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Pre-fledging survival in a Yellow-legged Gull *Larus michahellis* population in northern Iberia is mostly determined by hatching date

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ABSTRACT
Capsule: Pre-fledging survival in a Yellow-legged Gull *Larus michahellis* population in northern Iberia is negatively correlated to hatching date.
Aims: To explore which factors have more importance in determining the pre-fledging daily survival rates in a Yellow-legged Gull population from northern Iberia. Specifically, we tested for the effect of hatching date and order, body size and condition and meteorological conditions on pre-fledging survival.
Methods: Cormack–Jolly–Seber models with mixtures were used to model daily survival rates.
Results: Daily survival rates were mostly negatively affected by hatching date.
Conclusions: Hatching date was the most important factor affecting survival of chicks during the pre-fledging period in a Yellow-legged Gull colony from northern Iberia.

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To better understand the mechanisms underlying population dynamics of birds, it necessary to identify factors that shape survival rates at early life stages (Newton 2013). Although population dynamics in long-lived birds, such as most seabirds, are mostly determined by survival of adults (Gaston 2004, Newton 2013), abnormally high or low survival rates in young individuals might also have a relevant demographic impact (Oro *et al.* 2013). In colonial seabirds, pre-fledging survival is influenced by a broad range of factors, such as hatching date (Brouwer *et al.* 1995), clutch size and body condition (Gaston 2004). Adverse meteorological conditions, such as relatively long periods with extreme temperatures or precipitation can also have an impact on pre-fledging survival (Newton 1998).

Chicks commonly experience higher probabilities of survival when they are hatched earlier rather than later in a breeding season (Spear & Nur 1994), when they hatch first in the clutch and when they come from smaller clutches overall (Hahn 1981, Bollinger 1994, Dey *et al.* 2014, Nisbet *et al.* 2016), although eggs from larger clutches tend to have a higher probability of hatching (e.g. Reid *et al.* 2000). Furthermore, larger chicks, as well as those in a better body condition, also have better survival prospects (Moss *et al.* 1993, Arizaga *et al.* 2015), including over the long-term (Braasch *et al.* 2009). We might expect, therefore, that body condition at hatching will determine offspring survival probability during the nestling period. In addition, weather conditions during the breeding period can also have an impact on offspring survival (Bradley *et al.* 1997, Ouyang *et al.* 2015), for example, strong storms can cause high rates of chick mortality (Bonter *et al.* 2014). In this context we predict that precipitation and low temperatures could decrease the probability of survival.

The Yellow-legged Gull *Larus michahellis* is the most numerous gull found in the southwestern Palaearctic (Olsen & Larson 2004). In the past few decades, the population size has increased substantially because Yellow-legged Gulls have been able to exploit artificial food sources, such as discards from the fisheries industry or waste from open rubbish dumps (Ramos *et al.* 2009, Moreno *et al.* 2010, Arizaga *et al.* 2013). In northern Iberia, for example, such increases began during the 1980s and 1990s (Arizaga *et al.* 2009), but today the population increase has levelled off and some colonies have even started to decline (Arizaga *et al.* 2014).

The aim of this study is to explore factors that could potentially determine the pre-fledging survival probability of Yellow-legged Gulls breeding in northern Iberia. Specifically, we tested for the effect of hatching date and order, body mass and body condition and meteorological conditions on the pre-fledging survival.

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Data from this study were also used to evaluate whether survival within our population was low, similar or high in comparison to other gull species.

Methods

Study area and data collection

This study was carried out from 16 May to 24 June in 2011 at a breeding colony at Ulia (43°20′N 01°57′W, Donostia-S. Sebastián, Gipuzkoa, northern Spain), one of the main Yellow-legged Gull colonies on the Basque coast. The colony was estimated to hold approximately 500 breeding pairs (Arizaga *et al.* 2009), and although the population trend was uncertain, it was probably starting to decline (Arizaga *et al.* 2014). Survival varied from year to year, with first-year birds having a mean annual survival of 0.4–0.6, while adults had a mean annual survival of 0.8–0.9 (Juez *et al.* 2015).

The colony was visited 30 times during the survey period, from 16:00 to 20:00 h; nine other visits were suspended due to bad weather or for logistic reasons, but these did not coincide with the hatching period. We identified 39 nests in total and each was marked with a numbered metal peg. Chicks ($n = 88$) from these nests were individually identified with a combination of coloured Velcro bands until they showed sufficient tarsus growth to be ringed with a Darvic colour ring (Arizaga *et al.* 2010). The hatching period of these 88 birds coincided with the peak of hatching for nests within the colony. Hatching date (=day one), body mass (±10 g) and tarsus length (±0.1 mm) were measured for all chicks during their first or second day of hatching. Field work also consisted of searching for the marked chicks, hence we built a capture–recapture history for each bird. Apparently, levels of disturbance from the daily searches for chicks did not affect survival. We worked in a zone of the colony where chicks had access to either holes or dense vegetation, which allowed them to remain in or quite close to their hatching sites while remaining hidden from neighbouring adults that might encroach on their territories. During the study we never found dead chicks apparently killed by intra-specific aggression.

A meteorological station located 10 km from the colony (Jaizkibel mountain; Basque Agency of Meteorology) provided daily data on precipitation and temperature (mean and minimum) from 20:00 to 16:00 h of the next day. Thus, to test for the effect of meteorological conditions on survival from day t to $t+1$, we considered conditions from 20:00 h on day t to 16:00 h on day $t+1$.

Table 1. Rank of models assuming constant survival (φ) and constant and time-dependence on re-sighting probability (p) with and without mixture effects (p_m). Abbreviations: AICc, Akaike Information Criteria corrected for finite sample sizes; ΔAICc, difference in AICc between each model and the first one; np, number of parameters.

Models	AICc	ΔAICc	AICc weight	np	Deviance
φ, $p_m(t)$	1899.16	0.00	0.91	60	1772.49
φ, $p(t)$	1903.80	4.64	0.09	30	1842.15
φ, p_m	1981.73	82.57	0.00	4	1973.69
φ, p	2017.87	118.71	0.00	2	2013.86

Data analyses

Statistical analyses were carried out with U-Care 2.3.2 (Choquet *et al.* 2009) and MARK (White & Burnham 1999) programs. Daily survival was assessed with Cormack–Jolly–Seber (CJS) models, which allow the estimation of survival (φ; probability that a bird survives from t to $t+1$) and recapture probability (p; a bird that survives from t to $t+1$ is seen in $t+1$) separately.

Before starting to select models, we analysed the fit of the data to CJS assumptions. With that goal, we applied a goodness-of-fit (GOF) test on a starting CJS model where both φ and p varied with time (i.e. $\varphi(t)$, $p(t)$). The global GOF test was not significant ($\chi^2 = 108.544$, df = 138, $P = 0.960$), nor was the specific test to detect transients (P = author to correct in proof). However, we detected a trap-dependence effect ($P < 0.001$), indicating that not all chicks were detected with the same probability. This may be due to the fact that some chicks were easier to find than others, for example, those from nests situated in cavities in rocky, bare zones as compared to nests in zones with abundant tall vegetation. With the aim of accounting for this bias we used CJS models with mixtures on p (Pledger *et al.* 2003). Models with mixtures, either assuming constant (p_m) or time-dependence ($p_m(t)$) on p, fitted better to data than those without mixture effects (Table 1). Models assuming time-dependence on p were higher-ranked than models assuming constant p (Table 1). Therefore, we considered mixtures on p with time-dependence (i.e. $p_m(t)$) to test for the effect of different variables on φ.

Apart from models assuming constant or time-dependence on φ, we tested for the effect of four individual covariates: (1) hatching date, (2) tarsus length, (3) body mass and (4) body condition. Three (8%) of the nests had two eggs and the remaining 92% had three eggs, therefore we decided to not include the effect of clutch size on survival. Body condition was estimated with the residual values obtained from a regression line of body mass on tarsus length

($r = 0.244$, $F_{1,86} = 20.06$, $P < 0.01$) (Schulte-Hostedde *et al.* 2005). Moreover, we also tested for the effect of hatching order with three categories: first hatched chick, second or third hatched chick, or unknown (in some nests the first two chicks hatched within an interval of less than 24 hours). Finally, we also tested for the effect of meteorological conditions on survival. To test this, we added the daily values of precipitation, mean temperature and minimum temperature to models, assuming time-dependence on φ. We considered both single-factor and combinations of maximum three factors in additive models. Interactions were not considered due to sample size limitation. Overall, we tested 28 models.

Models with a difference in Akaike Information Criteria corrected for finite sample size (ΔAICc) less than 2 were considered to fit to the data equally well, and those with AICc > 2 were considered to fit to the data less well (Burnham & Anderson 1998). Because models with additional unsupported parameters will be likely to be within two AICc units and these models were non-competitive unless the extra parameter leads to a reduction in AICc (Arnold 2010), we analysed in detail the *B*-parameters from all models having an ΔAICc < 2 from the top model to check if the parameters affected φ. Parameters with a 95% confidence interval including zero showed a non-significant effect of the factor/covariate on φ (Taylor *et al.* 2004). Model averaging was carried out in order to obtain consensus parameter estimates. We only averaged models having a ΔAICc < 2 from the top model.

Results

Overall, the chicks had a mean tarsus length of 25.0 mm (se = 1.5 mm, range = 21.4–29.0 mm) and mean body mass of 59.2 g (se = 7.0 g, range = 40–75 g). There were 56 (63.6%) birds for which we were able to assess their hatching order. All chicks hatched between the sampling day 2 and 10 (mean ± se = 5.8 ± 0.2 days; day one = 16 May). It rained 9 days out of the 40 sampling days, and the means of the mean and minimum daily temperature were 13.9°C and 11.3°C, respectively.

Three models were observed to fit to the data equally well, and better than the rest (Table 2). Overall, three variables were included in these first models, though not all of them had the same weight (Figure 1). Thus, hatching date was the only variable included in all the models (Figure 1). A detailed look at the *B*-parameters revealed that only hatching date showed a significant effect on φ (Table 3).

Averaged survival values in relation to the hatching day showed decreasing survival rates for those chicks hatching late (Figure 2). Body mass and condition had a positive effect on survival (Figure 3), although this effect was not statistically significant, mostly due to the high variance associated with survival values of those chicks with either lower body mass or poorer condition.

The cumulative survival values within a period of 40 days after hatching of chicks hatching on day 1 was approximately 0.65, whilst for chicks hatching on day 9 was approximately 0.15 (Figure 4).

Discussion

This is one of the few studies aiming to determine the influence of multiple factors on the pre-fledging survival in a Yellow-legged Gull colony. Our results support the hypothesis that survival is mostly affected by hatching date.

Chicks hatching later had daily survival rates approximately 2% lower than those hatching early. For the entire nestling period, this difference resulted in a cumulative survival of approximately 0.65 for the chicks hatching early and approximately 0.15 for those hatching late in the season. This last value is among the lowest survival values registered for the genus *Larus* (Brouwer *et al.* 1995, Kim & Monaghan 2006,

Table 2. Ranking of the best models used to assess the effect of several factors on the pre-fledging daily survival rates (φ) of Yellow-legged Gull chicks in a colony of northern Iberia. Abbreviations: AICc, Akaike Information Criteria corrected for finite sample sizes; ΔAICc, difference in AICc between each model and the first one; np, number of parameters; date is hatching date; mass is body mass; residual is mass-size residual (body condition). All models were built using time-dependence on re-sighting probability with mixtures (for details see Table 1).

Models	AICc	ΔAICc	AICc weight	Np	Deviance
1. φ (date + mass)	1885.17	0.00	0.34	62	1754.04
2. φ (date + residual)	1885.66	0.48	0.27	62	1754.52
3. φ (date)	1885.77	0.60	0.25	61	1756.87

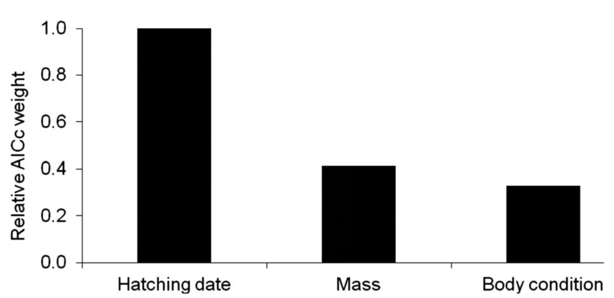

Figure 1. Relative AICc weight of those variables which were included in the best five CJS models (for details see Table 2) used to estimate daily survival rates of Yellow-legged Gull chicks.

Table 3. *B*-parameter estimates obtained from the models 1–3 of Table 2. Logit function, the 95% confidence interval is provided in parentheses and below that the standard error. Confidence intervals including zero indicate that the parameter did not have a significant effect on survival.

Factor	Model 1	Model 2	Model 3
Date	−0.20 (−0.35, −0.05) 0.07	−0.19 (−0.33, −0.05) 0.07	−0.18 (−0.32, −0.038) 0.07
Mass	+0.04 (−0.01, 0.08) 0.22		
Residual		+0.04 (−0.01, 0.09) 0.26	

Bogdanova *et al.* 2007). However, most of our birds were found to hatch early within the season (only 8 out of the 88 chicks hatched during the last two days, i.e. days 9 and 10), therefore, the negative impact of hatching late would be small within the population. Thus, it can be concluded that survival in our colony was within the range found for other white-headed large gull colonies.

The decreasing survival in late hatching chicks is a relatively well-documented phenomenon in colonial seabirds (e.g. Brouwer *et al.* 1995, but see Viñuela *et al.* 1996). Factors explaining this effect are diverse and are likely to vary in relation to several other factors, including site and year (Harris *et al.* 1992). Since our study was carried out using a descriptive, exploratory approach, we cannot determine which drivers could explain our results but we can provide some potential explanations. Adults that breed earlier in the season tend to be those with more experience which consequently have better breeding success (Bogdanova *et al.* 2007). Therefore, chicks hatching earlier in the season have better survival. Alternatively, or additionally, chicks hatching late in the season may be exposed to more deteriorated sanitary conditions within the colony (Rifkin *et al.* 2012) or to higher rates of inter- or intra-specific predation (Hunt & Hunt 1976). After hundreds of hours of visual surveys within the colony to search for ringed adults, we have never seen intra-specific predation, and the level of aggression of adults to neighbouring chicks is low, hence this is a factor that can be rejected. Additional explanatory factors are possible too, including weather effects. Normally, chicks suffer higher mortality during the first days after hatching (Bogdanova *et al.* 2007), so particularly bad conditions during such first days could have a strong, negative impact on survival. The period in which this study was conducted featured mild temperatures with no precipitation interrupted by periodic, subsequent fronts that were characterized by descending temperatures (up to −4°C below the mean) and precipitation (Figure 5). The first front of this sampling period occurred on the 10th day, that is, just one day after the hatching of the last chicks. Again there was a new front on the 15th day, so late hatching chicks suffered worse weather during their most vulnerable days. Thus, we should not ignore a possible effect of meteorological conditions on survival of late chicks.

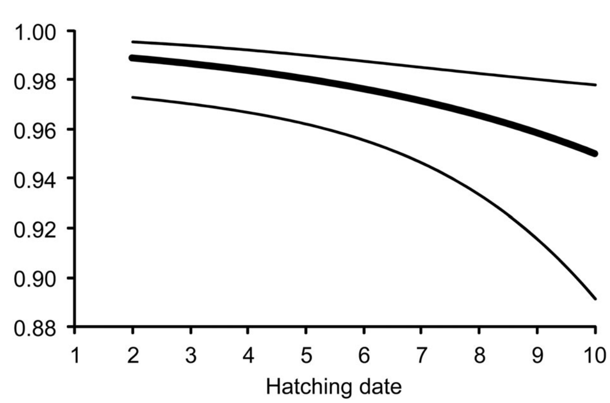

Figure 2. Daily survival rate (mean ± 95% confidence interval) in relation to the hatching day (day 1: 16 May) of Yellow-legged Gull chicks from a colony of northern Iberia in 2011. Values were obtained after averaging models 1–3 from Table 2.

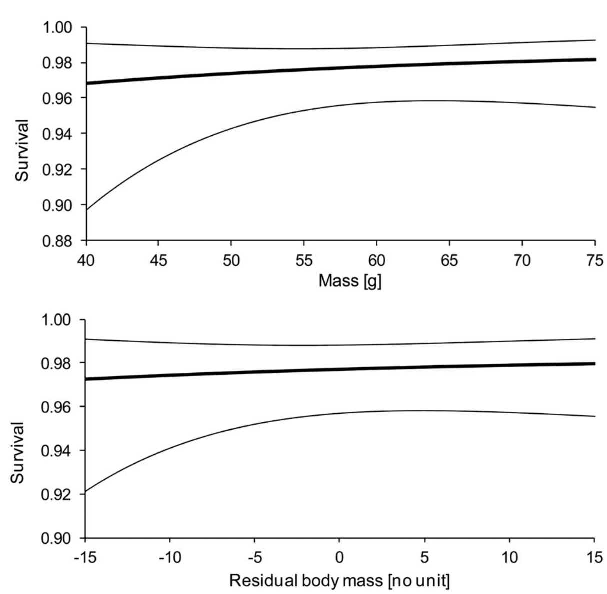

Figure 3. Daily survival rate (mean ± 95% confidence interval) of Yellow-legged Gull chicks in relation to (a) body mass or (b) body condition at hatching. Values were obtained after averaging models 1–3 from Table 2.

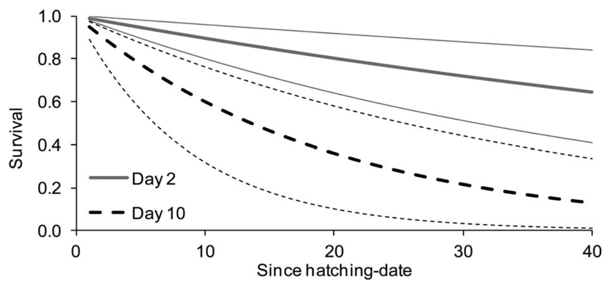

Figure 4. Accumulated survival rate (mean ± 95% confidence interval) of Yellow-legged Gull chicks in relation to hatching date. Chicks hatched on day 2 are represented with a grey line (thin solid line was its 95% CI) and the bold dashed line (thin dashed line was its 95% CI) represents chicks hatched on day 10.

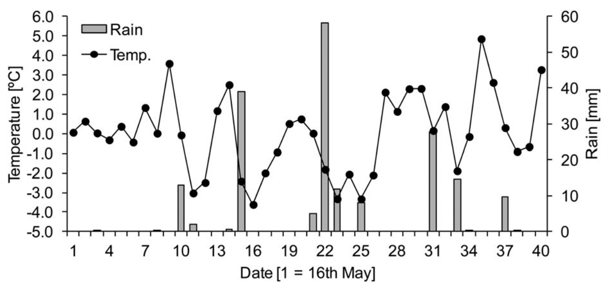

Figure 5. Variation in mean temperatures (°C) and total amount precipitation (mm) registered nearby the colony during the breeding season in 2011.

The best models also included a marginal, positive impact of hatching body condition on survival, suggesting to some extent a long-term effect of this factor on survival (Arizaga *et al.* 2015). However, a detailed analysis of this effect showed that chicks in better condition showed invariably relatively high daily survival rates, whereas chicks with poorer body condition had either high or low daily survival rates (Figure 3). This result suggests that poor physical condition was not a determinant of survival.

In conclusion, we observed that daily survival rates for Yellow-legged Gull chicks in a colony in northern Iberia were lower for later hatching chicks. Future research should explore: (1) how potential causal factors vary in order to explain pre-fledging survival in relation to year and (2) the ultimate causes explaining the impact of hatching date on survival.

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