Bird Study

ISSN: 0006-3657 (Print) 1944-6705 (Online) Journal homepage: http://www.tandfonline.com/loi/tbis20

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BIRD STUDY, 2017
http://dx.doi.org/10.1080/00063657.2016.1270898

Assessing the impact of extreme flooding on survival in a southern European population of White-throated Dippers *Cinclus cinclus*

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ABSTRACT

Capsule: There were only weak effects of winter flooding episodes on apparent annual survival of a White-throated Dipper breeding population in northern Iberia.

Aims: To test whether extreme winter flooding episodes affected survival in a breeding population of White-throated Dippers *Cinclus cinclus*.

Methods: Dippers were ringed during the breeding seasons of seven consecutive years on rivers in northern Iberia. Cormack–Jolly–Seber models were used to estimate apparent annual survival in relation to flooding during the winter periods.

Results: We obtained weak evidence for an effect of flooding during the winter on the surveyed population. Two of the six winters were characterized by having an exceptionally high discharge. Our models showed that survival in the subsequent breeding period tended to be lower, although models assuming constant survival were equally well supported.

Conclusion: Extreme flooding in winter may affect survival of some White-throated Dippers in northern Iberia, but its impact at the population level seems to be weak.

ARTICLE HISTORY
Received 6 June 2016
Accepted 17 November 2016

Climate change is considered to be one of the main factors driving the recent population declines in a number of bird species (Saether *et al.* 2000, Huntley *et al.* 2007, Jetz *et al.* 2007). There is increasingly robust evidence that global change is increasing climatic variability, which leads to more frequent or intense extreme climatic events, such as storms, droughts or flooding episodes (Min *et al.* 2011, Hansen *et al.* 2012, Seneviratne *et al.* 2014). Understanding the role of extreme weather on animal population dynamics is essential to predict the effects of global change on population trends (Huntley *et al.* 2007). Aquatic ecosystems will be also affected by this scenario because global warming is predicted to result in intensification of key processes in the water-cycle, such as precipitation, evaporation and runoff (Durack *et al.* 2012).

Global change will result in increasing water level fluctuations of river flows, a fact that will have a dramatic impact on aquatic ecosystems through changes in species communities, food networks or ecosystem functional traits (Royan *et al.* 2013, Royan *et al.* 2015). Thus, flooding episodes can promote invertebrate species extinction at a local scale, simplify the architecture of the trophic network and generate population declines at higher trophic levels (Ledger *et al.* 2012). The impact of hydrological extremes on riparian assemblages or species at higher trophic levels is, however, still poorly known (Royan *et al.* 2015).

Dippers (*Cinclus* spp.) occupy fast-flowing rivers on five continents (Voelker 2002) and feed chiefly on aquatic macroinvertebrates (Cramp 1988). Flooding episodes have been reported to have an impact on several aspects of bird populations, including territory occupancy (Chiu *et al.* 2013, Reiley *et al.* 2013), breeding performance (Arthur *et al.* 2012, Strasevicius *et al.* 2013) and survival (Chiu *et al.* 2013). In most cases, these effects are due to either during- or after-flood changes or decline of prey availability (Cumming *et al.* 2012). Different studies suggest that the underlying mechanisms explaining dipper population dynamics in relation to climatic causes are either mortality during the non-breeding season (mainly in winter) or a negative impact on fecundity (Saether *et al.* 2000). Breeding dipper populations seem to be very sensitive to severe winter conditions (e.g. Petersen *et al.* 2006). Winter mortality in dippers is normally associated with conditions that hamper food access, such as prolonged cold periods that result in iced rivers or long-term flooding episodes (Nilsson *et al.* 2011, Chiu *et al.* 2013).

Rivers in southern Europe do not ice in winter, so flooding is likely to be the main factor that could

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potentially affect survival. In Spain, with resident dipper populations (Regla & Arizaga 2016), flooding episodes at a local level would be expected to have an impact on local breeding birds. In this study, we aimed to quantify the effects of extreme flooding on a population of White-throated Dippers *Cinclus cinclus* (hereafter Dipper) in Spain. Specifically, we tested whether extreme winter flooding episodes negatively affected the survival of a resident breeding population. In this scenario, the wider aim is to understand whether these flooding events during the non-breeding period can shape the long-term trends in population dynamics of a predator that is highly dependent on the trophic web of riparian ecosystems.

Methods

Study area

This study was carried out on five rivers of the Oria river basin, in the province of Gipuzkoa, North Spain (Figure 1). The altitude of this province ranges from 0 to 1550 m above sea level and the mean annual precipitation (mostly as rainfall) is close to 1500 mm. With a mean length of 60 km (Oria river: 82 km) and a mean flow of 16 $m^3 s^{-1}$ (Oria river: 30 $m^3 s^{-1}$), the 6 main rivers of Gipuzkoa flow across a south–north axis into the Bay of Biscay. Dippers breed in the upper zones of these rivers and mostly in the subsidiary rivers and brooks that flow into them (Aierbe *et al.* 2001).

Data collection

Dippers were captured from March to August from 2008 to 2014 with mist nets placed across the stream, at 130 sampling points in total. Data used in this study were obtained from 180 sampling days (mean number of sampling days per year: 25 days; range: 14–39 days). Overall, we captured 269 individual birds of which 58 (21.6%) were recaptured once or more during the study period.

Once caught, the Dippers were ringed and aged as first-year birds (EURING code 3) or adults (EURING code 4) following the criteria of Svensson (1996), and the wing length was recorded (method II by Svensson 1996; 0.5 mm accuracy) in order to determine the sex (Arzak *et al.* 2014).

Hydrological data were collected from the Gipuzkoa Administration website (www.gipuzkoa.eus). We obtained the mean monthly flow (discharge) of the Oria river at a stream gauge situated downstream of the sampling rivers (Figure 1). Because we wanted to assess the impact of extreme flooding in the months prior to the breeding season, we considered here the mean values from November to February immediately before the breeding season. On average, during these months the Oria discharged water at a rate of 46 550 $m^3 s^{-1}$, and we found two years with higher-than-the-mean values: 2009 and 2013 (Figure 2). During these years, the discharge was approximately 20 000 $m^3 s^{-1}$ (40%) higher than the mean.

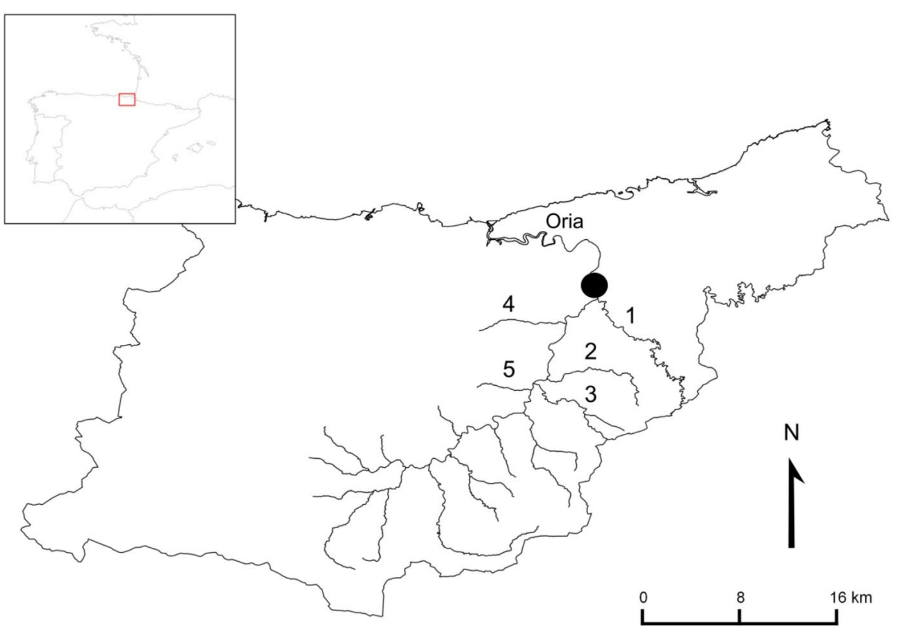

Figure 1. Map showing the position of the Oria River basin, province of Gipuzkoa, northern Spain. The sampling rivers within the basin are indicated with numbers: 1, Leizaran; 2, Zelai; 3, Araxes; 4, Asteasu; 5, Albiztur. The location of the hydrological station (closed circle) is also represented. The Oria river falls into the Bay of Biscay.

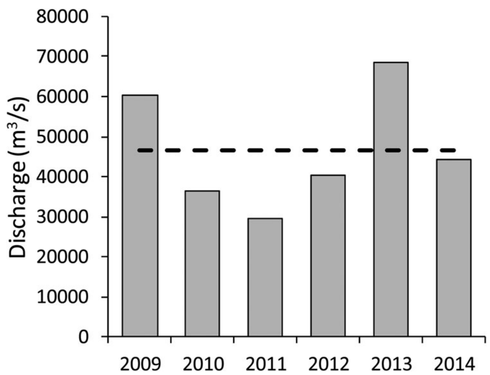

Figure 2. Mean November–February water discharge of the Oria River during the winter period. Dotted line represents mean discharge from 2009 to 2014.

Data analyses

Overall, the data formed a matrix of 269 rows (individuals) × 7 columns (years 2008–14). The m-array is shown in Table 1. We assessed survival using Cormack–Jolly–Seber (CJS) models, which allow us to estimate survival (ϕ: probability that a bird caught at time i is alive at i+1) and recapture probability (p: probability that a bird caught at i is alive and seen at i +1) (Lebreton *et al.* 1992). Since it is not possible to separate mortality from permanent emigration, these models estimate local survival rates (called 'apparent survival'). CJS models using a logit-link function were run in the software MARK 6.1 (White & Burnham 1999).

Before starting to select models, we tested that the data fitted to the CJS assumptions using the software UCARE (Choquet *et al.* 2009). The global goodness-of-fit on a CJS model where both ϕ and p varied with time [$\phi(t)$, $p(t)$] was not significant ($\chi^2 = 20.79$, df = 35, $P = 0.973$), nor was the specific test to detect transients ($Z = 1.21$, $P = 0.228$) or trap-dependence ($Z = 0.217$, $P = 0.828$). Thus, [$\phi(t)$, $p(t)$] was the basic model from which to start to select other models.

Corrected small sample sizes Akaike values (AICc) were used for ranking the fit of models to data (Burnham & Anderson 1998). Models with a ΔAICc < 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. Because models with additional unsupported parameters will be likely to be within 2 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 best-supported one in order to see if the parameters affected ϕ. Parameters with a 95% confidence interval including zero showed a non-significant effect of the factor/covariate (Taylor *et al.* 2004). Finally, we calculated model-averaged parameters for the top model and the subset of models with a ΔAICc < 2 in relation to the top one (Burnham & Anderson 1998).

We ran all possible models with various patterns in ϕ and p [constant or affected by time (t)]. From them, [ϕ, $p(t)$] was the best model with a ΔAICc > 2 in relation to the second one [$\phi(t)$, $p(t)$]. Therefore, we considered p to be affected by time. It is common that first-year birds have lower survival rates than older birds (Newton 1998) so, in theory, Dippers which were first caught as first-year birds could have lower survival than those caught as adults. To test this, we built a model considering a survival value for the first year after catching for those birds which were caught as first-year birds (t_1) and another value for the annual survival of the rest of years and those birds which were caught as adults (t_2): [$\phi(t_1,t_2)$, $p(t)$], nested within [$\phi(t)$ $p(t)$] as it can be created by setting t_2 parameters equal. To test for the effect of extreme flooding on ϕ, we considered six alternative models, including: the mean discharge during the months of November [ϕ(flow/Nov), $p(t)$] to February [ϕ(flow/Feb), $p(t)$] of each year, the mean annual winter discharge for the four months [ϕ(flow/Nov–Feb), $p(t)$], and whether a certain winter was or was not a winter with extreme flooding (i.e. 2009 and 2014 versus the rest), considered as a binary variable [ϕ(flow/b), $p(t)$]. Finally, we also tested whether survival differed between the two sexes: [ϕ(sex), $p(t)$]. We also considered that t_1 and t_2 could be sex-dependent: ϕ[sex(t_1, t_2)], $p(t)$.

Table 1. The m-array table summarizing capture–recapture data from a southern European population of Dippers surveyed from 2008 to 2014. The term *R*(*i*) refers to the number of birds which were released during each time period. Each individual is considered only once from March to August within each year.

Year	*R*(*i*)	2009	2010	2011	2012	2013	2014	Total
2008	47	11	1	1	0	0	0	13
2009	71		10	9	0	1	1	21
2010	53			12	3	2	0	17
2011	65				9	5	1	15
2012	42					4	1	5
2013	37						4	4

Results

We found a total of eight models to fit to the data equally well (Table 2). The six models considering an effect of flooding on survival were included within this subset, as well as two models assuming constant survival (Table 2). Alternative models considering either a sex-effect on survival or a survival rate differing from t_1 to t_2 showed higher AICc values (ΔAIC > 2) and hence did not support the data as well as the previous models (Table 2).

Table 2. Ranking of the models tested to assess the impact of extreme flooding on survival (ϕ) of a southern European Dipper population. Abbreviations: *p*, recapture probability; AICc, small sample sizes-corrected Akaike values; np, number of parameters; flow/b, survival varies between years with lower- and higher-than-the-mean discharges during the winter period (i.e. flooding considered as a binary factor); flow/Nov, /Dec, /Jan, /Feb, survival is affected by discharge volume in a given month – from November to February; flow/Nov–Feb, survival is affected by the sum of the discharge volume from November to February; *t*, time-dependent models.

Models	AICc	ΔAICc	AICc weight	np	Deviance
ϕ(flow/b), $p(t)$	472.33	0.00	0.18	8	131.58
ϕ(flow/Dec), $p(t)$	472.93	0.61	0.13	8	132.19
ϕ, $p(t)$	473.04	0.71	0.13	7	134.39
ϕ(flow/Nov–Feb), $p(t)$	473.06	0.73	0.13	8	132.31
ϕ, p	473.41	1.08	0.11	2	145.09
ϕ(flow/Nov), $p(t)$	474.12	1.79	0.07	8	133.37
ϕ(flow/Jan), $p(t)$	474.20	1.87	0.07	8	133.45
ϕ(flow/Feb), $p(t)$	474.29	1.96	0.07	8	133.54
$\phi(t_1, t_2)$, $p(t)$	474.95	2.63	0.05	8	134.20
ϕ(sex), $p(t)$	475.03	2.70	0.05	8	134.28
$\phi(t)$, p	478.26	5.93	0.01	7	139.62
ϕ[sex(t_1, t_2)], $p(t)$	478.65	6.32	0.01	10	133.64
$\phi(t)$, $p(t)$	479.83	7.50	0.00	12	130.51

After model averaging, we observed that the two years when there was a very high discharge during the winter period were those with lower survival rates (Figure 3), although the high confidence interval associated to these two means forces us to consider the difference with caution. Overall, the mean survival rate for the majority of the years was approximately 0.6, while fell down below 0.5 in winters with extreme flooding (Figure 3).

Discussion

Using data from a seven-year time series, we obtained weak evidence for an effect of flooding during the winter on a White-throated Dipper population breeding in a region of southern Europe. Of the six winters of the data set, two of them were characterized by having an exceptionally high discharge. Our models showed that annual survival after these winters tended to be lower, although the difference was weak, as models assuming constant survival were equally well supported. This suggests that high flooding may have had some impact but probably not on all individuals; hence effects might dilute at the population level. However, it is possible that our results may in part be relatively weak due to low statistical power owing to relatively small sample sizes. In other temperate areas, decreasing survival has been also attributed to winter flooding (Clobert *et al.* 1990).

The rivers from Gipuzkoa are short and they can discharge great water volumes very rapidly. During flooding episodes, birds have been found to make small local displacements into tributaries, where they might find alternative food until foraging conditions in the main rivers improved (Morrissey *et al.* 2004, Gillis *et al.* 2008). During flooding events, Brown Dippers *Cinclus pallasii* switch to small-bodied prey, which are still relatively abundant during seasonal flooding (Chiu *et al.* 2013). Such prey could help dippers to satisfy their energetic needs for a limited time but at a cost to their subsequent survival and fecundity (Chiu *et al.* 2013). Heavy rain and flooding may wash away even these small prey species, hence compromising local survival, at least in some basins. Additionally, as the Dipper is a visual forager, it must be also considered that increasing turbidity during flooding periods may hamper access to food (Goodge 1960), thus having an impact on survival. In this context, we observed that the two winters (2009 and 2013) with higher flooding were also those with higher mean values of turbidity (Figure 4).

Our models did not detect any significant effect of age and sex on survival. This contrasts with other studies on Brown Dippers, where either adults or males were found to show higher survival than first-year birds or females

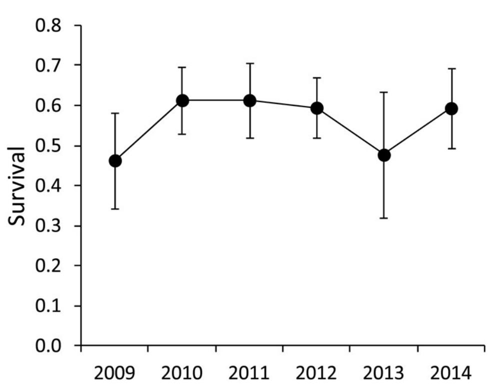

Figure 3. Model-averaged survival (mean ± se) from a southern European Dipper population. Survival in a given year refers to annual survival rate from the previous breeding season (year) to that year.

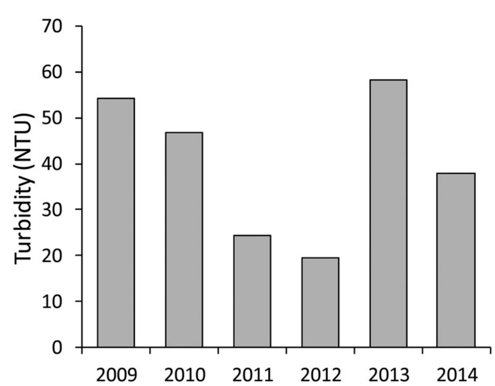

Figure 4. Mean November–February turbidity of the Oria River during the winter period.

(Chiu *et al.* 2013). Increased mortality in first-year birds is attributed to the inexperience of young birds, with their lower foraging efficacy, especially during adverse feeding conditions, such as flooding episodes (Chiu *et al.* 2013). In part, the lack of significant differences between the two age and sex classes could be attributed to relatively small statistical power, but other factors might have also have influenced this result. For instance, relatively good foraging conditions in the area for the whole annual cycle may reduce the occurrence of social conflicts, potentially promoting decreased survival expectation in the sub-dominant fraction of the population (first years versus adults or females versus males) (Moore *et al.* 2003).

In conclusion, we detected a slight effect of winter flooding on survival of a northern Spanish resident breeding Dipper population. Current models on climate change predict a decrease (up to 15–20%) of the precipitation for Gipuzkoa (K-Egokitzen 2011). This decrease will be also accompanied by a decrease in the amount of intense rain (CEDEX 2012). Thus, in this scenario it is expected that flooding episodes will have a decreasing impact on Dipper survival.

Acknowledgements

We are grateful to the people who collaborated in the field work, especially to the members of the Txingudi Ringing Station. Two anonymous reviewers and the Associate Editor provided very valuable comments that helped us to improve an earlier version of this work.

Funding

This research was funded by the Basque Government and the Gipuzkoa Administration.

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