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# Breeding biology and prey availability in the White-throated Dipper in Northern Iberia

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The breeding biology of a White-throated Dipper *Cinclus cinclus* population in the Atlantic region of the Iberian Peninsula was studied. Breeding was monitored in February–May 2015 at 215 nest-boxes and naturally occurring nests along 28 rivers in the five main river basins (Oiartzun, Urumea, Igara, Oria and Urola) in Gipuzkoa (N Spain). Of the 65 recorded nesting attempts, the average laying date was late March, average (±SD) clutch size was 4.3 ± 0.8 eggs, average productivity was 3.8 ± 1.0 chicks, and breeding success was 72%. In 18.5% of nest boxes, there were second clutches. The causes of nesting failure included predation, human disturbance and flooding. In 22 randomly selected occupied nest-boxes, we also studied the effect of food availability on breeding performance by assessing the macroinvertebrate communities in the nesting territories. The amount of macroinvertebrates had no significant effect on clutch size or productivity. Compared to other European populations, Dippers in Gipuzkoa had smaller clutches, which was compensated for by greater breeding success. This suggests that this population breeds in a relatively favourable environment that allows for higher survival rates, thereby reducing pressure on offspring clutch size.

Key words: Dipper, *Cinclus cinclus*, reproduction, clutch size, laying date, food availability, Gipuzkoa.

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Dippers (*Cinclus* spp.) occupy fast-flowing rivers on five continents (Voelker 2002) and feed chiefly on aquatic macroinvertebrates (Cramp 1988). In Europe, the White-throated Dipper *Cinclus cinclus* (hereafter, Dipper) is found across much of the mainland and on some of the larger islands (Hagemeijer & Blair 1997); in Iberia, it occupies the northern part of the peninsula and the main mountain ranges in the southern half (López *et al*. 2003).

The Dipper is found in ecologically well-preserved rivers and so is regarded as a good bioindicator (Ormerod & Tyler 1993). Thus, its presence and breeding performance are proxies for the quality of riparian habitats. Apart from some general descriptive works on breeding biology (reviewed in Tyler & Ormerod 1994), little has ever been published on the effects of food availability on breeding parameters in Dippers (Tyler & Ormerod 1992). Reduced foraging resources during the breeding season may affect aspects of breeding performances and a lack of food may lead to smaller clutch sizes and/or affect the number of fledged chicks (i.e. productivity) given nestling competition for food. Accordingly, food availability at nesting sites should be positively correlated with clutch size and/or productivity (Tyler & Ormerod 1992).

The rivers in northern Iberia from the eastern Pyrenees to Galicia harbour the largest Dipper population in the peninsula and one of the best preserved such populations in southern Europe

(Tucker & Heath 2004). However, the Dipper is one of the European passerines that will potentially be most affected by global change, above all in southern Europe (Huntley *et al.* 2007) where annual precipitation rates are expected to fall (Sánchez *et al.* 2017). It is important to assess how the factors driving current population dynamics including breeding parameters might change in the future, which will allow us to better understand the impact of climate change-associated mechanisms on bird populations.

The aim of the present study was thus to (1) describe in detail the Dipper's breeding biology in an Atlantic region in northern Iberia and (2) determine the influence of food availability on breeding parameters. This study was focused on Gipuzkoa, a province in northern Iberia whose Dipper population was monitored during two breeding seasons.

## Materials and Methods

### *Study area and data collection*

This study was carried out in the province of Gipuzkoa (N Spain), a very mountainous area (1,900 km$^2$) with a temperate oceanic climate (Köppen classification Cfb) and average annual precipitation of ca. 1,500 mm. The main rivers run south to north into the Bay of Biscay (average length 60 km) and have an average flow rate of 16 m$^3$/s. Dippers occupy the upper stretches of these rivers and their tributaries (Aierbe *et al.* 2001).

From November 2013 to February 2014, 215 Dipper nest-boxes were installed along 28 rivers in the province's main river basins (from east to west): Oiartzun (2 rivers), Urumea (7), Igara (1), Oria (12) and Urola (6).

Two nest-box sizes (30×30×30 and 20×22×20 cm) were installed indistinctly in all rivers and both types were occupied by Dippers (J. M. Sánchez, pers. obs.). However, the 20×22×20 cm box was easier to handle and install. Boxes were made of wood and had an open front. They were placed normally under bridges and always above the water line. The number of nest boxes surveyed per river basin was as follows: Oiartzun, 14; Urumea, 35; Igara, 6; Oria, 62; and Urola, 33.

Nest-boxes were monitored from February to the end of May (breeding period) in 2014 and 2015. Additionally, breeding was also monitored at natural nests in the same rivers. These latter nests were found by chance during nest-box monitoring. We decided to include them in our analyses to obtain a larger sample size. The following data were recorded at each nest site: (1) occupation or not by Dippers; (2) laying date of the first egg; (3) clutch size; (4) clutch order (first or second clutch); and (5) productivity (number of fledglings from a nest). The breeding success was determined as the proportion of nests where at least one chick fledged. Failed clutches were examined to assess the causes. From the end of February onwards, nest-boxes were surveyed at four-day intervals until the nest was occupied and the eggs laid. However, we were sometimes unable to follow this protocol (e.g. adverse weather) and so we determined the laying date on a weekly rather than a daily basis. Once a nest was occupied and the eggs laid, we visited it 20 days later to check for the presence of chicks. If at 20 days there were no chicks (failed clutch), we then

**Table 1**. Annual sample sizes used for breeding parameter estimates in Dippers breeding in either box or non-box nests. Only first clutches are considered.
*Nombre de nius, tant en caixes com naturals, emprats per calcular els paràmetres reproductors de la merla d'aigua. Només s'han tingut en compte les primeres postes.*

| | **Box nests** *Nius en caixa* | | **Non-box nests** *Nius naturals* | |
|---|---|---|---|---|
| | **2014** | **2015** | **2014** | **2015** |
| Breeding attempts / *Intent de cria* | 12 | 21 | 8 | 10 |
| Laying date / *Data de posta* | 8 | 11 | 7 | 3 |
| Clutch size / *Mida posta* | 7 | 20 | 7 | 7 |
| Productivity / *Productivitat* | 11 | 20 | 8 | 9 |
| Breeding success / *Èxit reproductiu* | 10 | 14 | 4 | 8 |

began to monitor it again at four-day intervals. If chicks were present, the nest was then visited 10 days later, which approximately coincided with the fledging date, to ring nestlings. The nest-boxes were revised using a Rigid™ device with a camera at the end of a flexible 90-cm arm.

We randomly selected 22 occupied nest-boxes to model the effect of food availability on breeding performance. Food availability was assessed by sampling the macroinvertebrate community at eight random points on a 500-m transect along the river (±250 m upstream and ±250 m downstream from the nest). Macroinvertebrates were sampled using a 25×25-cm Surber net and stored in a >80% ethanol dilution. In the laboratory, the samples were cleaned with tap water and dried at 50°C for 24 h. Finally, they were weighed in a balance (±0.01 g accuracy) to obtain the dry weight. The average dry weight of the eight sampling points in each territory was used as a surrogate for food availability.

**Table 2.** Breeding parameters in European Dipper populations. SD = standard deviation.
*Paràmetres reproductius de les poblacions de merla d'aigua europees. SD = Desviació tipus.*

| **Region**<br>***Regió*** | **Clutch size**<br>***Mida posta***<br>**Mean ± SD (n)**<br>***Mitja ± SD (n)*** | **Breeding success**<br>***Èxit reproductiu***<br>**%** | ***Second clutch***<br>***Segones postes***<br>**% (n)** | **Source**<br>***Font*** |
|---|---|---|---|---|
| **N. Europe** | | | | |
| Norway | 5.1 ± 0.7 (72) | 50.6 | Up to 65 (62) | (Efteland & Kyllingstad 1984) |
| **E. Europe** | | | | |
| Poland | 4.9 ± 0.6 (44) | | | (Czapulak *et al.* 1988) |
| Czechoslovakia | 4.7 (46) | 50.6 | 14.3 (35) | (Balát 1964) |
| Austria | 4.8 (33) | | | (Wagner 1985) |
| | 4.7 (27) | 65.5 | 39.0 (27) | (Priemetzhofer 1987) |
| | 4.5 ± 1.1 (49) | | 15.9 (63) | (Sackl & Dick 1988) |
| **Central Europe** | | | | |
| Germany | 5.1 (37) | | 23.0 (37) | (Ristow 1968) |
| | 5.0 (179) | | 38.0 (179) | (Rockenbauch 1985) |
| | 4.8 (88) | 80.4 | 11.8 (85) | (Zang 1981) |
| | 4.7 (180) | 68.4 | 49.0 (142) | (Schmid 1985) |
| | 4.6 (9) | | | (Haensel 1977) |
| | 4.3 (29) | | 10.3 (29) | (Steffens & Sturm 1978) |
| | 5.4 (39) | | | (Baake 1982) |
| Switzerland | 4.9 ± 0.6 (87) | 56.0 | 15.3 (150) | (Breitenmoser-Wursten 1988) |
| **Britain & Ireland** | | | | |
| Britain | 4.4 (705) | 51.4 | | (Shaw 1978) |
| Ireland | 4.2 ± 0.6 (467) | | 8.2 (466) | (Smiddy *et al.* 1995) |
| Scotland | 3.4 (9) | | | (Hewson 1967) |
| | 4.5 ± 0.8 (74) | | 32.8 (55) | (Hardy *et al.* 1978) |
| | 4.6 ± 0.7 (378) | | 19.3 (296) | (Wilson 1996) |
| | 4.6 (154) | | 6.3 (159) | (Newton 1989) |
| England | 4.8 (65) | 68.5 | | (Mawby 1961) |
| | 4.2 ± 1.0 (45) | 68.4 | 20.3 (69) | (Robson 1956) |
| | 4.3 (26) | 61.6 | | (Shooter 1970) |
| | 4.3 ± 1.0 (38) | | | (Tyler & Ormerod 1985) |
| Wales | 4.8 ± 0.6 (222) | | 19.4 (403) | (Tyler & Ormerod 1985) |
| | 4.4 ± 0.6 (25) | | | (Tyler & Ormerod 1985) |
| **Iberia** | | | | |
| Gipuzkoa* | 4.3 ± 0.8 (41) | 72.0 | 18.5 (65) | This study |
| Navarra | 4.8 ± 0.6 (117) | 71.2 | | (Esteban & Campos 1993/1994) |
| Catalonia | 4.7 (28) | | | (Mestre 1980) |

### *Statistical analyses*

Occupied nest-boxes without any sign of reproduction (i.e. neither eggs nor chicks) were excluded from the analyses. We took into account both nests in boxes and naturally occurring nests (hereafter, 'box' and 'non-box' nests).

Breeding parameter estimates were calculated, and data from 2014 and 2015 and from both box and non-box nests were compared using Generalized Linear Mixed Models (with year and type of nest as factor and the code of each nest – i.e. territory – as random factor since some nests were surveyed in both 2014 and 2015). In the GLMM, we used either a linear-link function with normal errors (response variable: laying week) or a log-linear link function with Poisson errors (response variable: clutch size, number of chicks). Moreover, to compare our results with those from other studies we ran one-sample *t* tests using our average values as references.

Finally, to test for the effect of food availability on breeding parameters, we conducted Generalized Linear Models with either clutch size or productivity as the response variable and the amount of food as the predictor. We used a log-linear link function with a Poisson error distribution. In this case we did not use the nest code as a random factor since the nests surveyed in 2014 were not repeated in 2015.

All statistical analyses were implemented using R (R Core Team 2014).

## Results

During 2014 and 2015, we detected breeding attempts in 28 nest-boxes (Table 1), of which five (18%) were used in both 2014 and 2015. Additionally, we found 18 naturally occurring nests.

Overall, we registered 65 clutches (51 first clutches and 12 second clutches; in the cases of two additional clutches, clutch order could not be determined). Therefore, 18.5% of the nests had a second clutch. Of these, three (25%) replaced clutches after predation. Eleven of the 12 second clutches were in the same nest as the first. The proportion of second clutches in Gipuzkoa did not differ significantly from the average recorded in Europe ($t$ = 0.655, d.f. = 15, $p$ = 0.522; Table 2).

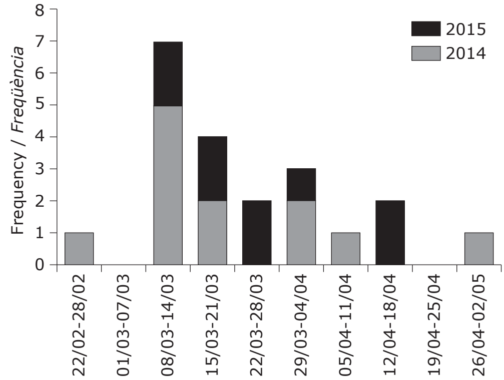


**Figure 1.** Laying dates for the first clutch. Data aggregated on a weekly basis for both box nests and non-box nests.
*Dates de posta del primer ou en les primers postes. Les dades estan agrupades setmanalment tant pels nius de les caixes com naturals.*

The laying period in Gipuzkoa lasted from late February to May, although most clutches were laid between the second week of March and April (mean week = 15–21 March, SD = 2.2 weeks; Fig. 1). The average laying week did not vary between 2014 and 2015 or between nest-boxes and natural nests (Year: $F$ = 0.070, $p$ = 0.794; Nest type: $F$ = 1.899, $p$ = 0.186; Year×Nest Type: $F$ = 0.130, $p$ = 0.722). Second clutches ($n$ = 5) were laid from mid-April (week 19–25 April) to May (week 3–9 May).

The mean clutch size in Gipuzkoa was 4.3 eggs (SD = 0.8; Fig. 2), significantly smaller than in other European areas ($t$ = 4.565, d.f.

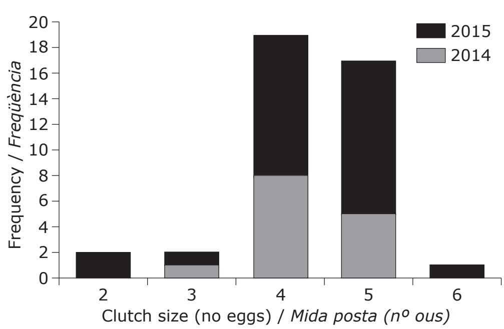


**Figure 2.** Frequency distribution of first clutch sizes in a Dipper population from Gipuzkoa. Data from box and non-box nests are pooled.
*Distribució de la mida de les primeres postes a la població de merles d'aigua de Gipuzkoa. Les dades del nius de caixes i naturals s'han agrupat.*

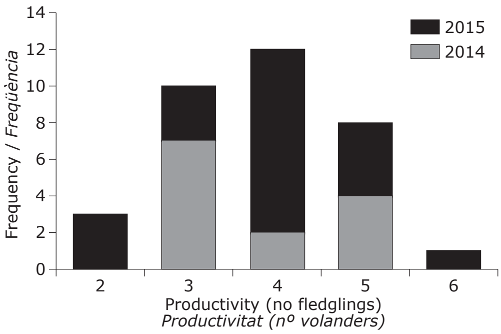


**Figure 3.** Frequency distribution of the number of fledglings (only nests with at least one chick were considered).
*Distribució del nombre de volanders (només s'han considerat els nius amb un pollet com a mínim).*

**Table 3**. Causes of breeding failure (only first clutches considered; 2014 and 2015 pooled).
*Causes de reproducció fallida. Les dades només són de primeres postes (anys 2014 i 2015 agrupats).*

| **Cause / *Causa*** | **Box *Caixa niu*** | **Non-box *Natural*** |
|---|---|---|
| Predation: mammal / *Depredació: mamífer* | 0 | 2 |
| Predation: bird / *Depredació: au* | 1 | 0 |
| Predation: reptile / *Depredació: rèptil* | 0 | 2 |
| Human disturbance / *Molèstia humana* | 0 | 2 |
| Flooding / *Inundació* | 1 | 0 |
| Unknown / *Desconegut* | 10 | 0 |

= 27, $p < 0.001$; Table 2). Indeed, the average clutch size was inferior to that reported in 78.6% of the studies shown in Table 2. Clutch size did not vary between years or types of nest (Year: $Z = 0.334$, $p = 0.738$; Nest type: $Z = 0.258$, $p = 0.796$; Year×Nest Type: $Z = 0.514$, $p = 0.607$).

We recorded an average productivity of 3.8 chicks/nest (SD = 1.0; Fig. 3) with no significant differences between years or nest types (Year: $F = 0.015$, $p > 0.05$; Nest type: $F = 0.040$, $p = 0.626$; Year×Nest Type: $F = 0.071$, $p > 0.05$). The breeding success of 72% of nests did not vary between 2014 and 2015 ($\chi^2 = 0.066$, $p > 0.05$) or between box and non-box nests ($\chi^2 = 0.397$, $p = 0.529$). In terms of clutch size, the mean productivity in Gipuzkoa was higher than in other areas of Europe ($t = 3.062$; d.f. = 11; $p = 0.012$; Table 2).

For the first clutches, the laying week did not affect either clutch size (parameter = 0.004, SE = 0.049, $p = 0.932$) or productivity (parameter = -0.059, SE = 0.068, $p = 0.384$; Figure 4).

Overall, 14 nests failed (Table 3), of which five were predated, two were destroyed or abandoned owing to human disturbances, and one was flooded after heavy rain.

The mean (±SD) dry biomass per territory was 0.12 ± 0.08 g (range: 0.03–0.32 g) but differed significantly between territories ($F = 6.370$, $p < 0.001$). Food availability in territories had no significant effect on either clutch size (Wald $\lambda = 0.081$, $p = 0.776$) or productivity (Wald $\lambda = 0.004$, $p = 0.949$; Fig. 5).

## Discussion

This is the first study of the breeding biology of Dippers in Gipuzkoa and one of the first such studies for Iberia and southern Europe. The breeding season in Gipuzkoa (from egg-laying to fledging, with a laying peak in late March-April) matches findings from nearby areas in both Iberia (Esteban & Campos 1993/1994) and western Europe (Tyler & Ormerod 1994). However, egg-laying in Gipuzkoa occurs about one month before reported dates for northern Europe, where the first clutches are laid in late April (Efteland 1975) or even May (Haartman 1969). The fact that northern European rivers remain frozen in early spring may explain this dissimilarity; egg-laying dates in the Dipper have been reported to correlate with average temperatures (negatively) and precipitations (positively) (Tyler & Ormerod, 1994).

A number of clutches were laid as early as late February, a phenomenon also detected in a nearby region (Esteban & Campos, 1993/1994). Under a scenario of global climate change, clutches before May may not be so rare, especially if floods in late winter become progressively less frequent (Sánchez *et al.* 2017). Interestingly, we have witnessed breeding displays in December (visit *www.ornitho.eus*), which might give rise to early egg-laying attempts if environmental conditions remain acceptable.

Dippers in Gipuzkoa had comparatively smaller clutch sizes than in other sites in Europe, although they seemed to compensate

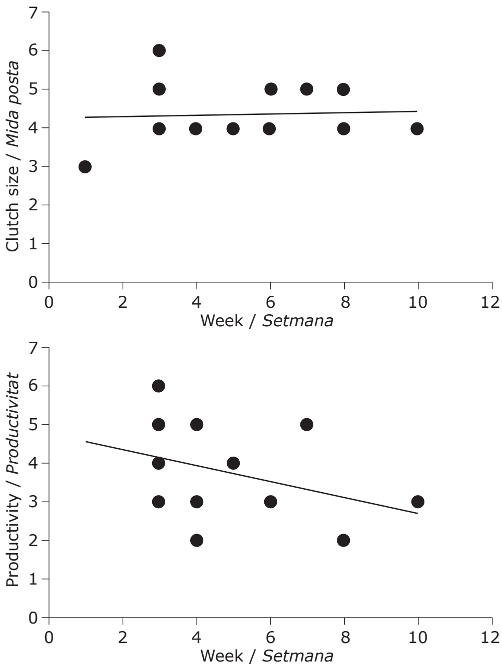


**Figure 4.** Relationship between egg-laying date (week) and breeding performance (clutch size or productivity). Data from 2014 and 2015 are pooled. Only first clutches considered.
*Relació entre la data de posta (setmana) i l'èxit reproductiu (mesurat com a nombre d'ous o productivitat). Les dades de 2014 i 2015 s'han agrupat. Només s'han considerat les primeres postes.*

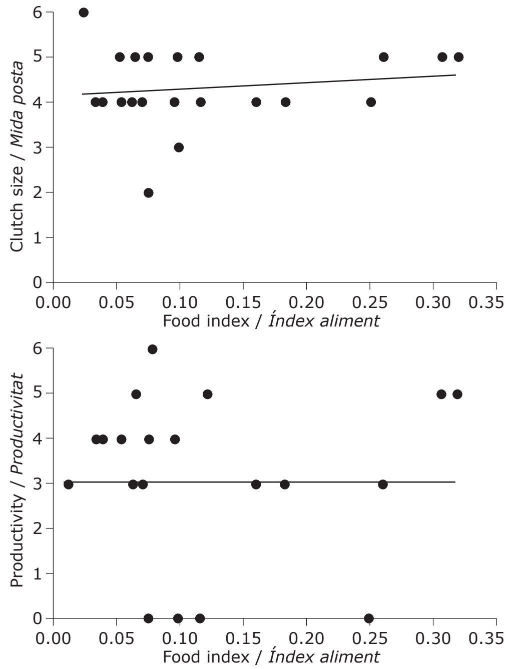


**Figure 5**. Relationship between food availability and Dipper breeding parameters (clutch size and productivity).
*Relació entre la disponibilitat d'aliment i els paràmetres reproductius de la merla d'aigua (nombre d'ous i productivitat).*

for this with a proportionally better breeding success rates. Thus, our findings suggest that the Gipuzkoa population breeds in a favourable environment inducing to higher survival rates, which reduces pressure on clutch size (Sánchez *et al.* 2017). However, our study was conducted over just two years and we had relatively small sample sizes, so more data (i.e. a longer time series) is required to confirm this hypothesis. Future research combining both breeding and survival parameters at a larger spatial scale will help disentangle the underlying causes driving life history strategies at population level. This research will also improve understanding of how dippers will respond to climate change.

The abundance of macroinvertebrates in nesting territories did not affect breeding performance. Several hypotheses may explain this unexpected result. As commented above, our small sample size (only 22 nests) may preclude finding any significant effect if food availability has little effect on breeding success. In addition, our study only lasted two years and conditions could have been especially favourable in terms of food availability during this period (Gordo & Avilés 2017). Alternatively, the lack of effects could be real and might indicate that food availability during the breeding season in the rivers of Gipuzkoa is above the level that constrains Dippers' breeding performance. Finally, neither should we rule out the possibility that the method used to quantify macroinvertebrate abundance failed to estimate food availability correctly, or that there were other possible confounding factors (e.g. the age of breeders) that were not controlled for.

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Gipuzkoa Provincial Council. We are grateful to the people who helped with fieldwork and especially to the Gipuzkoa forest rangers. P. Salmón and O. Gordo provided valuable comments that helped us improve an earlier version of this work.

## Resum

### Biologia reproductiva i disponibilitat de preses en la merla d'aigua al nord d'Ibèria

L'objectiu d'aquest treball és descriure la biologia reproductiva d'una població de merla d'aigua *Cinclus cinclus* de la regió atlàntica de la península Ibèrica. La reproducció es va estudiar de febrer a maig de 2014 i 2015 en 215 caixes nius i nius naturals en 28 rius de les cinc conques principals de Guipúscoa (Oiartzun, Urumea, Igara, Oria i Urola). En els 65 intents de nidificació registrats, la data mitjana de posta va ser a finals de març, la mitjana de la posta (± DE) va ser de 4,3 ± 0,8 ous, la productivitat mitjana va ser de 3,8 ± 1,0 pollets i l'èxit reproductiu va assolir el 72%. En el 18,5% de les caixes niu, hi va haver segones postes. Les causes del fracàs de les postes van incloure la depredació, les molèsties humanes o les inundacions. En 22 nius ocupats seleccionats a l'atzar, també vam estudiar l'efecte de la disponibilitat d'aliment en el rendiment de la reproducció mitjançant l'avaluació de la comunitat de macroinvertebrats en els territoris de cria. La quantitat de macroinvertebrats no va tenir un efecte significatiu sobre la mida de posta o la productivitat. En comparació amb altres poblacions europees, les merles aquàtiques a Guipúscoa van mostrar niuades més petites, compensades per un major èxit reproductiu. Això suggeriria que aquesta població es reprodueix en un entorn (comparativament) més favorable, fet que permetria majors taxes de supervivència i, per tant, reduiria la pressió sobre la mida de la posta.

## Resumen

### Biología reproductiva y disponibilidad de presas en el mirlo acuático en el norte de Iberia

El objetivo de este estudio es describir la biología reproductiva en una población de mirlo acuático *Cinclus cinclus* de la región atlántica de la península ibérica. La reproducción se monitoreó de febrero a mayo de 2014 y 2015 en 215 cajas nido y nidos naturales en 28 ríos de las cinco cuencas principales de Guipúzcoa (Oiartzun, Urumea, Igara, Oria y Urola). En los 65 intentos de nidificación registrados, las puestas se realizaron en promedio a finales de marzo, el tamaño promedio de la nidada (± DE) fue de 4.3 ± 0.8 huevos, la productividad promedio fue de 3.8 ± 1.0 pollos y el éxito reproductivo alcanzó el 72%. En el 18,5% de las cajas nido hubo segundas puestas. Las causas del fracaso de las puestas incluyeron depredación, molestias humanas o inundaciones. En 22 nidos ocupados seleccionados al azar, también estudiamos el efecto de la disponibilidad de alimento en el rendimiento de la reproducción mediante la evaluación de la comunidad de macroinvertebrados en los territorios de cría. La cantidad de macroinvertebrados no tuvo ningún efecto significativo sobre el tamaño de puesta o la productividad. En comparación con otras poblaciones europeas, los mirlos acuáticos en Guipúzcoa mostraron nidadas más pequeñas, aunque compensadas por un mayor éxito reproductivo. Esto sugeriría que esta población se reproduce en un entorno (comparativamente) más favorable, lo que permitiría mayores tasas de supervivencia y, por lo tanto, reduciría la presión sobre el tamaño de la puesta.

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