survival rates. *Bird Study* 33: 51–54. https://doi.org/10.1080/00063658609476892

Coulson, J. C., Duncan, N. & Thomas, C. 1982. Changes in the Breeding Biology of the Herring Gull (*Larus argentatus*) Induced by Reduction in the Size and Density of the Colony. *The Journal of Animal Ecology* 51: 7–39. https://doi.org/10.2307/4002

Craik, C. 1997. Long-term effects of North American Mink *Mustela vison* on seabirds in western Scotland. *Bird Study* 44: 30–39. https://doi.org/10.1080/00063659709461065

Cramp, S. 1971. Gulls nesting on buildings in Britain and Ireland. *British Birds* 64: 476–487.

Danchin, E., Boulinier, T. & Massot, M. 1998. Conspecific reproductive success and breeding habitat selection: Implications for the study of coloniality. *Ecology* 79: 2415–2428. https://doi.org/10.1890/0012-9658(1998)079[2415:CRSABH]2.0.CO;2

Eaton, M., Aebischer, N., Brown, A., Hearn, R., Lock, L., Musgrove, A., Noble, D., Stroud, D. & Gregory, R. 2015. Birds of Conservation Concern 4: The population status of birds in the UK, Channel Islands and Isle of Man. *British Birds* 108: 708–746.

Erikstad, K. E., Sandvik, H., Reiertsen, T. K., Bustnes, J. O. & Strøm, H. 2013. Persistent organic pollution in a high-Arctic top predator: Sex-dependent thresholds in adult survival. *Proceedings of the Royal Society B: Biological Sciences* 280: 20131483. https://doi.org/10.1098/rspb.2013.1483

Fairweather, J. A. & Coulson, J. C. 1995. Mate retention in the kittiwake, *Rissa tridactyla*, and the significance of nest site tenacity. *Animal Behaviour* 50: 455–464. https://doi.org/10.1006/anbe.1995.0259

Fridolfsson, A.-K. & Ellegren, H. 1999. A Simple and Universal Method for Molecular Sexing of Non-Ratite Birds. *Journal of Avian Biology* 30: 116–121. https://doi.org/10.2307/3677252

GISOM. 2023. Recensement national des oiseaux marins nicheurs en France hexagonale—Enquête 2020-2022 (p. 61). *GISOM Published report*. Concarneau, France.

Glutz Von Blotzheim, Bauer, K. & Bezzel, E. 1982. *Handbuch der Vögel Mitteleuropas*. *Akademische Verlagsgesellschaft*, Vol. 8. Wiesbaden, Germany.

Goutte, A., Barbraud, C., Herzke, D., Bustamante, P., Angelier, F., Tartu, S., Clément-Chastel, C., Moe, B., Bech, C. & Gabrielsen, G. W. 2015. Survival rate and breeding outputs in a high Arctic seabird exposed to legacy persistent organic pollutants and mercury. *Environmental Pollution* 200: 1–9. https://doi.org/10.1016/j.envpol.2015.01.033

Henry, J. & Monnat, J.-Y. 1981. Oiseaux marins nicheurs de la façade atlantique française (Temis). *Société pour l'Etude et la Protection de la Nature en Bretagne - Mission des Etudes et de la Recherche (SEPNB-MER)*; CGDD. https://side.developpement-durable.gouv.fr/doc/SYRACUSE/389726

Hudson, A. V. & Furness, R. W. 2008. The behaviour of seabirds foraging at fishing boats around Shetland. *Ibis* 131: 225–237. https://doi.org/10.1111/j.1474-919X.1989.tb02765.x

Issa, N. & Muller, Y. 2015. Atlas des oiseaux de France métropolitaine. Nidification et présence hivernale. *Delachaux et Niestlé*. LPO/SEOF/MNHN. France.

Jouanneau, W., Sebastiano, M., Rozen-Rechels, D., Harris, S. M., Blévin, P., Angelier, F., Brischoux, F., Gernigon, J., Lemesle, J.-C., Robin, F., Cherel, Y., Bustamante, P. & Chastel, O. 2022. Blood mercury concentrations in four sympatric gull species from South Western France: Insights from stable isotopes and biologging. *Environmental Pollution* 308: 119619. https://doi.org/10.1016/j.envpol.2022.119619

Kentie, R., Shamoun-Baranes, J., Spaans, A. L. & Camphuysen, K. 2023. Spatial patterns in age- and colony-specific survival in a long-lived seabird across 14 contrasting colonies. *Ibis* 165: 82–95. https://doi.org/10.1111/ibi.13120

Langley, L. P., Bearhop, S., Burton, N. H. K., Banks, A. N., Frayling, T., Thaxter, C. B., Clewley, G. D., Scragg, E. & Votier, S. C. 2021. GPS tracking reveals landfill closures induce higher foraging effort and habitat switching in gulls. *Movement Ecology* 9: 56. https://doi.org/10.1186/s40462-021-00278-2

Langlois Lopez, S., Bond, A. L., O'Hanlon, N. J., Wilson, J. M., Vitz, A., Mostello, C. S., Hamilton, F., Rail, J.-F., Welch, L., Boettcher, R., Wilhelm, S. I., Anker-Nilssen, T., Daunt, F. & Masden, E. 2023. Global population and conservation status of the Great Black-backed Gull *Larus marinus*. *Bird Conservation International* 33: e23. https://doi.org/10.1017/S0959270922000181

Lebreton, J.-D. & Clobert, J. 1991. Bird population dynamics, management and conservation: The role of mathematical modelling. In: *Bird population studies—Relevance to Conservation and management*:105–125. Oxford University Press, Oxford. https://doi.org/10.1093/oso/9780198577300.003.0005

Lequitte-Charransol, P., Le Saux, E. & Jiguet, F. 2021. Sexing first-calendar-year Carrion Crows *Corvus corone* from biometrics reveals variation between years in post-fledging sex ratio. *Ringing & Migration* 36: 82–90. https://doi.org/10.1080/03078698.2022.2098369

Linard, J.-C. & Monnat, J.-Y. 1990. Fonctionnement d'une population de goélands marins. Relations avec les populations de goélands argentés et bruns. *Published report SEPNB/SRETIE*. France.

Meissner, W. & Bzoma, S. 2011. Colour rings with individual numbers increase the number of ringing recoveries of small waders. *Wader Study Group Bull* 118: 114–117.

Monaghan, P. 2008. Aspects of the breeding biology of Herring Gulls *Larus argentatus* in urban colonies. *Ibis*: 121: 475–481. https://doi.org/10.1111/j.1474-919X.1979.tb06687.x

Nankinov, D. N. 1992. The nesting by the Herring Gull (*Larus argentatus*) in the towns and villages of Bulgaria. *Avocetta* 16: 93–94.

Oro, D., Cam, E., Pradel, R. & Martínez-Abraín, A. 2004. Influence of food availability on demography and local population dynamics in a long-lived seabird. *Proceedings of the Royal Society of London. Series B: Biological Science* 271: 387–396. https://doi.org/10.1098/rspb.2003.2609

Oro, D. & Pradel, R. 2000. Determinants of local recruitment in a growing colony of Audouin's gull. *Journal of Animal Ecology* 69: 119–132. https://doi.org/10.1046/j.1365-2656.2000.00379.x

Parsons, J., Chabrzyk, G. & Duncan, N. 1976. Effects of Hatching Date on Post-Fledging Survival in Herring Gulls. *The Journal of Animal Ecology* 45: 667–675. https://doi.org/10.2307/3574

Paulet, M. & Bioret, F. 2021. La mise en lumière du conflit humain-goéland et sa gestion en France. *VertigO* 21: 1–27. https://doi.org/10.4000/vertigo.32144

Pons, J. M. 1992. Effects of changes in the availability of human refuse on breeding parameters in a herring gull. *Ardea* 80: 143–150.

Pons, J.-M. & Migot, P. 1995. Life-history strategy of the herring gull: Changes in survival and fecundity in a population subjected to various feeding conditions. *Journal of Animal Ecology* 64: 592–599. https://doi.org/10.2307/5802

Pradel, R. 2005. Multievent: An Extension of Multistate Capture-Recapture Models to Uncertain States. *Biometrics* 61:442–447. https://doi.org/10.1111/j.1541-0420.2005.00318.x

Pradel, R., Wintrebert, C. M. A, & Gimenez, O. 2003. A Proposal for a Goodness-of-Fit Test to the Arnason-Schwarz Multisite Capture-Recapture Model. *Biometrics* 59: 43–53. https://doi.org/10.1111/1541-0420.00006

Robreau, H. 1999. Suivi de la population de Laridés et Sternidés sur l'île de Ré et la Réserve Naturelle de Lilleau des Niges (Charente-Maritime) *Published report LPO*: 50. Rochefort, France.

Rock, P. & Vaughan, I. P. 2013. Long-term estimates of adult survival rates of urban Herring Gulls *Larus argentatus* and Lesser Black-backed Gulls *Larus fuscus*. *Ringing & Migration* 28: 21–29. https://doi.org/10.1080/03078698.2013.811179

Ross-Smith, V. H., Robinson, R. A., Banks, A. N., Frayling, T. D., Gibson, C. C. & Clark, J. A. 2014. The Lesser Black-backed Gull *Larus fuscus* in England: How to resolve a conservation conundrum. *Seabird* 27: 41–61. https://doi.org/10.61350/sbj.27.41

Salas, R., Müller, W., Vercruijsse, H., Lens, L. & Stienen, E. 2020. Forced nest site relocations negatively affect reproductive investment in a colonial seabird species. *Biological Conservation* 246: 108550. https://doi.org/10.1016/j.biocon.2020.108550

Salathé, T. 1983. La prédation du Flamant rose *Phoenicopterus ruber roseus* par le Goéland leucophée *Larus cachinnans* en Camargue. *Revue d'Écologie (La Terre et La Vie)* 37: 87–115. https://doi.org/10.3406/revec.1983.4763

Sebastiano, M., Jouanneau, W., Blévin, P., Angelier, F., Parenteau, C., Gernigon, J., Lemesle, J. C., Robin, F., Pardon, P., Budzinski, H., Labadie, P. & Chastel, O. 2021. High levels of fluoroalkyl substances and potential disruption of thyroid hormones in three gull species from South Western France. *Science of The Total Environment* 765: 144611. https://doi.org/10.1016/j.scitotenv.2020.144611

Sebastiano, M., Jouanneau, W., Blévin, P., Angelier, F., Parenteau, C., Pallud, M., Ribout, C., Gernigon, J., Lemesle, J. C., Robin, F., Pardon, P., Budzinski, H., Labadie, P. & Chastel, O. 2023. Physiological effects of PFAS exposure in seabird chicks: A multi-species study of thyroid hormone triiodothyronine, body condition and telomere length in South Western France. *Science of The Total Environment* 901: 165920. https://doi.org/10.1016/j.scitotenv.2023.165920

Smith, A. T. & Peacock, M. M. 1990. Conspecific Attraction and the Determination of Metapopulation Colonization Rates. *Conservation Biology* 4: 320–323. https://doi.org/10.1111/j.1523-1739.1990.tb00294.x

Stanbury, A. J., Burns, F., Aebischer, N. J., Baker, H., Balmer, D. E., Brown, A., Dunn, T., Lindley, P., Murphy, M. & Noble, D. G. 2024. The status of the UK's breeding seabirds: An addendum to the fifth Birds of Conservation Concern in the United Kingdom, Channel Islands and Isle of Man and second IUCN Red List assessment of extinction risk for Great Britain. *British Birds* 117: 471–487.

Steigerwald, E. C., Igual, J., Payo-Payo, A. & Tavecchia, G. 2015. Effects of decreased anthropogenic food availability on an opportunistic gull: Evidence for a size-mediated response in breeding females. *Ibis* 157: 439–448. https://doi.org/10.1111/ibi.12252

Vidal, E., Medail, F. & Tatoni, T. 1998. Is the yellow-legged gull a super abundant bird species in the Mediterranean? Impact on fauna and flora, conservation measures and research priorities. *Biodiversity and Conservation* 7: 1013–1026. https://doi.org/10.1023/A:1008805030578

Vincent, T. 1986. Nidification urbaine du Goéland argenté (*Larus argentatus*) première donnée pour le département de la Somme. *Avocette* 10: 30–32.

Wanless, S., Harris, M. P., Calladine, J. & Rothery, P. 1996. Modelling Responses of Herring Gull and Lesser Black Backed Gull Populations to Reduction of Reproductive Output: Implications for Control Measures. *The Journal of Applied Ecology* 33: 1420–1432. https://doi.org/10.2307/2404781