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Supplemental Information

Evolutionary Response to Climate

Change in Migratory Pied Flycatchers

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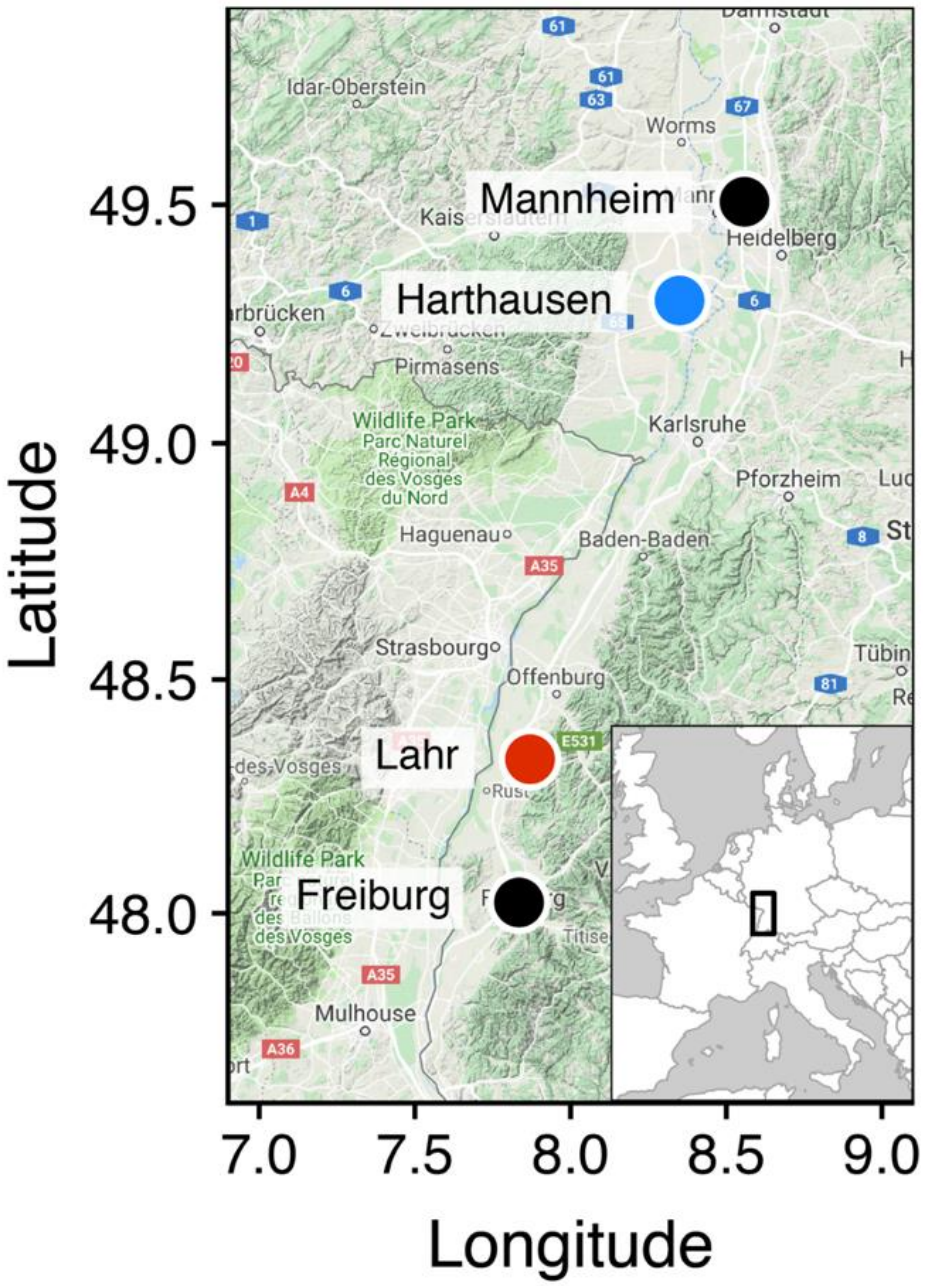


Figure S1. Field sites, located in the Upper Rhine Valley, Germany. Related to Figures 1-4. Black markers indicate the two weather stations (Freiburg and Mannheim, 173 km apart) whose data were averaged. Red marker (Lahr) shows field site of the captive flycatchers, 34 km from Freiburg. Blue marker (Harthausen) shows the wild population, 113 km from Lahr and 27 km from Mannheim. Inset: black rectangle shows the location within Central Europe; map sourced from Google Maps.

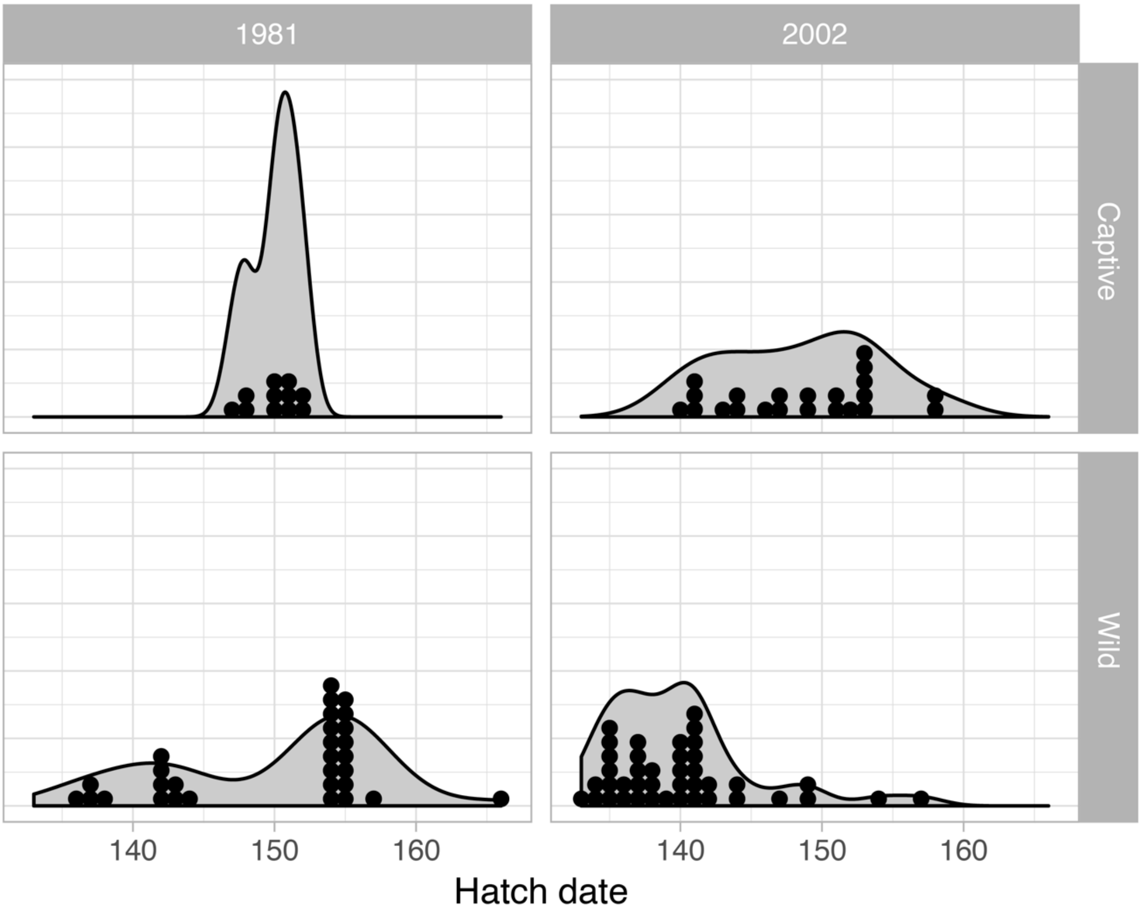


Figure S2. Hatch dates of captive (upper panels) and wild (lower panel) pied flycatchers in 1981 (left) and 2002 (right). Related to Figures 1-3. Each black circle represents one individual, shading indicates Kernel density estimates.

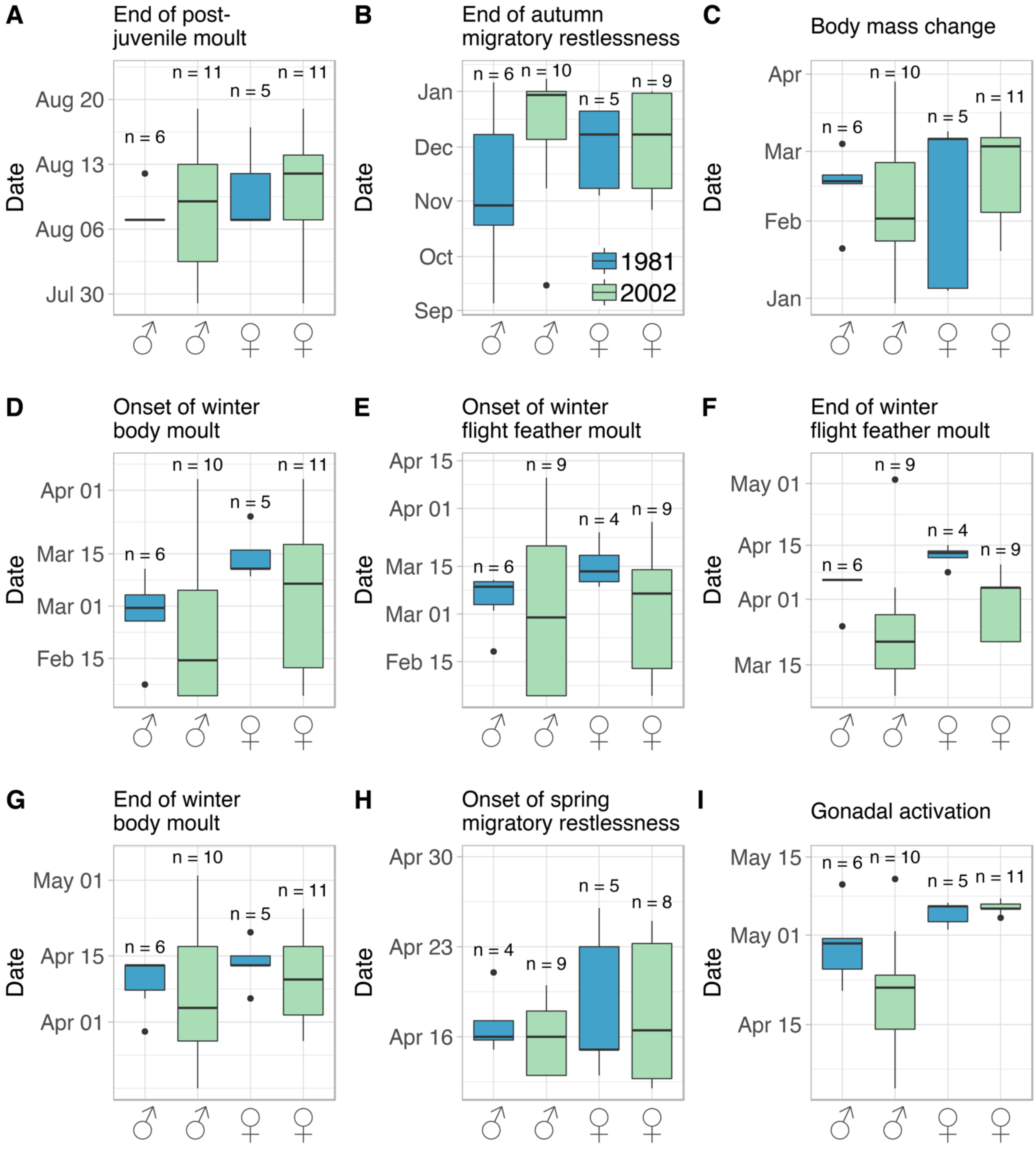
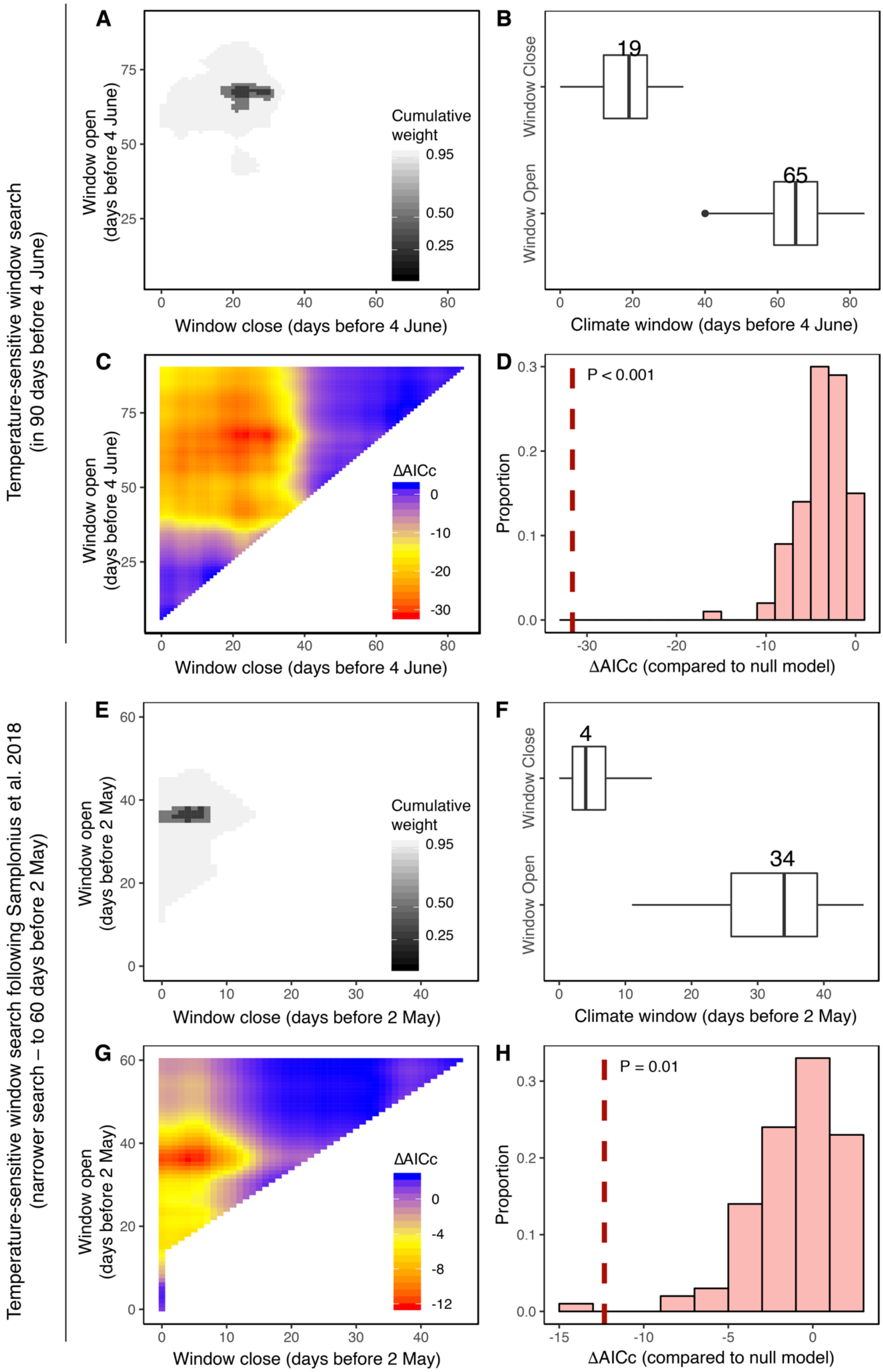


Figure S3. Timing traits by age and sex in 1981 and 2002. Related to Figure 2. Boxplots show the distribution of annual cycle events observed in captivity in 1981 (blue) and 2002 (green) for male and female flycatchers; for details, see Main text, Figure 2. **(A)-(I)** show individual timing traits as indicated by figure titles.



Temperature-sensitive window search
(in 90 days before 4 June)
A
Cumulative weight
0.95
0.50
0.25
Window open (days before 4 June)
Window close (days before 4 June)
B
Window Close
Window Open
19
65
Climate window (days before 4 June)
C
ΔAICc
0
-10
-20
-30
Window open (days before 4 June)
Window close (days before 4 June)
D
P < 0.001
Proportion
ΔAICc (compared to null model)
Temperature-sensitive window search following Samplonius et al. 2018
(narrower search – to 60 days before 2 May)
E
Cumulative weight
0.95
0.50
0.25
Window open (days before 2 May)
Window close (days before 2 May)
F
Window Close
Window Open
4
34
Climate window (days before 2 May)
G
ΔAICc
0
-4
-8
-12
Window open (days before 2 May)
Window close (days before 2 May)
H
P = 0.01
Proportion
ΔAICc (compared to null model)

Figure S4. Identification of the time window in which mean ambient temperature best explains flycatcher laydate. Related to Figure 4. (A–D) Only in a small number of windows did mean breeding site temperature show a strong relationship with laydate. The model-averaged best climate window occurred between March 29 and May 13. **(A)** Cumulative model weight; models summing to 0.95 of cumulative weight occupied a small range of windows. **(B)** Boxplots indicating the starting and ending dates of models summing to 0.95 cumulative weight; boxplots show the median as a line, the interquartile range as a box, and the farthest outliers less than 1.5 times the interquartile range from the box as whiskers. **(C)** Heatmap showing ΔAICc values for all tested climate windows. **(D)** Results of a randomization procedure to determine the probability that the observed signal is a false positive; histogram shows the lowest ΔAICc value for each randomization, and the red dashed line indicates the observed lowest ΔAICc value. **(E-H)** Samplonius et al. [S1] compared several flycatcher populations. Compared to our study, they used different years (1991-2015) and examined a narrower temporal range for possible climate windows. If we apply these methods to our population, estimated slopes of temperature and flycatcher laydate against year for 1991-2015 are comparable with Figure 4 in [S1]: temperature: 0.074 ºC yr^{-1}, 95% CI [0.0055,0.14]; laydate: -0.26 d yr^{-1}, 95% CI [-0.39, -0.13]). The model-averaged best climate window occurred between March 26 and April 27. The relationship between laydate and temperature, accounting for longitudinal change over time, was -1.1 d $ºC^{-1}$ (95% CI [-1.8,-0.37]), and the rate of annual change was -0.18 d yr^{-1} (95% CI [-0.31,-0.056]). Not accounting for longitudinal trend, the relationship between laydate and temperature was -1.5 d $ºC^{-1}$ (95% CI [-2.2,-0.75]). Our detected rate of change in laydate (-0.26 d yr^{-1}) was consistent with the advance predicted by Samplonius et al. [S1], given a measured change in temperature of 0.074 ºC yr^{-1} (see Figure 4 in that study). Similarly, our measured degree of plasticity (-1.1 d $ºC^{-1}$, accounting for the effect of year) is comparable with other flycatcher populations in Figure 3 in [S1].

Supplemental Reference

S1. Samplonius, J.M., Bartosova, L., Burgess, M.D., Bushuev, A.V., Eeva, T., Ivankina, E.V., Kerimov, A.B., Krams, I., Laaksonen, T., Magi, M., et al. (2018). Phenological sensitivity to climate change is higher in resident than in migrant bird populations among European cavity breeders. Glob Change Biol *24*, 3780-3790.