**Electronic supplementary material**

**Timing of spring departure of long distance migrants correlates with previous year’s conditions at their breeding site**

Françoise Amélineau, Nicolas Delbart, Philipp Schwemmer, Riho Marja, Jérôme Fort, Stefan Garthe, Jaanus Elts, Philippe Delaporte, Pierre Rousseau, Françoise Duraffour, Pierrick Bocher

Biology Letters

S1: deployment protocol

European curlews (*Numenius arquata arquata*) were captured at three study sites either during the winter in Germany and France, or during the breeding season in Estonia. Captures during the winter were performed at night using mist-nests on high-tide roosting sites. French birds were equipped at Lilleau des Niges nature reserve (île de Ré, 46°N 14’ 24’’, 1°W 30’ 17’’) and at Moëze-Oléron Nature Reserve (45°N 54’ 00’’, 1°W 4’ 27’’) in 2015 and 2016. German birds were equipped at three different sites along the German Wadden Sea coast (i.e. Hamburger Hallig: 54° N 36' 43", 8° E 50' 23"; Friedrichskoog: 54° N 2' 30", 8° E 52 ' 7" as well as near Hallig Helmsand: 54° N 3' 52’’, 8° E 57' 59") between 2015 and 2017. Estonian curlews were captured on their nest using walk-in traps in the region of Central-Estonia 58° N 59' 26", 25° E 53' 85" in 2015.

GPS tags were EOBS bird solar GPS-UHF tags (20 g, e-obs GmbH, Gruenwald, Germany) in Estonia, Ecotone Sterna GPS-UHF (35x16x10 mm, 7.5 g) in France and Ecotone Skua GPS-UHF-GSM (58x27x18 mm, 17 g) in Germany (Ecotone Telemetry, Gdynia, Poland). GPS tags were attached using Teflon harnesses with leg loop (France) or wing loop (Germany and Estonia) attachment methods. GPS tags recorded fixes every 5-60 min. GPS data were downloaded remotely via a base station situated at roosting or breeding sites. Ecotone Skua GPS-UHF-GSM also transmitted partial data via the cell phone network.

S2: Green-up date estimation by remote sensing

The remote sensing method [1] is based on the Normalized Difference Water Index (NDWI), which is the normalized difference of near infrared (NIR) and short-wave infrared (SWIR) surface reflectances. It has been designed to avoid the signal misinterpretation due to snowmelt at spring that disturbs the green-up date retrieval from the commonly used vegetation spectral index times series [2,3]. NDWI decreases with the progressive disappearance of the snow cover, and increases during the foliage development. The green-up date is thus recorded as the time when the NDWI starts increasing. Precisely it is taken as the last date within the March-July period when NDWI has increased by less than 20% of its total increase in this period.

Comparison with leaf budburst date measurements at ten sites in Siberian forests showed a 8-day root-mean square difference [1,4]. Comparison with citizen science observations showed that when pixels dominated by agriculture or water bodies are excluded from the dataset, the green-up date allows monitoring the interannual variations in leaf and flower spring phenology of a large cohort of species [5].

This method was applied to PROBA-V data from 2014 to 2017, at a resolution of 1km. Pixels dominated by agriculture and water were identified using the GLC2000 map [6] and rejected. The green-up at the nest site is the average of the green-up dates of all pixels located at less than 10 km from the nest.

Because the method is designed to catch the time at which NDWI starts increasing, it is more uncertain where the NDWI increase amplitude between spring and summer is low. Pixels are rejected when this amplitude is below an arbitrary threshold set equal to 0.1. That concerns pixels which are almost unvegetated, or pixels with purely evergreen vegetation for which seasonality is non-apparent in the remote sensing image time series.

References

1. Delbart N, Kergoat L, Le Toan T, Lhermitte J, Picard G. 2005 Determination of phenological dates in boreal regions using normalized difference water index. *Remote Sens. Environ.* **97**, 26–38. (doi:https://doi.org/10.1016/j.rse.2005.03.011)

2. Shabanov NV, Zhou L, Knyazikhin Y, Myneni RB, Tucker CJ. 2002 Analysis of interannual changes in northern vegetation activity observed in AVHRR data from 1981 to 1994. *IEEE Trans. Geosci. Remote Sens.* **40**, 115–130. (doi:https://doi.org/10.1109/36.981354)

3. Dye DG, Tucker CJ. 2003 Seasonality and trends of snow-cover, vegetation index, and temperature in northern Eurasia. *Geophys. Res. Lett.* **30**. (doi:https://doi.org/10.1029/2002GL016384)

4. Delbart N, Picard G, Le Toan T, Kergoat L, Quegan S, Woodward IAN, Dye D, Fedotova V. 2008 Spring phenology in boreal Eurasia over a nearly century time scale. *Glob. Change Biol.* **14**, 603–614. (doi:https:doi.org/10.1111/j.1365-2486.2007.01505.x)

5. Delbart N, Beaubien E, Kergoat L, Le Toan T. 2015 Comparing land surface phenology with leafing and flowering observations from the PlantWatch citizen network. *Remote Sens. Environ.* **160**, 273–280. (doi:https://doi.org/10.1016/j.rse.2015.01.012)

6. Bartholomé E, Bogaert P, Cherlet M, Defourny P, Mathoux P, Vogt P. 2002 Rescaling NDVI from the VEGETATION instrument into apparent fraction cover for dryland studies. In *GLC200 first results workshop*, Ispra.



Figure S1: Differences in green-up date between successive years. The boxplot depicts paired differences in green-up dates between the year and the previous year at each nest site, for 2016 and 2017. The green-up date unit is day of year. 2016: n= 17; 2017: n=18. A grey segment links both observations at each nest site. Blue: previous year. Yellow: year.

Table S1: Details on equipped birds: equipment site, logger type, breeding and wintering sites of equipped birds.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bird ID | Equipment site | Logger type | Wintering country | Breeding country | Nest longitude (°E) | Nest latitude (°N) | Migration distance (km) | Number of spring migrations tracked |
| DECU05 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 36.71 | 62.72 | 1779 | 1 |
| DECU06 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 40.97 | 64.04 | 2033 | 2 |
| DECU13 | Germany | Ecotone Skua GPS-UHF-GSM | Germany & Denmark | Russia | 37.14 | 63.05 | 1606 | 2 |
| DECU14 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 41.11 | 60.26 | 2015 | 2 |
| DECU20 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 34.22 | 62.85 | 1726 | 1 |
| DECU21 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 39.87 | 62.23 | 1986 | 1 |
| DECU22 | Germany | Ecotone Skua GPS-UHF-GSM | Germany | Russia | 39.93 | 62.33 | 1993 | 1 |
| FAB01 | France | Ecotone Sterna GPS-UHF | France | Russia | 39.86 | 59.75 | 3016 | 1 |
| IRU04 | France | Ecotone Sterna GPS-UHF | France | Russia | 40.65 | 64.57 | 3177 | 1 |
| IRU07 | France | Ecotone Sterna GPS-UHF | France | Russia | 52.52 | 58.64 | 3724 | 2 |
| IRU11 | France | Ecotone Sterna GPS-UHF | France | Russia | 36.58 | 60.52 | 2812 | 1 |
| IRU12 | France | Ecotone Sterna GPS-UHF | France | Russia | 43.89 | 57.37 | 3117 | 2 |
| LIM21 | France | Ecotone Sterna GPS-UHF | France | Russia | 47.39 | 60.72 | 3379 | 2 |
| LIM22 | France | Ecotone Sterna GPS-UHF | France | Russia | 34.49 | 55.46 | 2616 | 1 |
| LIM24 | France | Ecotone Sterna GPS-UHF | France | Finland | 26.04 | 61.91 | 2416 | 2 |
| LIM25 | France | Ecotone Sterna GPS-UHF | France | Belarus | 28.19 | 52.74 | 2186 | 2 |
| LIM29 | France | Ecotone Sterna GPS-UHF | France | Russia | 45.77 | 61.80 | 3361 | 2 |
| MOZ01 | France | Ecotone Sterna GPS-UHF | France | Russia | 32.09 | 54.29 | 2484 | 1 |
| MOZ02 | France | Ecotone Sterna GPS-UHF | France | Germany | 9.44 | 54.25 | 1126 | 1 |
| MOZ06 | France | Ecotone Sterna GPS-UHF | France | Russia | 40.25 | 64.59 | 3233 | 1 |
| MOZ07 | France | Ecotone Sterna GPS-UHF | France | Belarus | 28.18 | 52.74 | 2172 | 1 |
| MOZ10 | France | Ecotone Sterna GPS-UHF | France | Russia | 44.12 | 59.46 | 3270 | 1 |
| URI02 | France | Ecotone Sterna GPS-UHF | France | Russia | 40.60 | 63.55 | 2932 | 1 |
| Schilling | Estonia | E-OBS Bird Solar Tag | Denmark | Estonia | 25.97 | 58.95 | 1106 | 1 |
| Struve | Estonia | E-OBS Bird Solar Tag | UK | Estonia | 26.36 | 59.05 | 1728 | 1 |
| Barklay | Estonia | E-OBS Bird Solar Tag | Netherlands | Estonia | 25.97 | 58.18 | 1330 | 1 |