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# EFFECT OF AGE, COLONY OF ORIGIN AND YEAR ON SURVIVAL OF YELLOW-LEGGED GULLS *LARUS MICHAHELLIS* IN THE BAY OF BISCAY

# EFECTO DE LA EDAD, COLONIA DE ORIGEN Y AÑO SOBRE LA SUPERVIVENCIA DE GAVIOTAS PATIAMARILLAS *LARUS MICHAHELLIS* EN EL GOLFO DE VIZCAYA

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SUMMARY.—We studied sources of variation in apparent local survival of yellow-legged gulls ringed as chicks in a number of colonies with different size trends. Specifically, our aim was to test whether individuals hatched in colonies with decreasing population trends had lower survival rates than those from stable or increasing colonies. From 2006 to 2013, 3,024 chicks were colour-ringed in four colonies along the coast of the Basque Country (from east to west): Ulia, Santa Clara, Guetaria and Izaro. Sighting data of these gulls were compiled from August 2006 to June 2013. Cormack-Jolly-Seber models with mixtures were used to estimate apparent survival (hereafter, survival). Overall, survival differed between two age classes (first-year birds < older birds), colony of origin and in relation to year. The Izaro colony, one of the decreasing colonies, showed the lowest survival rate. However, survival was observed to be reasonably high in another declining colony. Hence we did not find a general link between survival and colony trends. Survival did not seem to be affected by colony size and we did not find evidence supporting a decrease in survival across the study period. More research is needed to disentangle factors explaining variation in local survival in yellow-legged gulls.

*Key words*: Cormack-Jolly-Seber models, dumps, population dynamics, seabirds.

RESUMEN.—Estudiamos el origen de la variación en la supervivencia local aparente de gaviotas patiamarillas marcadas (anilladas) como pollos en colonias con distinta tendencia de población. Específicamente, el objetivo del trabajo fue comprobar si los individuos que nacieron en colonias con tendencias de población negativas tuvieron una supervivencia más baja que los que nacieron en colonias estables o con tendencias de población positivas. De 2006 a 2013, 3.024 pollos fueron marcados con anillas de color en cuatro colonias en el País Vasco: Ulia, Santa Clara, Guetaria e Izaro. A partir de agosto de 2006 y hasta junio de 2013 se recopiló información relativa al avistamiento de estas aves. Utilizamos modelos de Cormack-Jolly-Seber con “mixtures” con el fin de determinar la supervivencia local aparente. En conjunto, la supervivencia varió entre clases de edad (primeros años < aves con más

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de un año de vida), en función de la colonia de origen y el año. La tasa de supervivencia más baja fue hallada en la colonia de Izaro, una de las colonias con tendencia poblacional decreciente. No obstante, la supervivencia fue razonablemente alta en otra colonia con también una tendencia poblacional negativa. En consecuencia, no observamos un patrón claro entre la supervivencia y la tendencia poblacional de las colonias. La supervivencia no se vio afectada por el tamaño de la colonia ni descendió durante el periodo de estudio. Se requiere más investigación para determinar cuáles son los factores que explican la variación de la supervivencia a nivel local.

*Palabras clave*: aves marinas, dinámica poblacional, modelos de Cormack-Jolly-Seber, vertederos.

## Introduction

Seabirds are long-lived species of high interest to humans not only from a conservation standpoint but also because some of them have become/are considered pests (Belant and Ickes, 1996; Vidal *et al.*, 1998; Rock, 2005). This is the case with many large white-headed gulls (*Larus* spp.) worldwide (Olsen and Larson, 2004). Due to the superabundance of fish discards and waste at rubbish dumps (Arizaga *et al.*, 2013; Oro *et al.*, 2013), some large gulls have experienced a population growth strong enough to generate sanitary (Monaghan *et al.*, 1985; Ramos *et al.*, 2010), safety (Brown *et al.*, 2001), ecological (Vidal *et al.*, 1998; Rusticali *et al.*, 1999; but see Oro and Martínez-Abraín, 2007) or social problems (Raven and Coulson, 1997; Rock, 2005). Apart from an improved reproductive output (Brown, 1967; Oro *et al.*, 1995; Duhem *et al.*, 2002; Rock, 2005), the high survival rates of first-year birds and adults may have also promoted such increases (Breton *et al.*, 2008).

The yellow-legged gull *L. michahellis* is one of the most abundant large gulls in the southwestern Palaearctic, occurring in southern Europe, northern Africa and the Macaronesian islands (Bermejo and Mouriño, 2003; Olsen and Larson, 2004). It has also colonised some sites along the French Atlantic coast, the English Channel and some inland wetlands in central Europe (Geroudet, 1984; Yésou, 1991; Olsen and Larson, 2004). Within Iberia, the Atlantic coast hosts a resident population of more than 80,000 breeding pairs (Molina, 2009), as well as those of mostly Mediterranean origin that overwinter in this region (Galarza *et al.*, 2012).

Situated within the southeastern bay of Biscay, the Basque coast holds the most easterly colonies of the northern Iberian Atlantic yellow-legged gull population (subspecies *L. m. lusitanius*) (Olsen and Larson, 2004). The Basque colonies comprise 4,000 pairs spread between 29 breeding nuclei (Arizaga *et al.*, 2009). The yellow-legged gull within this region is resident; for example, 70% of first-year birds remain at distances < 50 km from their natal site (Arizaga *et al.*, 2010), a phenomenon promoted by the strong dependence of the colonies on locally concentrated feeding resources (Arizaga *et al.*, 2014a), mostly harbours with relatively active fisheries and a few open rubbish dumps. Between 1980 and 2000, the population was observed to increase by about. 150% (Arizaga *et al.*, 2009). Thereafter, however, the oldest and largest colonies started to decline (Arizaga *et al.*, 2009), a phenomenon confirmed post 2010 (Arizaga *et al.*, 2014b; Galarza, 2014). In parallel, the most recently created colonies (post 2000) were still growing or stable (Arizaga *et al.*, 2014b; Galarza, 2014). Such local variation could be due to several factors: variation in productivity, survival and/or breeding site fidelity (Newton, 2013).

We have studied whether there is local variation in survival of yellow-legged gulls ringed as chicks in four colonies in northern Iberia, and have then tried to find any links between survival and colony population trends and size. We expected that survival in colonies with decreasing population trends would be lower than that in stable or increasing colonies. Alternatively, colony size, and not its trend, might also drive survival. Larger colonies often promote fast food depletion at a local scale (Gaston, 2004) and hence might result in high intraspecific competition (Newton, 2013), which could lead to lower survival rates.

## MATERIAL AND METHODS

### *Sampling area and data collection*

Yellow-legged gull chicks c. 20 days old were ringed in four coastal colonies of the Basque Country (from east to west): Ulia, Santa Clara, Guetaria and Izaro (fig. 1). Demographically, Ulia and Izaro are declining and Santa Clara and Guetaria showed uncertain trends (table 1; fig. 2). Although in relative terms both Ulia and Izaro had a similar trend pattern (an annual decrease around 5%), in absolute terms Izaro lost c. 700 pairs, while Ulia lost 200 pairs (fig. 2).

During the breeding seasons of 2006 to 2013, 3,024 chicks were marked with both a metallic and a field-readable colour ring (Supplementary Electronic Material). Normally, ringing was carried out on one or a few days at each colony, so the protocol was designed to ring as many chicks as possible during the visits. All chicks were ringed in late June or early July, only under good meteorological conditions to prevent possible handling effects on nestling survival.

Our data consisted of sightings of live gulls reported by birdwatchers or by us, between August 2006 and June 2013. Sighting data were obtained from wherever these birds were found, including the colonies. Overall,

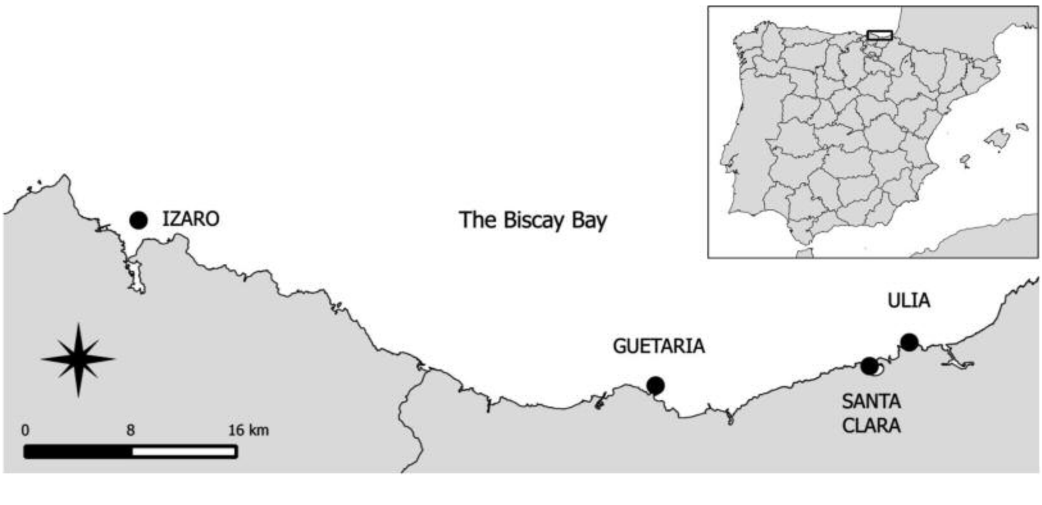


FIG. 1.—The location of the four yellow-legged gull study colonies on the Basque coast, northern Spain. Provincial limits are shown to assist colony location.
*[Localización de las colonias estudiadas, en la costa vasca, norte de España. Para facilitar la localización de las colonias se muestran los límites de provincia.]*

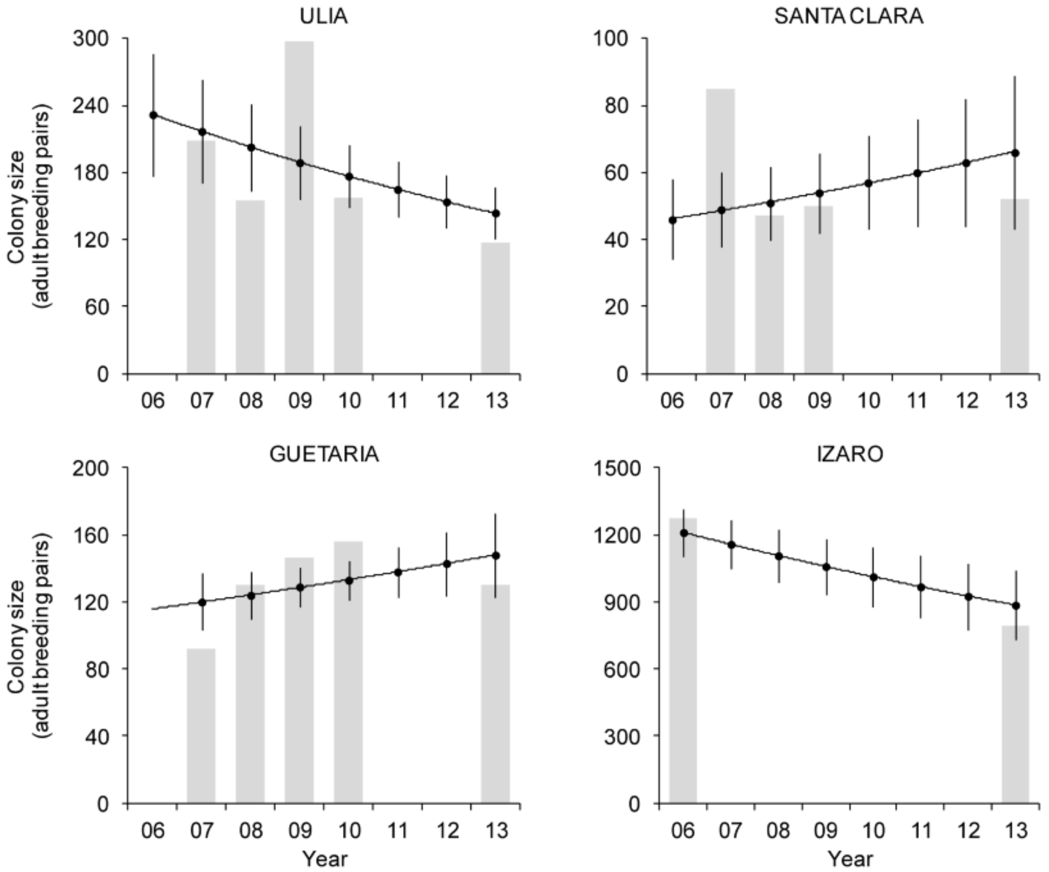


FIG. 2.—Estimate (±SE) and observed (grey bars) size of four yellow-legged gull colonies in northern Iberia.
*[Tamaño estimado (±SE) y observado (barras grises) de cada una de las cuatro colonias de gaviota patiamarilla durante el periodo de estudio.]*

we compiled 10,611 sightings relating to 1,569 individuals (Supplementary Electronic Material). Data from the few gulls (< 2%) found dead or injured were discarded.

*Capture-recapture models*

Survival was assessed using Cormack-Jolly-Seber (CJS) models (Lebreton *et al.*, 1992), which estimate survival ($\phi$; probability that a bird survives from $t$ to $t+1$) and resighting probability ($p$; probability that a bird seen at $t$ and still alive on $t+1$ is seen at $t+1$) separately.

Overall, we obtained a matrix of eight columns (years 2006 to 2013) by 3,024 rows (individuals). Each row in the matrix represents whether a certain individual was seen (1) or unseen (0) in a given year. The first "1" corresponds to the year when each individual was ringed. The m-array is shown in the Supplementary Electronic Material. We considered four groups (colonies) in this matrix.

TABLE 1

Size trends in four yellow-legged gull colonies in the Bay of Biscay (period: 2000-2013). Statistics obtained from TRIM (Pannekoek and Van Strien, 2005). The slope shows the annual change (in percentage) in colony size.
*[Tendencia en el tamaño de la población de cuatro colonias de gaviota patiamarilla en el Cantábrico (periodo: 2000-2013). Estadísticos obtenidos en TRIM (Pannekoek y Van Strien, 2005). La pendiente indica la tasa de cambio anual (en porcentaje) del tamaño de la colonia.]*

| **Colony** | **Wald[1]** | ***P*** | **Slope (±SE)** | **Trend** |
|---|---|---|---|---|
| Ulia | 9.57 | 0.002 | −6.6 ± 2.0 | Moderate decrease |
| Santa Clara | 0.85 | 0.357 | +5.2 ± 6.0 | Uncertain |
| Guetaria | 0.72 | 0.397 | +3.5 ± 4.2 | Uncertain |
| Izaro | 6.12 | 0.013 | −4.5 ± 1.8 | Moderate decrease |

[1] Wald statistics: Wald test for the significance of slope.

The fit of the data to CJS assumptions (no trap-dependence, no transients) was tested using a goodness of fit (GOF) test (Lebreton *et al*., 1992; Choquet *et al*., 2009). The U-CARE software (Choquet *et al*., 2001) was used to run the GOF directional *Z*-tests which allow us to detect departures from such assumptions. The global GOF test was significant ($\chi^2$ = 472.25, $P$ < 0.001). More specifically, we observed to have both trap-dependence (a positive effect, i.e. “trap happiness”; $Z$ = −3.14, $P$ < 0.001), and transients ($Z$ = 17.29, $P$ < 0.001). We obtained similar results for each colony when they were considered separately.

Transients could be associated with lower survival rates of first-year birds (juveniles) compared to older birds (Newton, 1998; 2013). Accordingly, we forced $\phi$ to vary between two age classes (first-year birds/older birds, represented by $\phi_{fy}$ and $\phi_{ad}$, respectively) in all the models we tested. Regarding $p$, we used CJS models with mixtures (called mixture models; Pledger *et al*., 2003) to account for the effects of individual sighting variations (all birds are not seen with the same probability) which cause a trap-dependence effect. These models incorporate a single mixture parameter (pi) in order to model the heterogeneity of $\phi$ and $p$, respectively. In our case the mixture parameter was estimated only for $p$.

Before starting to model survival rates eliminating non-significant effects we reduced the number of resighting parameters. In particular, we built a model assuming an effect of age ($\phi_{fy}$ and $\phi_{ad}$), colony of origin (c) and year (y) on $\phi$ [$\phi_{fy}$(c + y), $\phi_{ad}$(c + y)]. We tested different candidate models on $p$, considering an effect of year, colony, or year + colony (+, additive models; models with interactions between factors were not considered due to sample size limitations). [$\phi_{fy}$(c + y), $\phi_{ad}$(c + y), $p$(y)] was the model with the lowest AICc (table 2), hence we fixed $p$(y) to test for the effect of several factors on $\phi$.

Apart from checking an effect of the colony and year on $\phi$ [assuming two age categories, i.e. $\phi_{fy}$ and $\phi_{ad}$], we also tested whether alternative models considering seven age classes might fit the data better

TABLE 2

Ranking of the models tested to determine which variables affecting *p* (resighting probability) best fitted our data set. All *p* values were calculated using mixtures. Abbreviations: AICc, small sample size-corrected Akaike values; ΔAICc, difference in AICc values in relation to the first model; np, number of parameters.
*[Modelos testados para determinar las variables que influyen en p (probabilidad de avistamiento). Los valores de p se calcularon considerando "mixtures". Abreviaciones: AICc, valores Akaike corregidos para muestras de tamaño pequeño; ΔAICc, diferencia del AICc del modelo en relación al AICc del primer modelo; np, número de parámetros.]*

| Model | AICc | ΔAICc | AICc Weight | np | Deviance |
|---|---|---|---|---|---|
| 1. $\phi_{fy}$(c+y), $\phi_{ad}$(c+y), *p*(y) | 7548.17 | 0.00 | 0.84 | 67 | 633.15 |
| 2. $\phi_{fy}$(c+y), $\phi_{ad}$(c+y), *p*(y+c) | 7551.64 | 3.47 | 0.18 | 109 | 549.07 |
| 3. $\phi_{fy}$(c+y), $\phi_{ad}$(c+y), *p*(c) | 7611.30 | 63.13 | 0.00 | 57 | 716.87 |
| 4. $\phi_{fy}$(c+y), $\phi_{ad}$(c+y), *p* | 7640.79 | 92.62 | 0.00 | 54 | 752.52 |

* Factors: $\phi_{fy}$ and $\phi_{ad}$, survival varies between two age classes (first-year birds/older birds); c, colony; y, year.

(i.e., survival does not have two values, one for first-year birds and another one for older birds), but each age class (1st-year, 2nd-year, 3rd-year… birds) has its own survival rate [ϕ(7a)]. We also tested whether survival was affected by colony size. This variable was not constant over time (table 1; fig. 2), so to test for its effect on ϕ we included colony size (fig. 2) in those models that considered that ϕ varied over time (years). Finally, we also considered models assuming linear trends of survival.

Corrected Akaike values (AICc) were used to rank goodness of fit of models to data (Burnham and Anderson, 1998). Models with an AICc difference < 2 in relation to the first model were considered to fit the data equally well (Burnham and Anderson, 1998). Burnham and Anderson (1998) advise that the cut-off point mentioned above is arbitrary so they also suggest the possibility of considering larger threshold values. Within a given model, a variable was considered to have a significant effect on ϕ when the 95% confidence interval (CI) associated with the parameter estimates did not include zero. CJS models were run using MARK 7.1 (White and Burnham, 1999).

## RESULTS

Overall, 52% of the gulls ringed as chicks were seen alive during the period extending from April to September of the subsequent years. This percentage, however, differed between colonies, ranging between 36% at Izaro to 52% at Guetaria (Supplementary Electronic Material).

The model with the lowest AICc considered that survival differed between two age classes (first-year birds, older birds), colony of origin and in relation to year (table 3). Overall, survival was higher in adults than in first-year birds (table 4). Gulls from Izaro had the lowest mean survival rate for

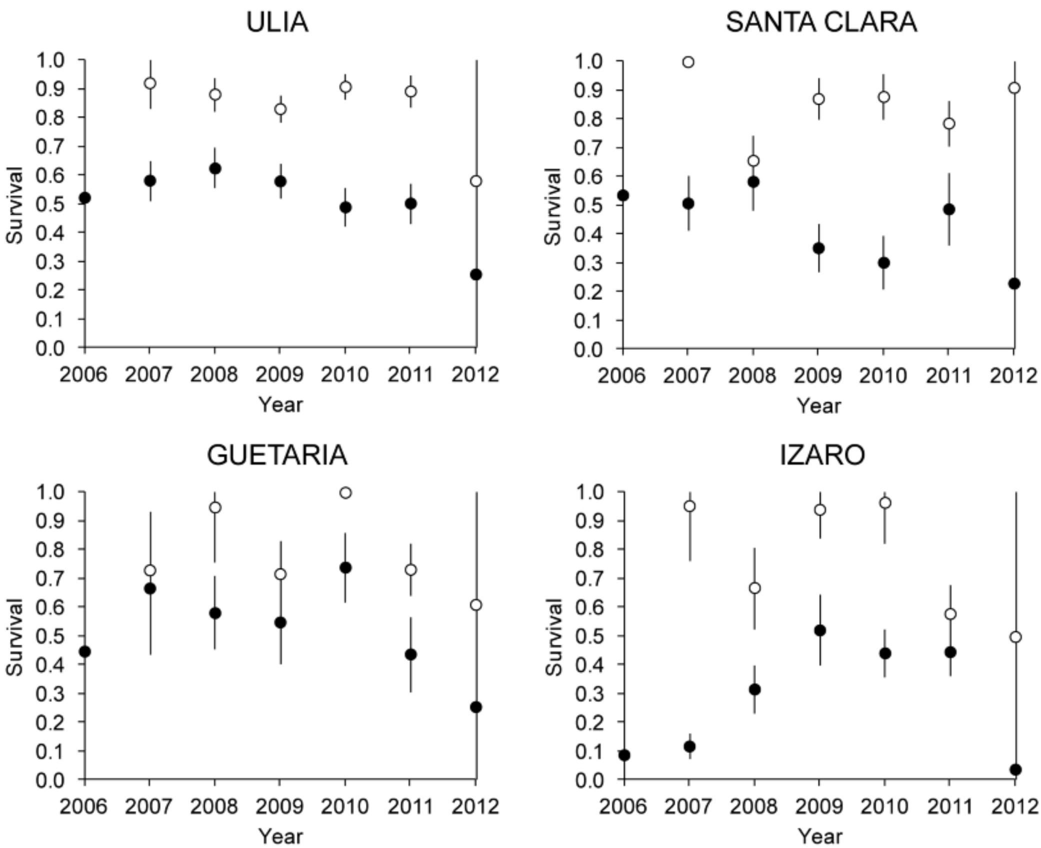


FIG. 3.—Mean (±SE) yearly survival (2006 represents survival from 2006 to 2007, and so on) of yellow-legged gulls from four colonies and in relation to age classes: dark dots, first-year birds; open dots, older birds.

*[Supervivencia anual media (±SE) (2006 representa la supervivencia de 2006 a 2007, y así sucesivamente) de gaviotas patiamarillas marcadas en cuatro colonias y su variación en relación con la edad: puntos negros, primeros años; puntos claros, aves de más de un año de vida.]*

both age classes, although if we attend to standard errors, only birds in their first year of life had lower survival rates than older birds (table 4). Survival differed from year to year for each colony and age category (table 3; fig. 3) but the best models did not support linear trends of this parameter across the study period. These year-associated variations were rather high (even > 0.3; fig. 3). There was no of an effect of colony size on survival (table 3).

## DISCUSSION

During 2006-2013 the survival of a yellow-legged gull population breeding along the coast of the southeastern Bay of Biscay varied between two age classes: first-year birds and older ones. First-year birds had lower survival rates than older birds. On average, the annual survival probability of first-year gulls was up to 0.4 points (range 0 to 1) below the rates observed in older

TABLE 3

Ranking of the models used to test the effect of several factors on survival. All models consider an effect of year on *p* [i.e., *p*(y)] with mixtures. Abbreviations: AICc, small sample size-corrected Akaike values; ΔAICc, difference in AICc values in relation to the first model; np, number of parameters. *[Modelos testados para determinar el efecto de distintas variables en la supervivencia. En cada uno de los modelos se asumió un efecto del año en p [i.e., p(y)] y "mixtures". Abreviaturas: AICc, valores Akaike corregidos para muestras de tamaño pequeño; ΔAICc, diferencia del AICc del modelo en relación al AICc del primer modelo; np, número de parámetros.]*

| Models | AICc | ΔAICc | AICc Weight | np | Deviance |
|---|---|---|---|---|---|
| 1. $\phi_{fy}$(c+y), $\phi_{ad}$(c+y) | 7548.17 | 0.00 | 0.99 | 67 | 633.15 |
| 2. $\phi$(c+y) | 7564.27 | 16.11 | 0.00 | 43 | 698.51 |
| 3. $\phi_{fy}$(c), $\phi_{ad}$(c) | 7572.37 | 24.20 | 0.00 | 23 | 747.24 |
| 4. $\phi$(7a+c) | 7585.21 | 37.04 | 0.00 | 43 | 719.45 |
| 5. $\phi$(c) | 7600.01 | 51.84 | 0.00 | 19 | 782.95 |
| 6. $\phi$(t+c) | 7612.28 | 64.11 | 0.00 | 19 | 795.23 |
| 7. $\phi_{fy}$(c), $\phi_{ad}$ | 7639.37 | 91.21 | 0.00 | 20 | 820.31 |
| 8. $\phi_{fy}$, $\phi_{ad}$(c) | 7651.74 | 103.57 | 0.00 | 20 | 832.67 |
| 9. $\phi_{fy}$(t+c), $\phi_{ad}$(c) | 7657.13 | 108.96 | 0.00 | 19 | 840.08 |
| 10. $\phi_{fy}$(t), $\phi_{ad}$ | 7667.20 | 119.03 | 0.00 | 16 | 856.20 |
| 11. $\phi$(y) | 7677.55 | 129.38 | 0.00 | 22 | 854.44 |
| 12. $\phi_{fy}$(c), $\phi_{ad}$(t+c) | 7677.75 | 129.59 | 0.00 | 19 | 860.70 |
| 13. $\phi_{fy}$(size), $\phi_{ad}$ | 7688.15 | 139.98 | 0.00 | 17 | 875.13 |
| 14. $\phi$(t) | 7688.82 | 140.65 | 0.00 | 16 | 877.82 |
| 15. $\phi_{fy}$, $\phi_{ad}$ | 7697.69 | 149.52 | 0.00 | 17 | 884.67 |
| 16. $\phi$(7a) | 7699.93 | 151.76 | 0.00 | 22 | 876.82 |
| 17. $\phi_{fy}$(y), $\phi_{ad}$(y) | 7701.38 | 153.21 | 0.00 | 28 | 866.12 |
| 18. $\phi$ | 7702.26 | 154.09 | 0.00 | 16 | 891.25 |
| 19. $\phi_{fy}$(t), $\phi_{ad}$(t) | 7716.93 | 168.76 | 0.00 | 16 | 905.92 |
| 20. $\phi_{fy}$(t+c), $\phi_{ad}$(t+c) | 7733.93 | 185.76 | 0.00 | 19 | 916.88 |
| 21. $\phi_{fy}$, $\phi_{ad}$(t) | 7758.13 | 209.96 | 0.00 | 16 | 947.13 |
| 22. $\phi$(size) | 7771.30 | 223.14 | 0.00 | 16 | 960.30 |
| 23. $\phi_{fy}$(size), $\phi_{ad}$(size) | 7826.58 | 278.41 | 0.00 | 17 | 1013.56 |
| 24. $\phi_{fy}$, $\phi_{ad}$(size) | 7836.55 | 288.39 | 0.00 | 17 | 1023.54 |

* Factors: $\phi_{fy}$, survival of first-year birds (from ringing year to the next year); $\phi_{ad}$, survival of adult birds; $\phi$(7a), each age class has a specific survival; c, colony; y, year (survival varies from year to year); t, linear year-effect on survival; size, colony size.

birds, as might be expected for inexperienced first-years when compared to older birds (Newton, 1998). However, since all were ringed as chicks, the post-fledging survival of first-years birds could have been overestimated since some pre-fledging mortality was still likely (Brouwer *et al*., 1995; Nager *et al*., 2000). The colonies were not visited after ringing and ringed dead chicks were seldom found in subsequent years, so we were unable to estimate mortality from ringing date to fledging. Overall, mean annual adult survival rates (c. 0.8) were similar to that of other closely related species (e.g., Chabrzyk and Coulson, 1976; Pons and Migot, 1995; Allard *et al*., 2006; Neubauer *et al*., 2014), and in the yellow-legged gull in particular (Brooks and Lebreton, 2001; Oro, 2008). In first-year birds, the observed survival in our colonies, Izaro excepted, was also similar to that in closely related species (Kadlec and Drury, 1968; Harris, 1970; Chabrzyk and Coulson, 1976). With a mean annual survival rate of 0.28, this survival was even lower than the 0.38 rate reported in a study of first-year herring gulls *Larus argentatus* (Paynter, 1966). Annual survival in Basque yellow-legged gull colonies is similar to that in other yellow-legged gull or closely related species' populations, except for the Izaro colony, where we found abnormally low survival rates in first-year birds. This result implies certain possible adverse conditions around this colony that should be investigated.

Survival also varied between colonies of origin, even though the colonies were situated rather close together; 60 km separated the easternmost and westernmost colonies. The yellow-legged gull within the Bay of Biscay is resident and most are associated with resources available within a 50 km radius of their natal colonies (Munilla, 1997; Arizaga *et al*., 2010). Our results would favour the idea that very local conditions may have a direct impact on yellow-legged gull demography. However, we did not find evidence supporting an effect of colony size on survival, so it is still unclear whether density-dependent processes are acting (Marvelde *et al*., 2009; Newton, 2013). The Izaro colony, of 1,500+ pairs, has been the largest in the study area until recently (Arizaga *et al*., 2009). Competition for food was/is likely to be especially high around Izaro (Gaston, 2004) and is likely to have influenced survival more dramatically than in other colonies, where populations are much lower. This effect seems to be much more marked in first-years than in older birds (table 4). This explanation, however, should be tested specifically, since we found no evidence supporting an effect of colony size on survival, so other factors that may affect the Izaro colony directly or indirectly cannot be excluded.

We also observed that survival varied from year to year. Such fluctuations, however, did not seem to fit any linear trends. Although several open rubbish dumps that were intensively used by local gulls have been closed recently (Arizaga *et al*., 2013, 2014a), a link

TABLE 4

Mean (±SE) yearly survival values for each age category and colony. Data obtained from the model one of the table 3.

*[Supervivencia interanual (media±SE) para cada edad y colonia. Datos obtenidos del primer modelo de la tabla 3.]*

| Colony | first-year birds | older birds |
|---|---|---|
| Ulia | 0.51 ± 0.05 | 0.84 ± 0.05 |
| Santa Clara | 0.43 ± 0.05 | 0.84 ± 0.05 |
| Guetaria | 0.53 ± 0.06 | 0.79 ± 0.06 |
| Izaro | 0.28 ± 0.08 | 0.77 ± 0.09 |

between closure and local survival rates remains obscure. These year-associated variations in survival may imply an unstable scenario, where local fluctuations in such parameters as food availability and competition may have major consequences on local apparent survival rates.

In conclusion, we found that apparent survival rates varied between age classes, colony of origin and year. These colony- and year-associated variations, however, were independent of colony size or linear survival trends. Further research is needed to determine which factors explain such variations, and whether the closure of open rubbish dumps is having a negative impact on yellow-legged gull survival.

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## SUPPLEMENTARY ELECTRONIC MATERIAL

Additional supporting information may be found in the online version of this article. See volume 62(1) on www.ardeola.org

**Table S1:** Number of yellow-legged gull chicks ringed and resighted.

**Table S2**: Summary of capture-recapture data for each origin colony.

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