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Supplementary material

SUPPLEMENTARY MATERIAL

WEATHER EFFECTS ON NESTLING SURVIVAL OF GREAT TITS VARY ACCORDING TO THE DEVELOPMENTAL STAGE

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APPENDIX 1: ASSESSING THE EFFECT OF CAPTURE DAY ON FLEDGING SURVIVAL

Introduction

Our results point to a relationship between precipitation at ages 7-8 days of nestlings and nest fledging probability. This age period coincided with our adult capture day using spring traps at nest-boxes. Thus, it is possible that the precipitation effect was caused or enhanced by interferences at the nest. Manipulation at the nest as a possible cause of nest desertion is ubiquitous in avian studies. However, the causes of desertions are manifold and very difficult to disentangle in the field (Wischhoff et al. 2019), especially because the desertion may be a life-history strategy in itself regardless of human interference (Verhulst et al. 1997).

Nest desertion as a strategy may occur depending on current clutch value, opportunities to renest, weather, and predation risk (Székely et al. 1996). Even though human disturbance does not constitute a natural predation risk, it may act as if it was, with extensive negative effects on wildlife (Ciuti et al. 2012, Hutfluss and Dingemanse 2019). Nest-box trapping is a century-old, traditional method and perhaps the easiest way to capture wild adult birds. Nevertheless, its impacts on nest desertions and how to avoid them remain elusive and restricted on anecdotal and personal experience.

A permeating rule is that great tit adults should not be captured at least until nestlings are 6-10 days old (Wilkin et al. 2009, Vaugoyeau et al. 2017), or in adverse environmental conditions (Schlicht et al. 2015). In this supplement, we will investigate whether the precipitation effect shown for great tit nest fledging probability may be attributed completely or partially to adult capture at nest-boxes, and whether it is best to wait until nestlings are older, or when precipitation conditions are good.

Capture day effect may be embedded in precipitation effect if there is a correlation between capture day and precipitation at these ages. A correlation would occur, for example, if breeding phenologies were tightly linked to a seasonal variation in precipitation. This would mean that a mechanism between precipitation and nest fledging probability is less probable, and likely caused by capture day alone. However, the correlation between these variables is very low (Pearson R = 0.08), which allowed us to discard this mechanism. Another possibility is that capture day modulated or enhanced the effect of precipitation. If this is the case, then we can assess the effect of capture day by expanding our statistical model by including an interaction between capture day and precipitation, which is detailed below.

Material and Methods

To test the hypothesis that the day of capture influences nest fledging probability, in 2017 we changed the day of adult capture from nestling age 7 to 10 days. As any biological field procedure, these captures are not infallible, and thus some of them did not occur on the exactly intended date. In the case of females, 22% of captures occurred outside intended days, or, overall, captures occurred 0.4 days (SD: 0.9) after the intended day (Figure A1). This unintentional variation is serendipitous as it allows to include a wider range of capture days on the analysis, and because it partially overcomes the statistical dependency of capture days relative to the year of 2017. Thus, we used capture day as a continuous variable. Similar to our model selection approach used in the main text, we assessed the effect of capture day via the inclusion of it on a baseline model and then comparing AICc values. In this case, the baseline model includes precipitation as a predictor of nest fledging probability.

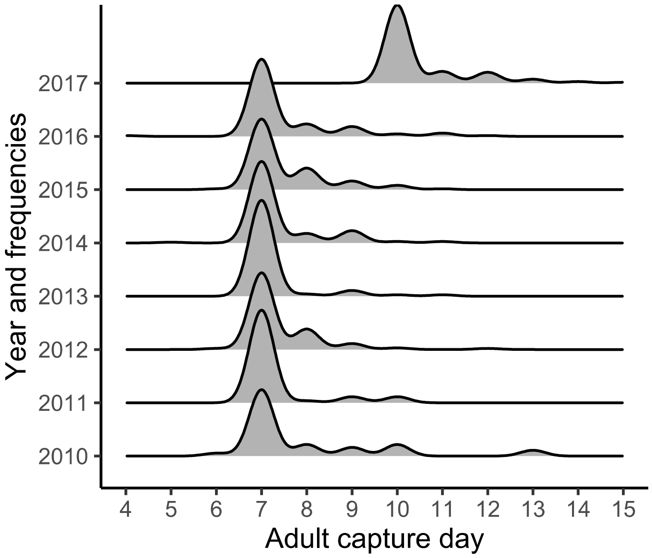

Figure A1. Adult capture day distribution among years. Sampling distribution of capture day relative to nestling age. Each year is presented separately, and in 2017 we intentionally captured adults when nestlings were 10-days old.

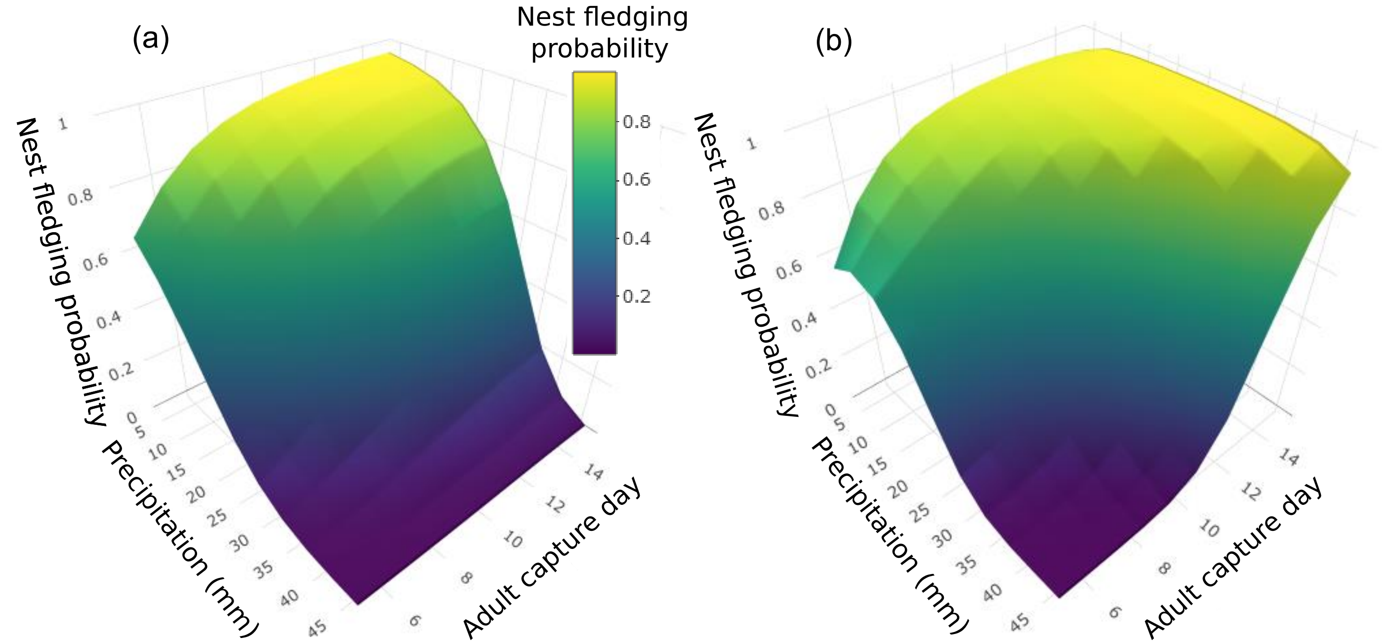

Figure A2. Modelled link between capture day, precipitation, and nest fledging probability. The best model included interactions between squared variables on the logit scale. Thus, the relationship among variables is clearer if visually compared. The model in a) does not include interactions for the sake of comparison with b). The model in b) was the best and includes non-linear interactions between capture day and precipitation.

We used the combined within- and between-year effects model from Table 3 as a starting point, but to avoid over parameterization we removed all effects whose confidence intervals included zero. We then progressively added capture day variables and interactions to the baseline model and calculated their AICc. We allowed the inclusion of squared capture effects and outlined possible nested model compositions manually (Table A1).

Results

Several models performed better than the baseline. The best model included non-linear interactions, and among the top five models (ΔAICc <-2 relative to the best), all included some type of interaction between precipitation and capture day. The model with the lowest AICc had both precipitation and capture day significant parameters (confidence intervals excluding zero, Table A2). Additionally, the interaction between the squared effects of these two variables was significant (Table A2). These results indicate that capture day influences fledging survival, both independently and in conjugation with precipitation. These two variables interact in a complex fashion, which can be seen in Figure A2. Capture day, otherwise showing small and linear effects with precipitation on the logit scale when interactions are not included (Figure A2a), is dependent on precipitation and seems to have a greater effect when precipitation is high (Figure A2b).

Discussion

Biologists in the field often must make decisions that are not backed up scientifically. The capture day in great tits, as it occurs with other birds, is mostly based on judgment calls. Here we showed capture day may influence nest fledging probability irrespective of precipitation, but this influence may be amplified whenever it is raining/snowing.

Even in the absence of rain/snow, the capture at age 7 days had relatively low modelled fledging probability (88%). Capturing at age 7 days in heavy conditions of rain/snow (20 mm. day $^{-1}$) may decrease fledging probability to 41%. In contrast, when adult captures are made when nestlings are 10 days old, fledging probability is high in dry days (95%) and decrease little in heavy rain/snow conditions (88%). Meaning that rain/snow detrimental effects is largely conditional on the nestling age.

It is worth noting that although our results indicate an effect of capture day, our experimental design was far from ideal. Assuming that mortality is inherently high when nestlings are 7-day old, then capturing when they are 10-day old introduced a sampling bias towards the ones that survived to this age. In this situation, the nestling population may already be resilient to human interference. Moreover, as later capturing was done largely on one particular year, it is impossible to know whether survival was higher due to another factor and not caused by capture day.

All things considered, as a rule of thumb, it is best to capture adults when nestlings are at least 10 days old – when typical days of rain/snow conditions (< 20 mm. day^{-1}) has little effect on offspring. In our case, only 2% of nests (16 nests) were exposed to higher precipitation larger than 20 mm.day^{-1}, which means that the model may perform poorly to predict nest fledging probability in worse weather conditions.

Similarly to what we found, an experimental study with great tits indicated that trapping adults when nestlings are 7 days older had higher rates of nest desertion compared to adults trapped when nestlings were 10 days old (Cole et al. 2012). As our results show, environmental conditions may come at play when capturing as early as 7 days old. Thus, capturing at age 10 or latter may be the advisable approach.

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Table A1. List of models considered to assess the effect of capture day. Mean prec. = mean precipitation. ΔAICc values are relative to the baseline model nest fledging probability presented at Table A1. The line in boldface is the best model (lowest AICc).

Mean prec.	(Mean prec.)^2	Capture day	(Capture day)^2	Mean prec. x Capture day	(Mean prec.)^2 x Capture day	Mean prec. x (Capture day)^2	(Mean prec.)^2 x (Capture day)^2	AICc	ΔAICc
X	X							920.4	-21.6
X	X	X						915.2	-26.8
X	X	X		X				917.2	-24.8
X	X	X		X	X			917.7	-24.3
X	X	X			X			916.6	-25.4
X	X	X	X					916.8	-25.2
X	X	X	X	X				918.8	-23.2
X	X	X	X	X	X			919.3	-22.7
X	X	X	X		X			918.3	-23.7
X	X	X	X			X		918.5	-23.5
X	X	X	X	X		X		920.4	-21.6
X	X	X	X	X	X	X		921.0	-21.0
X	X	X	X		X	X		920.4	-21.6
X	X	X	X			X	X	914.4	-27.6
X	X	X	X	X		X	X	914.7	-27.3
X	X	X	X	X	X	X	X	914.7	-27.3
X	**X**	**X**	**X**		**X**	**X**	**X**	**913.0**	**-29.0**
X	X	X	X				X	915.6	-26.4
X	X	X	X	X			X	914.3	-27.7
X	X	X	X	X	X		X	916.3	-25.7
X	X	X	X		X		X	915.2	-26.8

Table A2. Parameters of the best model to predict the effect of capture day. Effects of the precipitation and capture day on nest fledging probability in a population of great tits breeding in nest-boxes in Southern Germany. The 'combined within & between year effects' column show the selected model via AICc from a set of climate variables and possible time windows of influence in nest fledging probability. Parameters are presented with 95% credible intervals in parentheses and parameters with CI excluding zero are shown in bold. The number of hatchlings was included as a factor, and here we present the parameter estimate only for the level n = 7 hatchlings and range of parameters of others brood sizes in brackets.

Fixed effects		Parameters
Intercept		-1.5 (-3.2, 0.2)
Hatch day	β_{lin}	**-0.4 (-0.6, -0.1)**
Mean precipitation (ages 7-8)	β_{lin}	**-0.5 (-0.9, -0.1)**
	β_{sqr}	-0.1 (-0.3, 0.1)
Capture day	β_{lin}	**0.5 (0.1, 0.9)**
	β_{sqr}	-0.1 (-0.3, 0.2)
Number of Hatchlings	β_1	3.7 [2.4, 3.7]
Interactions		
Mean precipitation x Capture day	β_{lin} x β_{lin}	Not selected
(Mean precipitation)^2 x Capture day	β_{sqr} x β_{lin}	-0.1 (-0.3, 0)
Mean precipitation x (Capture day)^2	β_{lin} x β_{sqr}	-0.4 (-0.9, 0.1)
(Mean precipitation)^2 x (Capture day)^2	β_{sqr} x β_{sqr}	**0.3 (0.03, 0.6)**
Random Effects* (σ^2)		
Plot		0.2 (0.1, 0.3)
Date		0.0 (0.0, 0.0)
Year		0.3 (0.1, 0.5)
Female ID		0.0 (0.0, 0.0)
Male ID		0.0 (0.0, 0.0)

APPENDIX 2: SUPPLEMENTARY FIGURES AND TABLES

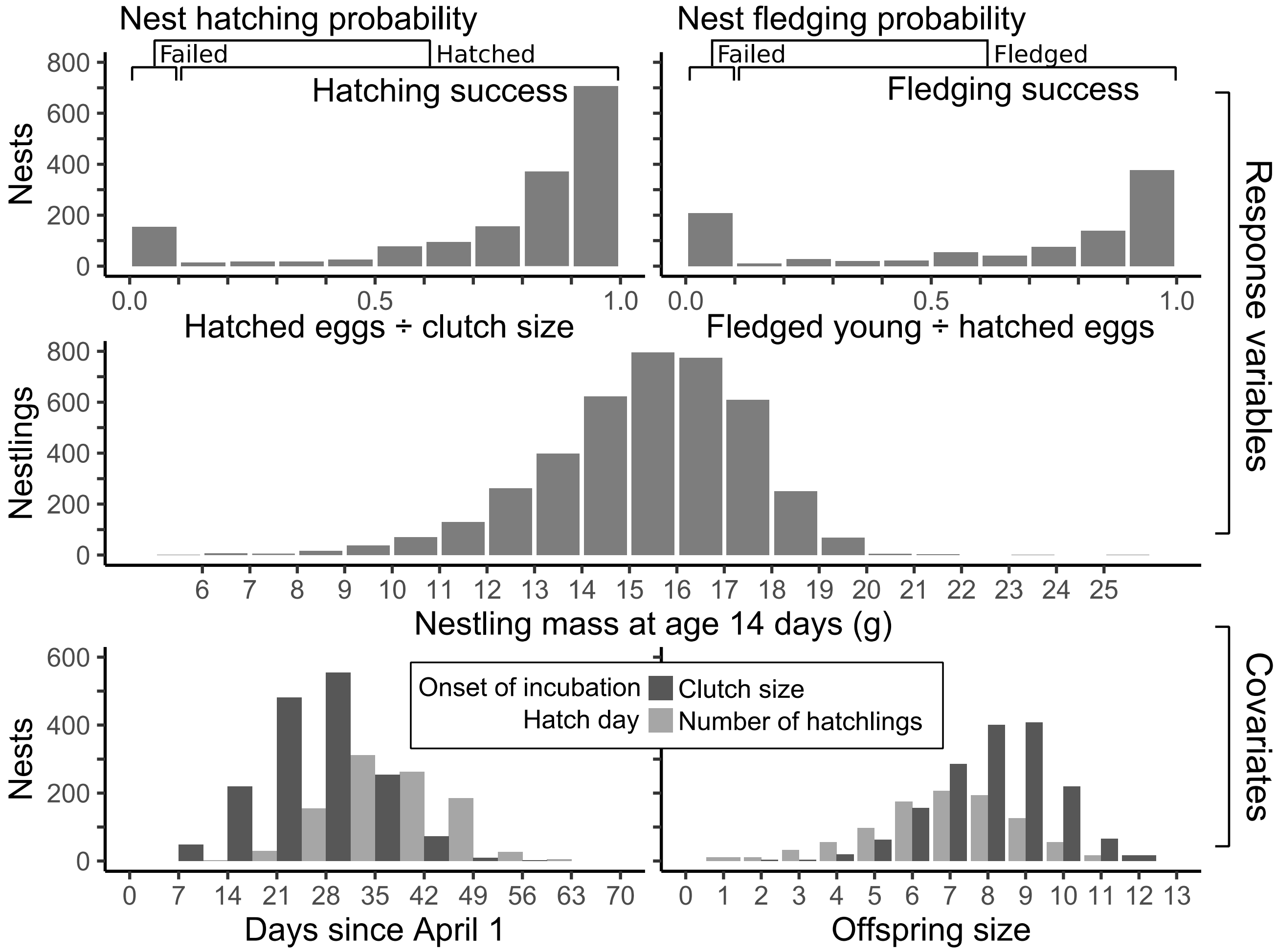

Figure A3. Histograms for various breeding parameters. The three upper histograms show the data distribution of the response variables used on the main results. Lower row show covariates included in models. Horizontal square brackets on the upper row show how data were pooled to generate the response variables 'nest hatching probability', 'nest fledging probability', 'hatching success' and 'fledging success'.

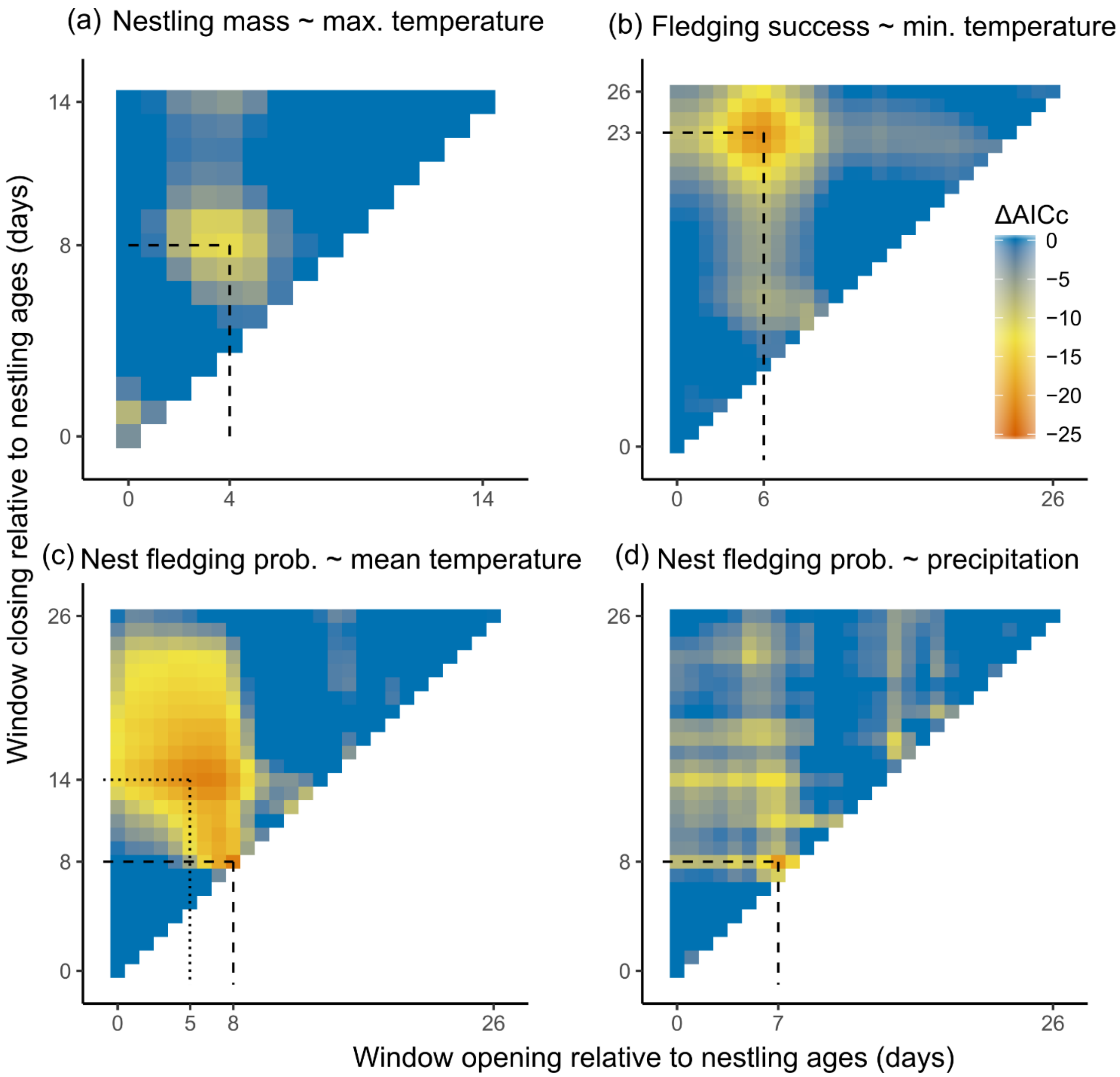

Figure A4. Landscape representation of AICc values of selected models. Models including different time windows of temperature and precipitation effects to predict nest traits of great tits in Southern Germany. Colours show ΔAICc values relative to models without weather variables. Models with ΔAICc ≥ 0 are presented as the same shade of blue. Dashed lines show the selected models (lowest ΔAICc). The models from (c) and (d) were equally probable, and when possibilities were considered on the same model, the best temperature window changed to 5-14 days (dotted lines).

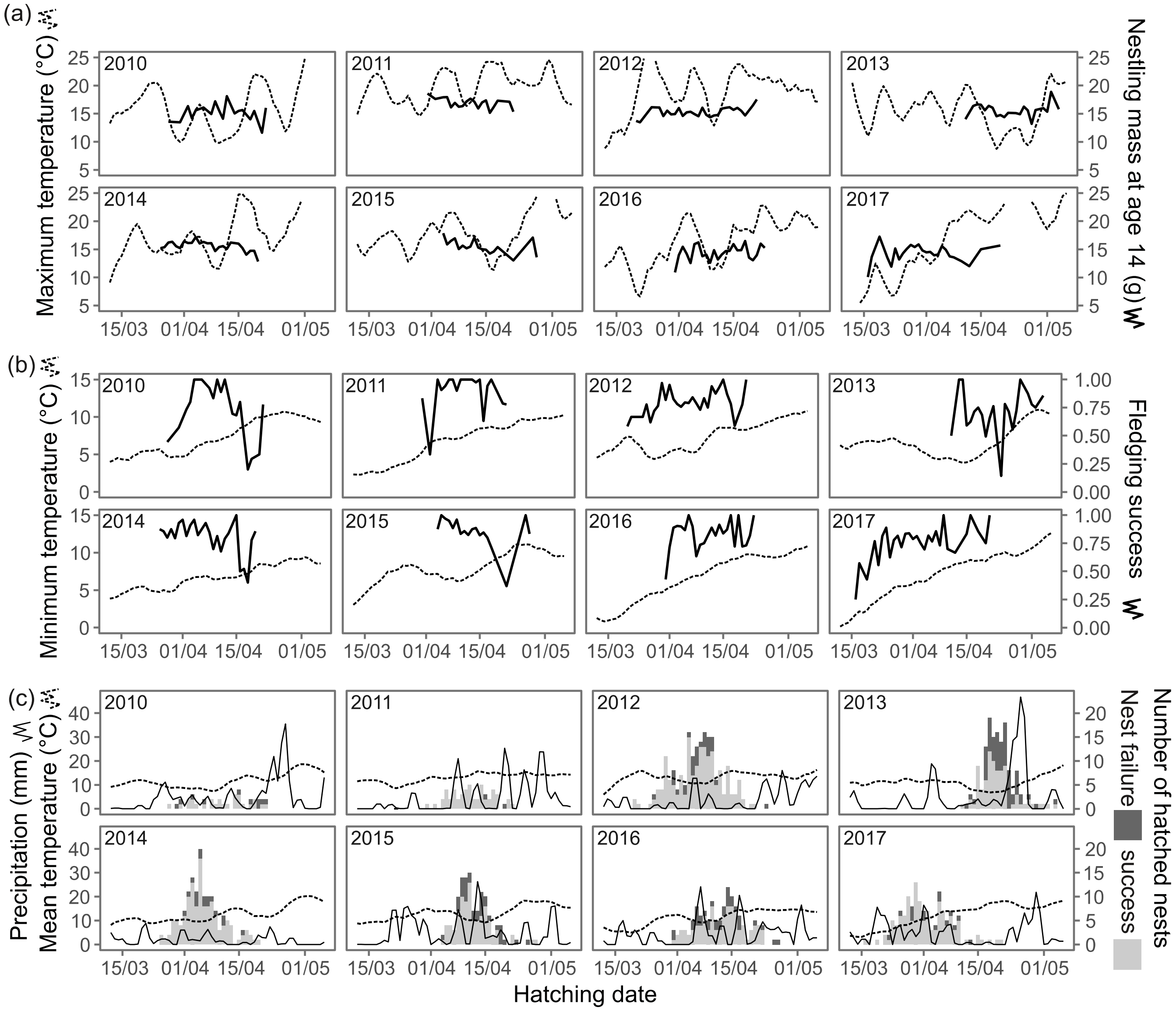

Figure A5. Relative timelines of various breeding parameters. Nestling mass, fledging success and nest fledging probability (right y-axes) of great tits in Southern Germany according to temperature and precipitation (left y-axes) in eight years (2010-2017). Temperature and precipitation lines are moving averages based on selected time windows of nestling age. The x-axis refers to the date of hatching. For those nests that hatched on a given day, the same x-value shows information of two later events later in time: the weather conditions and the corresponding breeding parameters. For example, for a given nest that hatched on day x, we show the environmental conditions during the nestling phase (weather time window), and the outcomes of the nest traits later in the nest stage (right y-axes). Grey bars of the number of nests with success of failure are stacked.

Table A3. Numerical data from the main text Figure 1. Time window model selection. Assessment of the most probable time windows of temperature and precipitation influencing five components of fitness in great tits in Southern Germany from 2010 to 2017. Windows of 'hatching success' and 'nest hatching probability' are in days relative to the onset of incubation. Windows of 'fledging success' and 'nest fledging probability' are in days of nestling age. The first row of each component of fitness shows the baseline model with covariates and without any climate variables. Subsequent rows show the best results of a search for the best window for temperature and precipitation. The variables were included in each baseline model. The search was further split by whether the squared effect of the climate variable was included along with the linear (L+Q) or not (L). We searched best windows using a single measure of precipitation (daily accumulated) and three measures of temperature (daily mean, minimum and maximum). The ΔAICc values are presented relative to the baseline model (lower is better). We considered that models that differed in less than AICc = 2 were equivalent. Thus, we emphasize models including a given time window that are 'better than the baseline model', 'equivalent to best model', and if it was selected based on criteria in the Methods section. Models with bold have the lowest AICc.

Component of fitness	Climate variable	Effects	Daily summary	Window range (days of incubation or after hatching)	AICc / ΔAICc	Better than the baseline model	Equivalent to the best model	Selected model	$P_{\Delta AICc}$
Hatching success	None				3472.6				
	Temperature	L	Mean	9 - 17	**-9.3**	Yes	Yes		0.21
			Min.	1 - 18	-8.1	Yes	Yes		0.31
			Max.	16 - 16	-8.4	Yes	Yes		0.22
		L+Q	Mean	9 - 18	-8.4	Yes	Yes		0.44
			Min.	7 - 18	-8.8	Yes	Yes		0.48
			Max.	16 - 16	-8.7	Yes	Yes		0.55
	Precipitation	L	Mean	20 - 20	-2.3	Yes			0.95
		L+Q	Mean	20 - 20	-2.7	Yes			0.99
Nest hatching probability	None				1005.1				
	Temperature	L	Mean	0 - 0	-2				0.47
			Min.	0 - 0	-2.2	Yes			0.46
			Max.	0 - 0	-1.1				0.76
		L+Q	Mean	0 - 0	-1.1				0.79
			Min.	0 - 0	-0.5				0.91
			Max.	15 - 16	-0.1				0.97
	Precipitation	L	Mean	4 - 6	-3.1	Yes	Yes		0.51
		L+Q	Mean	4 - 5	**-4.2**	Yes	Yes		0.58

Nestling mass	None				15602.5				
	Temperature	L	Mean	4 - 14	-6	Yes			<0.001***
			Min.	5 - 14	-8.3	Yes			<0.001***
			Max.	4 - 8	-7	Yes			<0.001***
		L+Q	Mean	4 - 9	-8.9	Yes			<0.001***
			Min.	2 - 2	-8.7	Yes			<0.001***
			Max.	4 - 8	**-11.6**	Yes	Yes	Yes	<0.001***
	Precipitation	L	Mean	2 - 14	-1.7				0.11
		L+Q	Mean	2 - 14	1.3				0.06
Fledging success	None				2294.5				
	Temperature	L	Mean	6 - 21	-7.8	Yes			0.02*
			Min.	6 - 23	**-20.6**	Yes	Yes	Yes	<0.001***
			Max.	5 - 20	-5.6	Yes			0.42
		L+Q	Mean	2 - 7	-7.3	Yes			0.54
			Min.	6 - 23	-18.8	Yes	Yes		0.02*
			Max.	2 - 7	-8.1	Yes			0.47
	Precipitation	L	Mean	12 - 17	-6.4	Yes			0.48
		L+Q	Mean	10 - 19	-17.8	Yes			0.04*
Nest fledging probability	None				942.0				
	Temperature	L	Mean	7 - 14	-18.2	Yes			<0.001***
			Min.	9 - 9	-14.7	Yes			<0.001***
			Max.	7 - 14	-17.3	Yes			<0.001***
		L+Q	Mean	8 - 8	**-20.8**	Yes	Yes	Yes	<0.001***
			Min.	8 - 15	-15.5	Yes			<0.001***
			Max.	6 - 14	-19.4	Yes	Yes		<0.001***
	Precipitation	L	Mean	6 - 14	-14.8	Yes			<0.001***
		L+Q	Mean	7 - 8	-19.5	Yes	Yes	Yes	<0.001***
	Composite model	-	-	5 - 14 / 7 - 8	-33.6	-	-	-	-