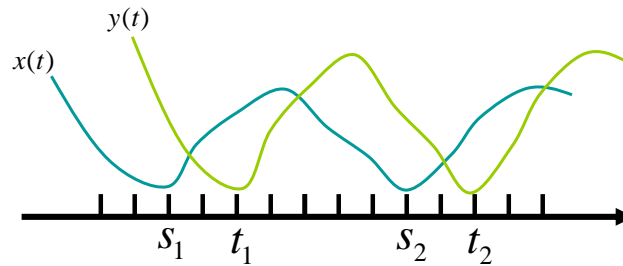


Supporting Text

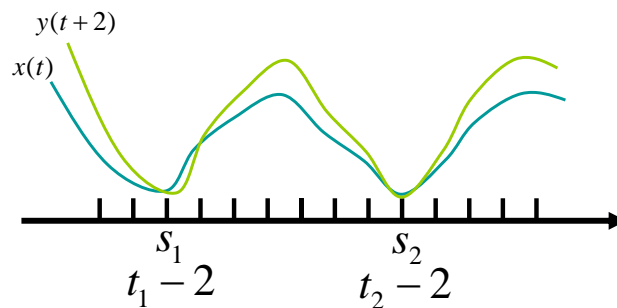
Measuring Synchrony

Optimal Phase Shift. A characteristic feature of the Canadian lynx time series (L1–L22) is the regular fluctuations with peaks (troughs) roughly every 7–11 years. The degree of synchrony between two lynx series $x(t)$ and $y(t)$ defined on the same (or at least overlapping) time intervals may be assessed by comparing the low (high) points s_1, \dots, s_p of $x(t)$ and the low (high) points t_1, \dots, t_q of $y(t)$. Specifically, we may ask what time shift k that makes s_1, \dots, s_p “optimally aligned” with $t_1 + k, \dots, t_q + k$.

To illustrate, let $x(t)$ and $y(t)$ be the two curves in the figure below.



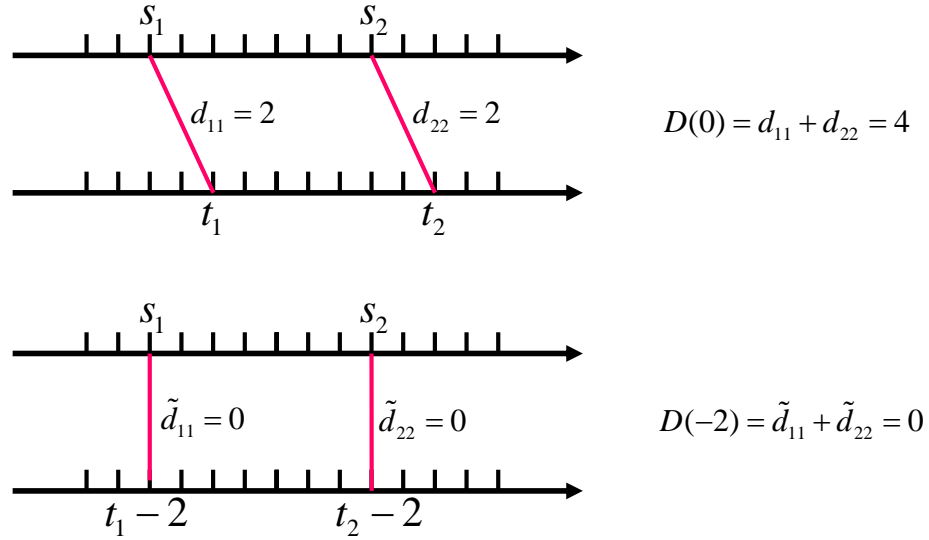
Here, s_1 and s_2 are the low points of $x(t)$, and t_1 and t_2 are the low points of $y(t)$. The best alignment of the troughs is found by replacing $y(t)$ with $y(t + 2)$, which implies that we replace t_1, t_2 by $t_1 - 2, t_2 - 2$:



To find the optimal alignment computationally, we define the distance between s_1, \dots, s_p and $t_1 + k, \dots, t_q + k$ as

$$D(k) = \min \left(\sum_{i=1}^p \min_j |s_i - t_j - k|, \sum_{j=1}^q \min_i |s_i - t_j - k| \right).$$

For the above example, we find $D(0)$ and $D(-2)$ as illustrated below:



The optimal shift k is defined as the local minimizer of $D(k)$ around 0. For optimal performance, the range of k values to optimize over should depend on the period of the cycles. As a rough guide, the range of k may extend half a period to the left of 0 and half a period to the right of 0. In the present paper, we let

$$k \in \{-5, -4, \dots, 4, 5\}.$$

Correlation. A commonly used method of assessing the degree of synchrony between two time series $x(t)$ and $y(t)$ defined on the same time interval is to calculate Pearson's correlation coefficient,

$$r = \frac{Cov(x, y)}{\sqrt{Var(x)Var(y)}} = \frac{\sum_{t=1}^n (x(t) - \bar{x})(y(t) - \bar{y})}{\sqrt{\sum_{t=1}^n (x(t) - \bar{x})^2 \sum_{t=1}^n (y(t) - \bar{y})^2}}.$$

This measure quantifies the strength of the linear relationship between x and y .

Simulations

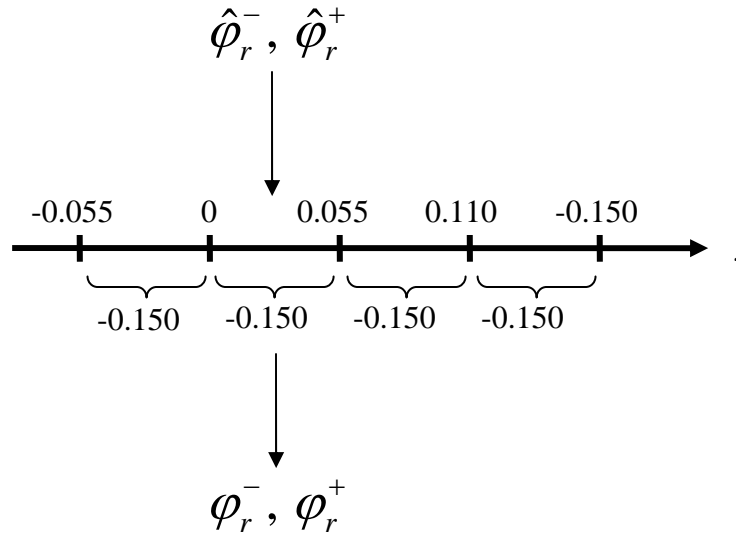
Model Used to Generate Synthetic Data. The following self-exciting threshold autoregressive (SETAR) model with external forcing was used to generate synthetic data corresponding to the Pacific region (P), Continental region (C), and Atlantic region (A):

$$y_{r,t} = \begin{cases} \beta_{r,0}^- + \beta_{r,1}^- y_{r,t-1} + \beta_{r,2}^- y_{r,t-2} + \varphi_r^- f_t + \psi_r^- \varepsilon_{r,t}, & y_{r,t-2} \leq \theta_r \\ \beta_{r,0}^+ + \beta_{r,1}^+ y_{r,t-1} + \beta_{r,2}^+ y_{r,t-2} + \varphi_r^+ f_t + \psi_r^+ \varepsilon_{r,t}, & y_{r,t-2} > \theta_r \end{cases} \quad (1)$$

Here,

- $y_{r,t}$ represents the log-abundance at a site in region $r \in \{P, C, A\}$ in year t .
- f_t is the external forcing, $f_t = \sin(2\pi\omega t)$ where $\omega = (7.5)^{-1}$.
- $\varepsilon_{r,t}$ is independent (in time and space) $N(0,1)$ noise.

Table 4 shows the values used for the parameters in **Eq. 1**. The parameter values in the table were derived from estimates of **Eq. 2** by using observed lynx time series from each of the three regions, with the North Atlantic oscillation (NAO) as an external forcing. The numerical range of NAO is different from that of the external forcing term used in the simulations, and the estimates $\hat{\varphi}_r^-$ and $\hat{\varphi}_r^+$ for the NAO parameters using observed lynx time series also have some uncertainty. The external forcing parameters φ_r^- and φ_r^+ used in our simulations were determined from these estimates by a discretization (binning) followed by a scaling, as shown in the diagram below:



The noise variance parameters were defined as $\psi_r^- = \varphi_r^- / 3$ and $\psi_r^+ = \varphi_r^+ / 3$.

Migration. Although some lynx migrate during all phases of the cycle, field studies show that the (effective) migration rate is considerably higher during years of decreasing densities. More observational data are certainly needed to make firm conclusions regarding relative rates of effective dispersal in the different phases of the lynx cycle. Our model simplified this aspect of lynx demography to one migrant in the decreasing phase and zero in the other phases. One migrant during some years is a sufficiently low number of migrants to allow simulation of considerable differentiation between populations of a pair, which is necessary to compare the level of differentiation under different conditions. Simulations of pairs of populations with five emigrants in the decreasing and low phase and one emigrant in the other phases (10 offspring in decreasing years and emigration scenario 1 depicted in Fig. 2B) showed higher differentiation between Atlantic/Continental dynamic (AC) populations than between Continental dynamic (CC) populations after 1,000 years (F_{ST} 0.034 versus 0.029; i.e., 18% difference compared with 21% for the same scenario with 1 and 0 migrants), indicating that, qualitatively, our results do not depend on this simplifying assumption.

Significance Levels in the Genetic Simulations. Significance was determined in a permutation test: the 400 F_{ST} values resulting from the two batches of 200 runs to compare were randomly divided into two groups (10,000 times). If the observed difference in means was $> 95\%$ of the means of the random groups, the levels of differentiation were considered significantly different (one-sided test). In order to minimize the effect of random variation from year to year, the average F_{ST} for the 10 last years (991–1000) for each simulation run was used. The mean difference in F_{ST} between 400 replicates of CC and AC populations was significant (CC: $F_{ST} = 0.138$; AC: $F_{ST} = 0.148$; $P = 0.007$). AA populations (mean $F_{ST} = 0.141$) were more differentiated than CC populations, but this difference was not significant ($P = 0.45$); they were however significantly less differentiated than AC population pairs ($P = 0.008$).

Effects of Climate and Snow

Stenseth *et al.* (ref. 1; see www.sciencemag.org/feature/data/1037845.shl) reported that when the NAO or its first lag is included as a covariate in the decrease phase of the SETAR model fitted to two panels of 21 Canada lynx series, significant NAO effects were found in 7 lynx series, and marginally significant NAO effects were found in 5 more series (5% significance level). Interestingly, the NAO coefficients are generally positive for lynx from the western part of Canada (Pacific-maritime and western part of Continental), but then switch to negative values for lynx from the eastern part of Canada (eastern part of Continental and Atlantic-maritime). It was speculated that snow conditions could be a structuring factor.

The importance of snow for the population dynamics of lynx is demonstrated by observing that properties of snow enter the functional response curve (Mark O'Donoghue, unpublished data) as implied by Stenseth *et al.* (N.C.S., A. Shabbar, K.-S.C., S.B., E.K.R., D.E., J.W.Hurrell, O.C.L., and K.S.J., unpublished data).

$$\varphi(x) = \frac{(0.221 + 0.591 \cdot \text{phase})x}{1 + (0.603 + 0.667 \cdot \text{phase} + 0.0735 \cdot \text{snow})x} + \text{noise},$$

where $\varphi(x)$ denotes the observed kill rate and x the hare density; phase = 1 over the decrease phase of the lynx cycle and 0 otherwise; snow is the snow-depth at day 150 since December 1. This model was selected by Akaike's Information Criterion (AIC) among a range of models with some of the coefficients set to 0. The fitted functional response curve suggests that the lynx suffer lower hunting efficiency with deeper snow conditions, more so over the decrease phase than the increase phase of the population cycle.

1. Stenseth, N. C., Chan, K.-S., Tong, H., Boonstra, R., Boutin, S., Krebs, C. J., Post, E., O'Donoghue, M., Yoccoz, N. G., Forchhammer, M. C. & Hurrell, J. W. (1999) *Science* **285**, 1071-1073.