

Hatching phenology is lagging behind an advancing snowmelt pattern in a high-alpine bird

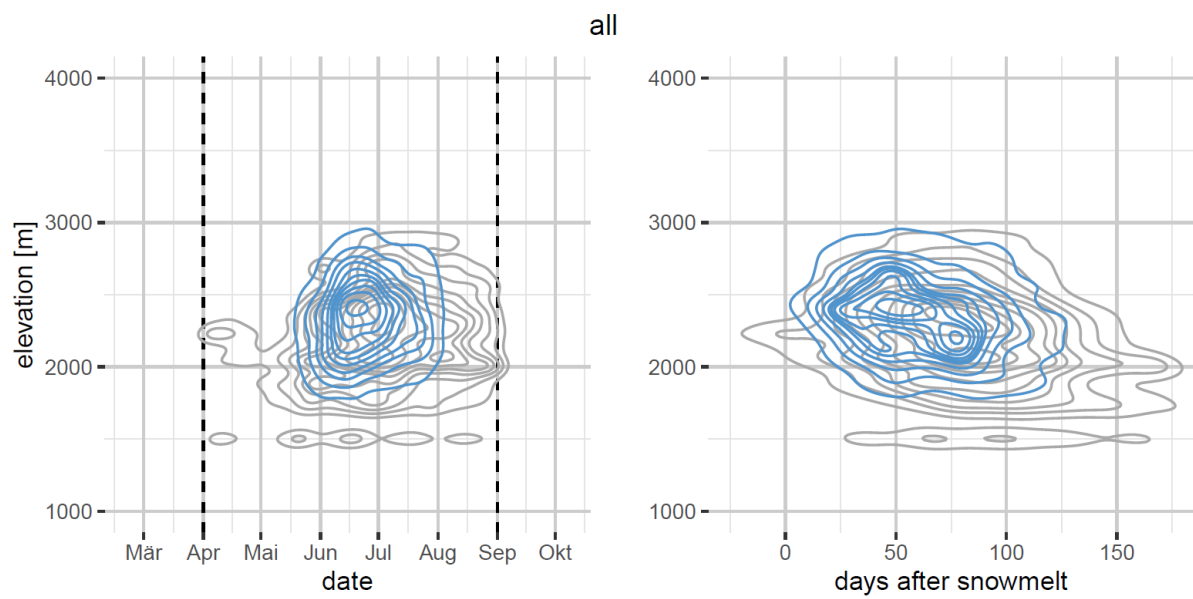
Christian Schano^{1,2,*}, Carole Niffenegger¹, Tobias Jonas³, Fränzi Korner-Nievergelt¹

¹ Swiss Ornithological Institute, Sempach, 6204, Switzerland

² University of Zurich, Department of Evolutionary Biology and Environmental Studies, 8057, Zurich, Switzerland

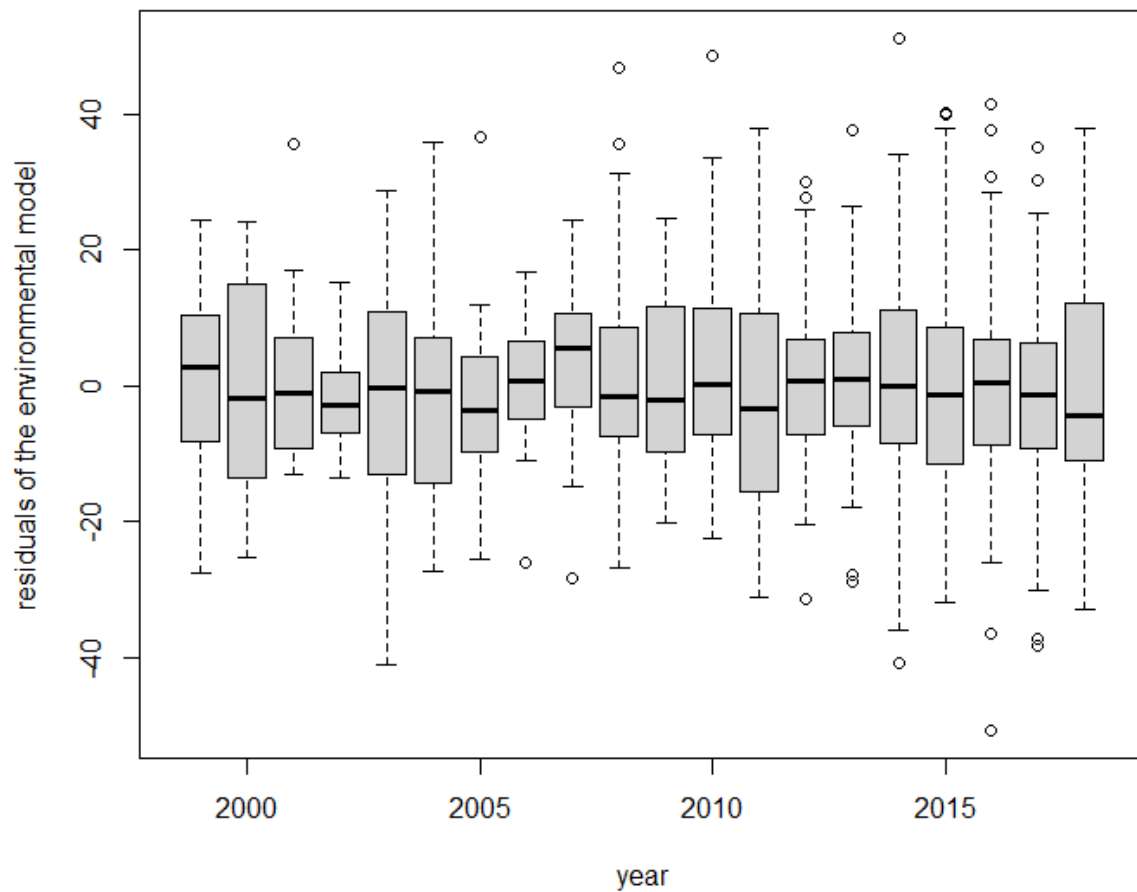
³ WSL Institute for Snow and Avalanche Research SLF, Snow Hydrology, 7260, Davos Dorf, Switzerland

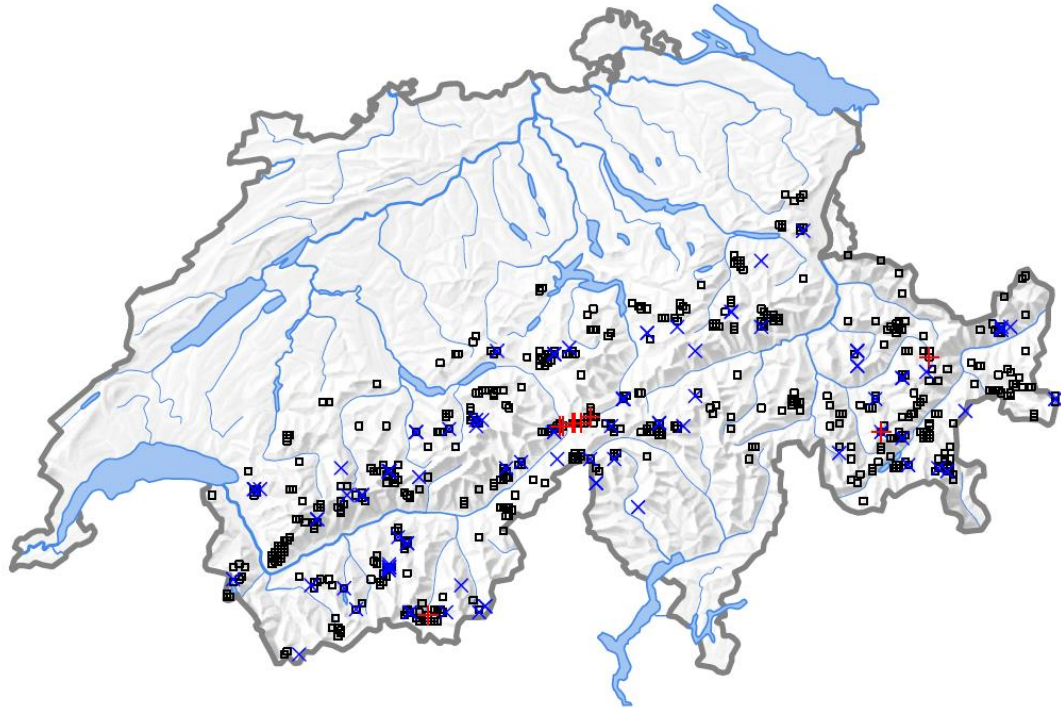
* christian.schano@vogelwarte.ch



Supplementary 1 Kernel densities with 10% mass distribution increments ranging from 95% to 5% for snowfinch hatching dates (blue) and observer presence (grey) by date (left) and relative to snowmelt (right) and elevation.

Supplementary 2 Residuals of the environmental model plotted against the year showing mean (horizontal, fat black lines), interquartile range (boxes), 1.5 times interquartile range (whiskers) and outliers (points) per year.

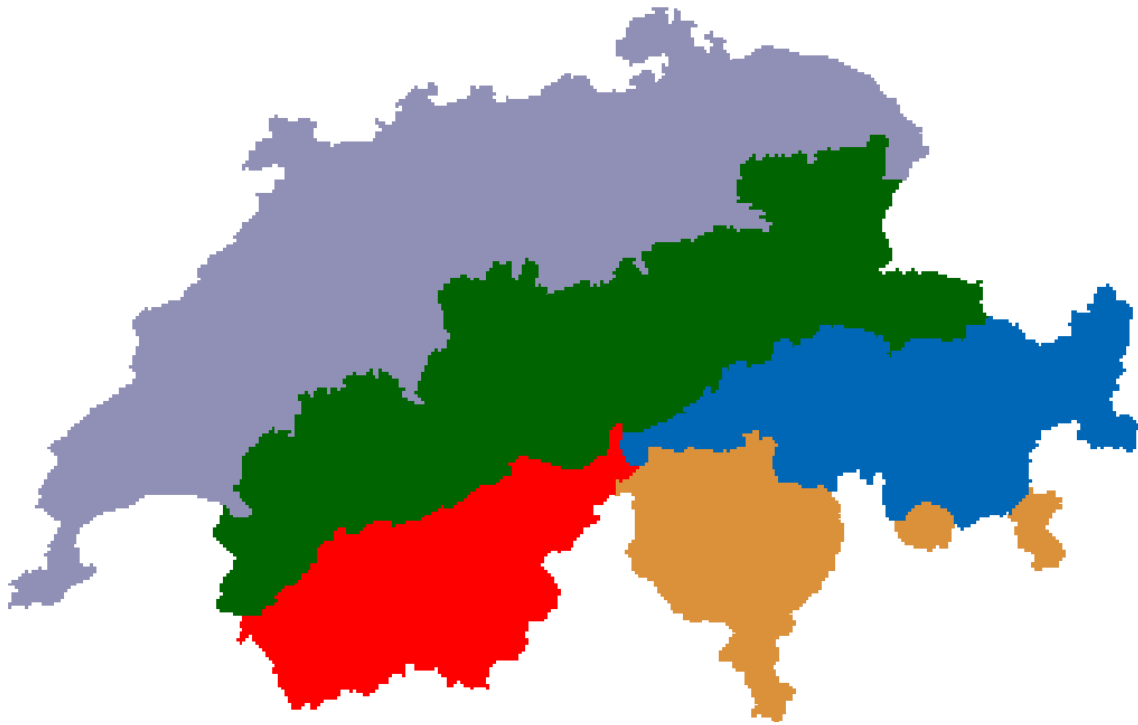




Supplementary 3 Map of Switzerland with observations of snowfinches 1999 - 2018. 1x1km grid cells with snowfinch observations from citizen scientists (black squares), standardized monitoring programs (blue "xx") and the brood monitoring program data (red "++") where calculating hatching dates was possible (© swisstopo).

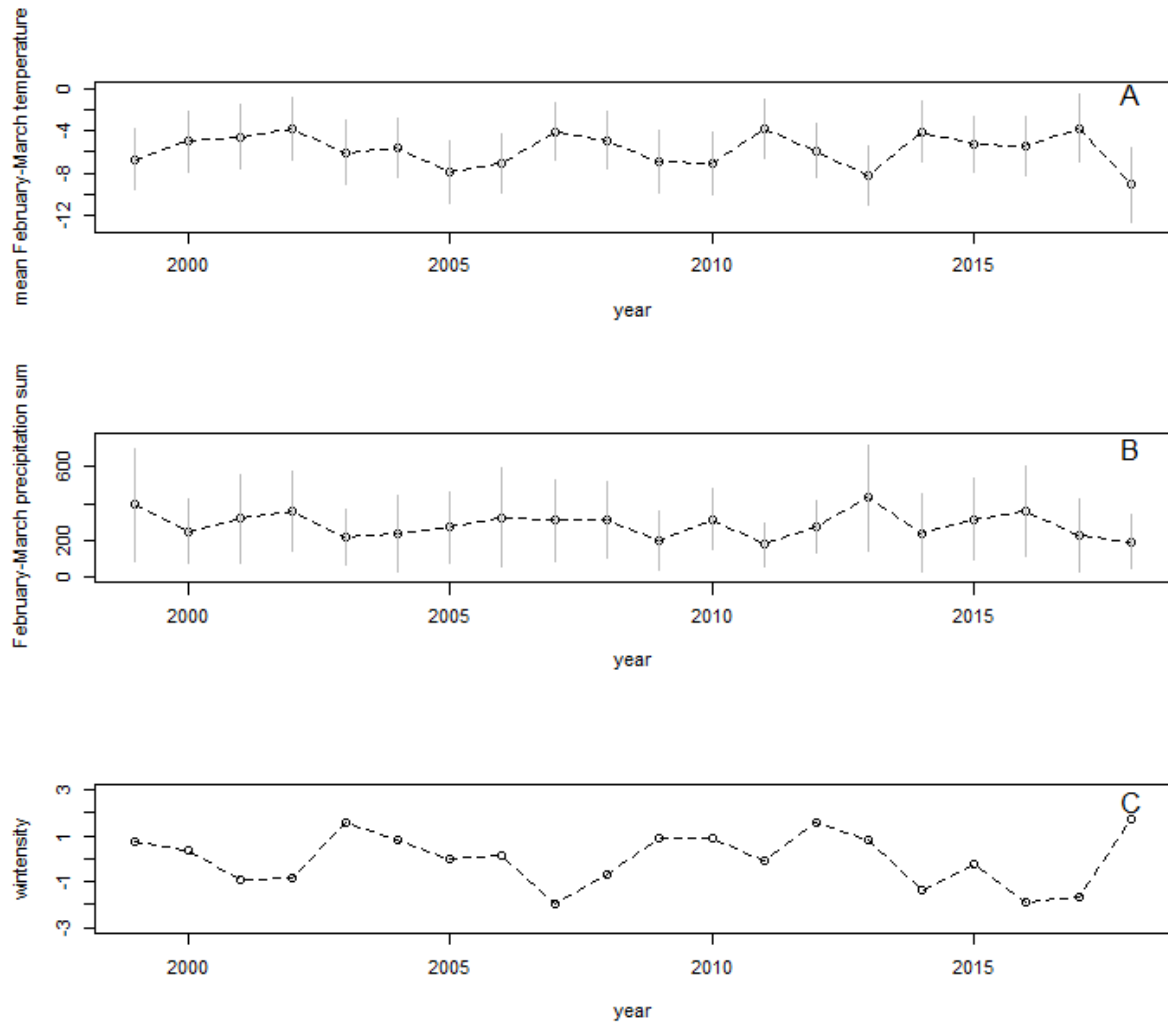
Supplementary 4 Atlas codes, descriptions and formulas used to calculate hatching dates. Abbreviations stand for (F) fledgling period – 7 days, (H) hatching period – 21 days, (I) incubation period – 13 days, and (N) nest building period – 13 days. Mean hatching dates per observation are based on the arithmetic mean between earliest calculated (hatchmin) and latest calculated (hatchmax) hatching date.

Atlas code	Description	Associated life event	Formula
8	Alarming adult indicating a nest or chicks close by	I or H	$\text{hatchmin} = \text{doyobs} - H + F - 1$ $\text{hatchmax} = \text{doyobs} + I$
10	Adult with nesting material or building nest	N	$\text{hatchmin} = \text{doyobs} + I + 1$ $\text{hatchmax} = \text{doyobs} + N + I$
11	Adult with distraction-display or injury-feigning	H	$\text{hatchmin} = \text{doyobs} - H + F - 1$ $\text{hatchmax} = \text{doyobs}$
12	Used nest from current season	I or H	$\text{hatchmin} = \text{doyobs} - H + F - 1$ $\text{hatchmax} = \text{doyobs} + I$
13	Recently fledged young	H or F	$\text{hatchmin} = \text{doyobs} - H + F - 1$ $\text{hatchmax} = \text{doyobs} - H$
14	Adults entering or leaving a potentially occupied nest	I or H	$\text{hatchmin} = \text{doyobs} - H - 1$ $\text{hatchmax} = \text{doyobs} + I$
15	Adult carrying fecal sac of chick	H	$\text{hatchmin} = \text{doyobs} - H - 1$ $\text{hatchmax} = \text{doyobs}$
16	Adult carrying food for chicks	H	$\text{hatchmin} = \text{doyobs} - H - 1$ $\text{hatchmax} = \text{doyobs}$
18	Nest with breeding adult	I	$\text{hatchmin} = \text{doyobs} + 1$ $\text{hatchmax} = \text{doyobs} + I$
19	Nest with eggs or chicks	I or H	$\text{hatchmin} = \text{doyobs} - H - 1$ $\text{hatchmax} = \text{doyobs} + I$



Supplementary 5 Biogeographic regions used for analysis of spatiotemporal patterns in snowfinch hatching dates (© swisstopo). Eastern Alps (blue), Northern Alps (Green), Southern Alps (orange), Western Alps (red) and excluded regions (grey).

Supplementary 6 Yearly mean temperature (a), precipitation (b) and winter intensity (c) for all kilometer squares with snowfinch observations between 1999 and 2018 indicating means (circles), ± 1.96 standard deviations (grey vertical lines), connected with a dotted line. We did not plot standard deviations for winter harshness, since we only had single estimates for the entire study area



Supplementary 7 Model description, used data and formulas for models used in the analysis. Model coefficients (β), elevation (elev), mean observer day (obsday), April-May precipitation sum (prcp), February-March average daily temperature (tave), winter intensity (winter), year (year, yeareff), among-year variance (σ_{year})

Model description	Used data	Formula
Long-term trends in hatching date	Hatching date for 1x1km grid cells with snowfinch observations in current season.	$\sim \beta_1 * elev_i + \beta_2 * elev_i^2 + \beta_3 * year_i + \beta_4$ $* elev_i * year_i + \sigma_{year}$ $* yeareff_{year[i]}$
Long-term trends in snowmelt start	Snowmelt start for 1x1km grid cells with snowfinch observations in current season and calculated for all 1x1km grid cells in Switzerland above 1500 m asl.	$\sim \beta_1 * elev_i + \beta_2 * elev_i^2 + \beta_3 * year_i + \beta_4$ $* elev_i * year_i + \sigma_{year}$ $* yeareff_{year[i]}$
Long-term trends in snowmelt end	Snowmelt end for 1x1km grid cells with snowfinch observations in current season and calculated for all 1x1km grid cells in Switzerland above 1500 m asl.	$\sim \beta_1 * elev_i + \beta_2 * elev_i^2 + \beta_3 * year_i + \beta_4$ $* elev_i * year_i + \sigma_{year}$ $* yeareff_{year[i]}$
Spatiotemporal patterns in hatching date	Snowfinch data from 1135 breeding records	$\sim \beta_{region[i]} + \beta_1 * elev_i + \beta_2 * obsday_i + \beta_3$ $* year_i + \beta_4 * elev_i^2 + \beta_5$ $* year_i * elev_i + \sigma_{year}$ $* yeareff_{year[i]}$

Spatiotemporal and environmental variables affecting hatching date	Snowfinch data from 1135 breeding records	$\sim \beta_{\text{region}[i]} + \beta_1 * \text{elev}_i + \beta_2 * \text{obsday}_i + \beta_3 * \text{year}_i + \beta_4 * \text{elev}_i^2 + \beta_5 * \text{year}_i * \text{elev}_i + \beta_6 * \text{winter}_i + \beta_7 * \text{prcp}_i + \beta_8 * \text{melt}_i + \beta_9 * \text{tave}_i + \sigma_{\text{year}} * \text{yeareff}_{\text{year}[i]}$
---	--	--

Supplementary 8 Pearson`s correlation coefficients between all predictors used for the spatiotemporal and the environmental model.

	elevation	observer day	year	winter intensity	snowmelt	precipitation	temperature	elevation ²
elevation	-	0.224	0.217	-0.161	0.347	-0.263	-0.573	0.998
observer day		-	0.429	0.117	0.124	0.046	-0.260	0.226
year			-	-0.288	0.031	-0.059	-0.081	0.211
Winter intensity				-	-0.033	-0.056	-0.557	0.002
snowmelt					-	0.266	-0.358	0.337
precipitation						-	0.039	-0.267
temperature							-	-0.570
elevation ²								-