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Assessing the impact of colour-ring codes on parameter estimates from Cormack–Jolly–Seber models: a test with the Yellow-legged Gull (*Larus michahellis*)

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Abstract The type of ring (i.e. its colour combination: the colour of the alphanumeric characters and the base colour of the ring) used in population dynamics studies could have an effect on parameters such as resighting probability (p); for instance, we might expect a lower p value when using rings with white characters than when using rings with dark characters. We performed an experiment using two types of colour rings (white or black characters on a dark base) in Yellow-legged Gulls in order to test our hypothesis. To do this, we used Cormack–Jolly–Seber (CJS) models incorporating variation in p among the birds. We obtained no evidence supporting an effect of type of ring on either survival or p .

Keywords Birdwatching · Colour ring · Cormack–Jolly–Seber models · Ringing · MARK software

Zusammenfassung

Der Einfluss von Farbring-Codes auf Parameterschätzungen mittels Cormack-Jolly-Seber Modellen: ein Experiment mit Mittelmeermöwen (*Larus michahellis*)

Der Ringtyp (Farbringkombinationen aus alphanumerischen Kodierungen und der Grundfarbe des Ringes), der

in Studien zur Populationsdynamik benutzt wird, könnte einen Einfluss auf Bestimmungsgrößen wie die Wiederfundwahrscheinlichkeit (p) haben. Deshalb würden wir einen geringeren p -Wert für Ringe mit weißen Buchstaben erwarten als für Ringe mit dunklen Buchstaben. Wir führten ein Experiment an Mittelmeermöwen durch, bei dem wir zwei verschiedene Typen von Farbringen (weiße und schwarzen Buchstaben auf einer dunklen Grundfarbe benutzten, um unsere Hypothese zu testen. Dafür wendeten wir Cormack–Jolly–Seber (CJS) Modelle mit verschiedenen p -Werten an. Wir können keinen Nachweis liefern für einen Effekt des Ringtyps weder auf die Überlebensrate noch auf die Wiederfundwahrscheinlichkeit.

Introduction

Bird individualization through ringing or other types of marks that are designed to be read at distance is one of the most commonly used tools in avian research. For instance, bird ringing is crucial in population dynamics studies where capture–recapture models are applied (Siriwardena et al. 1998; Peach et al. 1999; Aradis et al. 2008; Robinson et al. 2008).

The generalization of the use of colour rings or other marks to be read at distance has improved our capacity to estimate parameters associated with population dynamics (Lebreton et al. 1992; Pradel et al. 1997; Papadatou et al. 2012). A notable portion of the data used in models of population dynamics is based on data reported by birdwatchers (e.g. Tavecchia et al. 2001; Juez et al. 2015).

It is important to know whether some types of marks are easier to read than others in order to optimize the efficiency of field work. It is a frequent claim among birdwatchers that dark rings with clear characters are more difficult to

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read than clear rings with dark characters (pers. comm.). This may be due to a lower contrast between the colour of the ring and the colour of the alphanumeric characters, or the fact that clear characters often become filled with dirt, making them really hard to read at distance.

The effect of the type of ring (i.e. its colour combination: the colour of its alphanumeric characters and the base colour of the ring) on parameter estimates of capture–recapture models has, to our knowledge, never been tested. In theory, estimates of survival should not be affected by the particular colour combination used in a ring, only the estimated resighting probability, p (Lebreton et al. 1992). However, according to experienced birdwatchers, a lower p value can be expected when using rings with white characters than when using rings with dark characters. Thus, the type of ring used could affect survival estimation (or other parameters which are estimated) if the model fitted assumes that p does not vary among different types of rings.

Therefore, in this paper, we report an experiment we performed using two types (colour combinations) of colour rings in order to test for an effect of ring type on the parameters obtained from Cormack–Jolly–Seber (CJS) models. If the type of ring has an effect, we expected that it would influence the estimated p value but not survival.

Materials and methods

Model species

The Yellow-legged Gull is the most abundant gull of the southwestern Palaearctic (Olsen and Larson 2004). It is distributed across the circum-Mediterranean region, Iberia and the Macaronesian islands (Bermejo and Mouriño 2003; Olsen and Larson 2004). Moreover, the species has also colonized some regions along the coast of France, 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), aside from the gulls of mostly Mediterranean origin that overwinter within this region (Galarza et al. 2012).

Study area and data collection

Gulls were ringed as chicks in three colonies situated along the coast of the southeastern Bay of Biscay, within the Basque region, in northern Iberia (from east to west): Ulia (43.34°N, 01.96°W), Lekeitio (43.36°N, 02.50°W) and P. Lucero (43.36°N, 03.11°W). These colonies host, respectively, ca. 500, 1200 and 50 breeding pairs (Arizaga et al. 2009).

We ringed 198 chicks in 2012 when they were ca. 20–25 days old with a metallic, engraved colour ring (Cantos 2000). In each colony, we tried to ring equal numbers of chicks with the two types of rings used in our experiment: (1) an orange ring with four dark (black) characters, and (2) a red ring with four clear (white) characters. The two types of rings had characters of a similar form and size (font size 10 × 5 mm; font width 1 mm). We used both numbers and letters to create unique character combinations.

Ringling was carried out in just one or a few days at each colony, so the protocol was designed to enable the ringling of as many chicks as possible during the visits. All chicks were ringed in late June and the beginning of July and only under good meteorological conditions in order to prevent possible handling effects on nestling survival. Sighting data on alive gulls, reported by birdwatchers or by us, were compiled from August 2012 to June 2014. Sighting data were obtained from wherever these birds were seen. Overall, we compiled data on 569 sightings relating to 150 individuals (Table 1).

Capture–recapture models

We used Cormack–Jolly–Serber (CJS) models to estimate survival, which allowed us to separately estimate survival (ϕ , the probability that a bird survives during the period from t to $t + 1$) and p (the probability that a bird still alive at $t + 1$ is seen at $t + 1$) (Lebreton et al. 1992).

We sampled monthly for 2 years, so we obtained a matrix of 24 columns (12 months from June/July of a ringling year to June of the next one) by 198 rows (individuals). Each individual gull was also assigned to one of six factors corresponding to the six colony and ring-type combinations (3 colonies × 2 ring types). Thus, we considered six groups.

Table 1 The number of Yellow-legged Gulls ringed (as chicks) with each type of ring at each colony, the number of gulls seen alive during the subsequent 24 months, and the number of sightings obtained overall (many gulls were seen more than once)

Colony/ring	Ringed	Seen (alive)	Sightings
Ulia			
White letters	50	31 (62.0 %)	164
Black letters	48	32 (66.7 %)	209
Lekeitio			
White letters	31	18 (58.1 %)	57
Black letters	30	14 (46.7 %)	62
P. Lucero			
White letters	19	13 (68.4 %)	40
Black letters	20	16 (80.0 %)	37

Before starting to select models, we explored the fit of the data to CJS assumptions using a goodness-of-fit (GOF) test (Choquet et al. 2009). CJS models assume that all marked individuals have the same probability of recapture and survival from time t to $t + 1$ (i.e. no trap dependence, no transients). The U-CARE software (Choquet et al. 2009) was used to run the GOF global test, which did not indicate significance ($\chi^2 = 82.009$, $p = 0.999$, $df = 142$). The specific test to detect transients could not be calculated as all of the birds were marked within a single time unit (the first one in the series, corresponding to June/July of 2012). We detected a trap happiness effect ($Z = -3.537$, $p < 0.001$), indicating unequal detectability among individual gulls. This is likely to be caused by the fact that the sampling effort was not uniformly spatially distributed, so gulls visiting sites associated with a higher sampling effort were more likely to be detected (i.e. they provided a higher number of sightings). CJS models were then run in software MARK 6.2 (White and Burnham 1999).

Regarding ϕ , we tried to reduce the number of models to be tested given that we were interested in models in p . Hence, we only considered combinations that assumed effects of ring type and age. The latter effect was tested due to the fact that survival during the first weeks after the ringing date (ϕ_1) is expected to be lower than the month-to-month survival later on (ϕ_2) (Juez et al. 2015). Models assuming age dependence (ϕ_1 , ϕ_2) were nested within [ϕ (time)], as they could be created by setting ϕ_2 parameters equal. Within our data set, where all gulls belonged to a same cohort (all birds were ringed as chicks in 2012), the effects of age and time could not be distinguished. However, even in this case, models assuming two age categories (ϕ_1 , ϕ_2) fit the data better than models with time dependence (Juez et al. 2015). For p , we considered all possible single or additive combinations assuming an effect of ring type or time, both with and without the effects of mixtures of p values. We used CJS models with mixtures of p values

to account for the effects of interindividual variations in detectability (not all birds are seen with the same probability). These models included a mixture parameter (p_i) in order to account for two groups of birds with a lower and a higher p , respectively (Pledger et al. 2003).

Overall, we tested 16 models. We used Akaike values corrected for small sample sizes (AICc) to rank how well the models fitted to the data (Burnham and Anderson 1998). Models with an AICc difference of <2 were considered to fit the data equally well, and those for which the difference was >2 were considered to fit to the data less well. CJS models were run in the software MARK 6.2 (White and Burnham 1999), using the sin-link function.

Results

Overall, a high proportion (62.6 %) of the 198 Yellow-legged Gulls ringed as chicks were seen during the subsequent 24 months. The ring type did not influence the proportion of the ringed gulls that were seen later ($\chi^2 = 0.914$, $p = 0.386$, $df = 1$). Similarly, the number of sightings in relation to the number of gulls ringed did not vary according to the type of ring ($\chi^2 = 1.267$, $p = 0.283$, $df = 1$).

One model was observed to fit the data better than the rest (Table 2). This included effects of age on survival and mixture on p , which also was time dependent (i.e. p varied from month to month). Accordingly, we did not obtain any evidence supporting an effect of ring type on either ϕ or p . Models assuming an effect of ring type on p were ranked lower than those that only assumed a dependence of p on time. Thus, the model [ϕ_1 , ϕ_2 , $p_m(\text{ring})$; $p_m = p$ with mixtures] showed an AICc of 2352.78, while the model [ϕ_1 , ϕ_2 , $p_m(\text{time})$] showed an AICc of 2290.33. A third model assuming an additive effect of both factors on p [ϕ_1 , ϕ_2 , $p_m(\text{ring} + \text{time})$] was also ranked lower (AICc:

Table 2 Ranking the best ten models used to test for the effects of several factors on survival (ϕ : ϕ_1 is the survival between the ringing date at the end of June/July 2012 and August 2012; ϕ_2 is the constant monthly survival for the subsequent months) and resighting with (p_m) or without (p) mixture effects

Models	AICc	Δ AICc	AICc weight	np	Deviance
1. ϕ_1 , ϕ_2 , $p_m(\text{time})$	2290.33	0.00	0.91	49	1209.71
2. $\phi_1(\text{ring})$, $\phi_2(\text{ring})$, $p_m(\text{time})$	2295.07	4.74	0.09	51	1209.68
3. ϕ_1 , ϕ_2 , $p(\text{time})$	2310.18	19.84	0.00	25	1284.21
4. $\phi_1(\text{ring})$, $\phi_2(\text{ring})$, $p(\text{time})$	2314.51	24.18	0.00	27	1284.17
5. ϕ_1 , ϕ_2 , $p(\text{ring} + \text{time})$	2330.88	40.55	0.00	48	1252.64
6. $\phi_1(\text{ring})$, $\phi_2(\text{ring})$, $p(\text{ring} + \text{time})$	2335.15	44.81	0.00	50	1252.15
7. ϕ_1 , ϕ_2 , p_m	2351.47	61.13	0.00	5	1367.67
8. ϕ_1 , ϕ_2 , $p_m(\text{ring})$	2352.78	62.45	0.00	7	1364.90
9. $\phi_1(\text{ring})$, $\phi_2(\text{ring})$, p_m	2335.52	65.19	0.00	7	1367.64
10. $\phi_1(\text{ring})$, $\phi_2(\text{ring})$, $p_m(\text{ring})$	2356.38	66.04	0.00	9	1364.38

AICc Akaike values corrected for small sample sizes, Δ AICc difference in AICc values in relation to the first model, np number of parameters, $time$ time dependence (i.e. survival varies depending on the month)

2380.54) than the time-dependent model. Models with no mixtures were still ranked lower than those with mixtures. Thus, the model [ϕ_1 , ϕ_2 , $p(\text{ring})$] showed an AICc of 2386.36. According to model 1, survival (\pm SE) from the ringing date (late June or July) to August was 0.81 ± 0.06 , whereas monthly survival during subsequent months was 0.94 ± 0.01 . The 46 estimated p values were found to range from 0.07 ± 0.06 to 0.31 ± 0.07 .

Discussion

Using Cormack–Jolly–Seber models that accounted for variations in the resighting probability (p) among the birds, we obtained no evidence of an effect of ring type (i.e. colour combination used on the ring) on either survival or p . Even though colour rings with black characters are often thought to be easier to read at distance than those with clear characters and a dark background, our results suggest that this bias has a negligible effect on parameter estimates from CJS models.

The heterogeneity in p was probably sufficiently high to obscure any other factors that also affect this parameter, possibly including the type of ring used. For instance, some birdwatchers could be better at reading certain types of rings, while other birdwatchers could be better at reading other types of rings, so when all birdwatchers are considered together, no ring type is significantly favored in terms of readability. Moreover, some gulls are seen more frequently than others, as they visit areas close to birdwatching points (Juez et al. 2015). This causes a heterogeneity in p which is probably (as suggested in this work) of a greater magnitude than a possible effect of the type of ring on p . In this scenario, the use of different colour rings in studies, especially those relating to large-scale monitoring programs where several types of colour-ring combinations can be used, should not lead to any statistical problems. If possible, however, we recommend testing for the effect of ring type on p by adding this alternative model to the original one when utilizing CJS models.

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