Climatic connectivity may drive bird migration strategies

To maximize fitness, migratory organisms must choose the best place and time to perform their fundamental activities in the face of unpredictable variation in ecological conditions. Because natural selection strongly penalizes the individuals that fail to synchronize their activities with current environmental conditions, species have evolved to track cyclical or otherwise predictable changes in ecological settings. In contrast, fluctuations over shorter periods of major ecological factors that heavily affect most organisms, like temperature or precipitations, may occur rather unpredictably. The need to accommodate such stochastic fluctuations is the apparent evolutionary reason why many organisms have retained some level of temporal flexibility in the time schedule of their activities ('phenology').

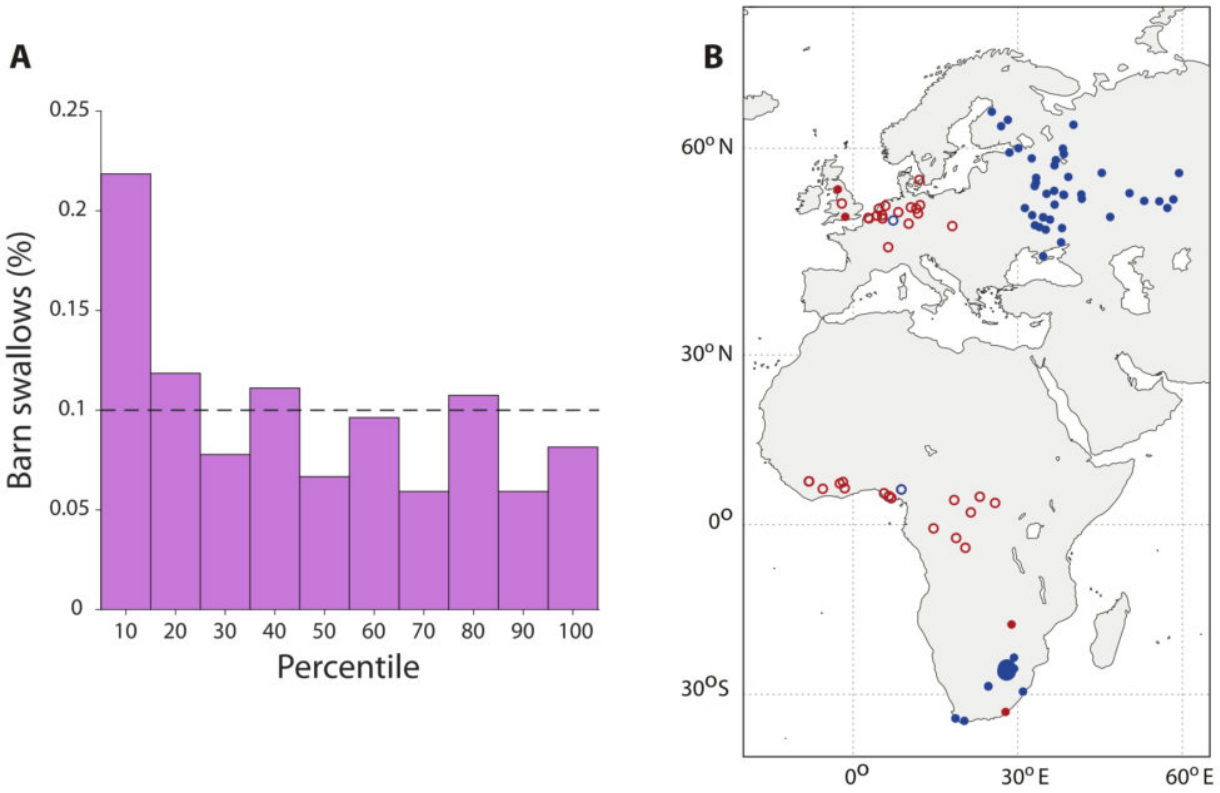

Fig. 1. A. Ranking of partial correlations coefficients between time series of temperatures at arrival time in Europe and time series of temperatures at departure time from Africa. Climatic series in the actual African locations are contrasted to alternative locations in the whole sub-Saharan African subcontinent. The dashed line is the expected distribution that would have been found if no site selection occurred (complete random process). B. Geographical locations of the 61 barn swallows for which time series of temperatures at departure time from Africa explained at least 10% of the variance of time series of temperatures at arrival time in Europe. Marker filling identifies individuals in the two clusters that are either North of 7°S (cluster N, empty circles) or South of 18°S (cluster

S, filled circles), which correspond to the clusters of individuals that could be identified based on previous analyses of the migratory connectivity of the same species. Colors code for signs of the partial correlation coefficients between time series of temperatures at departure time from Africa and time series of temperatures at arrival time in Europe (red for positive and blue for negative). Dot size is proportional to the number of individuals found at the given location.

Plants and resident animals can directly sense the progress of seasonal variation in local ecological conditions, while migratory animals that periodically move over large distances have no direct clue as to the conditions that they will experience along their migration journey and at destination, weeks to months later. Migrants are therefore particularly susceptible to environmental uncertainties and, consequently, to the negative effects of human-driven, rapid climate change. The fitness advantages of appropriate timing of life-history events, however, is expected to select the ability to capitalize on any environmental cue that allows buffering the negative effects of unpredictability, for instance, large-scale climatic connections between distant geographical regions.

Together with our colleague Nicola Saino, we used information from ringing data for 270 barn swallows *Hirundo rustica* that were captured during breeding in Europe and were later recovered during wintering in Africa (or vice versa) during the period 1930-2009. We tested if correlations exist between temperatures in the wintering sites in sub-Saharan Africa just before the start of northward pre-nuptial (‘spring’) migration and the temperatures at their individual breeding sites in Europe at the time of spring arrival from migration, several weeks later. We found that such correlations do indeed exist, suggesting that migrants may obtain information on the temperatures at destination while they are still on their wintering grounds. Such time-lagged temperature correlations were not generally very strong, as could be expected. However, mild advantages arising from tuning migration schedules according to proxies on future conditions at destination can provide a selective advantage.

We also found that temperatures in the breeding European sites of individual barn swallows at the time of arrival from spring migration have significantly stronger correlations with those in their wintering sites than with those in any other locations in sub-Saharan Africa. This suggests that the choice of the wintering location might be aimed to maximize the information on annual conditions at the breeding site that is available before the start of migration. Notably, the sign of the temperature correlations between the wintering and the breeding sites varied between geographical barn swallow populations that could be identified based on previous analyses of migratory connectivity. Western European barn swallows often winter in equatorial Africa and experience positive temperature correlations whereas Eastern European barn swallows winter in southern Africa and experience negative correlations.

Our results lead to hypothesize that other migratory species may use information from

environmental cues at one end of their migration journey to adaptively modulate their migration phenology. In addition, they suggest that the existence of time-lagged climatic correlations can have a role in shaping the evolution of migration strategies, in the choice of the wintering sites and, ultimately, in the evolution of migratory connectivity. Whether this will boost the ability of populations to cope with the effects of current climate change or not, will largely depend on whether differential climate change in the breeding and in the non-breeding staging areas disrupts the existing climatic correlations between them.

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