Diatomflickeringprioortoregimeshift


Potential early warnings signals for regime shifts are studied intensively in the field of ecology. Wang and colleagues investigated changes in the diatom assemblage composition during the event, indicating a shift to a new regime. The data were collected in Lake Erhai, China, and concluded that the regime shift was significant and occurred around 2001.

We propose that the results may be more representative of the data processing method of the diatom data. Although flickering behaviour before regime shifts may be observed in some palaeoenvironmental records, we question whether this behaviour applies to diatoms in Lake Erhai. There is a Reply to this Brief Communication Arising by Wang et al. Nature 498, http://dx.doi.org/10.1038/nature12773 (2013).

Wang et al. base their conclusions on changes in standard deviation, skewness and lag 1 autocorrelation of the diatom assemblage composition (detrended correspondence analysis; DCA) and its diversity (Hill’s diversity index N2; HDI) in a sediment core. The statistics were calculated with a 59-year sliding window on the residuals from a linearly interpolated time series, detrended by subtracting a smooth exponential moving average.

We were intrigued by these results, and while investigating the underlying statistical analyses, we noticed three points. First, decreasing timeseries resolution as well as the depth of the samples, represented approximately 1 year in the upper part and approximately 4 years in the deeper part of the sediment profile (Supplementary Fig. 2 in ref. 1). Greater temporal aggregation in the deeper profile reduces the temporal variance in diatom composition, giving a reduced standard deviation for the oldest data. Second, linear interpolation to produce an annual timeseries alters the statistical properties of the timeseries by reducing the standard deviation, increasing autocorrelation and broadening the expected distribution of skewness.

Coarser resolution in the older sediment results in more interpolated values and thus lower standard deviation and higher autocorrelation. Third, their detrending does not subtract a smooth curve, but a phase-shifted version of the original data with a tendency to overshoot when the original curve changes direction. This result is in large residues when there are abrupt changes in the data. These are expected in the highest resolution part of the core, where there is least averaging and interpolation. These sensitivity tests applied don’t seem to address the fundamental problem of under-sampled temporal data.

To assess the null expectation of the methods, we used a simulated timeseries with a characteristic similarity to those of the DCA and added uncorrelated noise (Fig. 1a). Random variation of the underlying simulated time series is reduced unevenly by aggregation that mimics the sampling from Lake Erhai and interpolation (Fig. 1b). Standard deviation is reduced by factors of approximately 6 in the older data and approximately 3 in the more recent data (Fig. 1c). The cumulative standard deviation over time reported in the paper by Wang et al. has a similar magnitude to that expected from a purely random process analysed with their methods. The skewness broadens when the sliding windows are data with varying standard deviations, and there is a slight shift towards a positive value (Fig. 1d). The skewness reported also displays an overshoot towards the negative values within the bounds of expected values. Data processing introduces stronger autocorrelation in the older data, and this is reduced gradually with improved temporal resolution (Fig. 1e), consistent with the pattern that they described.

We reanalysed the data from the paper by Wang et al. without interpolation, using a more robust detrending approach and accounting for differences in temporal aggregation by implicitly assuming variance heterogeneity (Fig. 2a, b). There is a gradual increase of approximately 50% in the DCA standard deviation, much smaller than the increase they reported, and the HDI standard deviation does not change (Fig. 2c, d). Skewness in DCA and HDI displays quite different patterns, not observed in their paper, and remains within the approximate 95% confidence bounds (±1.0) expected from a random normal process. Autocorrelation does not decrease overtime and is generally low.

The trends in standard deviation, skewness and autocorrelation reported as potential early warning signals of a “regime shift in the trophic state of Lake Erhai” by Wang et al. are inconsistent with the null expectation of their methods and are not reproduced with more robust methods. We therefore suggest that these may be an artefact of the numerical methods used and the inherent problems in time-series analysis of samples with uneven temporal spacing from sediment cores.

Figure 1 | Simulated data processing and early warning signals. a, One simulation of the underlying data-generating process and the time series resulting from temporal aggregation, interpolation and smoothing b, Residuals from the simulated process, and from the data processing in ref. 1. c–e, Distribution of standard deviation, skewness and lag 1 autocorrelation (AR1) from 1,000 simulations using 59-year sliding windows during the period between 1883 to 2000. This figure is for comparison with Fig. 3 of ref. 1. Grey horizontal lines mark 0 on the y-axis.
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REPLYING TO J.Carstensen, R.J.Telford & H.J.Birks

Some issues have been raised with regard to our paper by Carstensen et al. We confirm that in our original manuscript we indeed used detrended correspondence analysis (DCA), Hill's diversity index (HDI), and LOESS smoothing functions. Our conclusions regarding the early warning signals were based on these analyses, even though there may be other methods available. We have re-analyzed our data using the method described in Carstensen et al. and have found that our conclusions remain valid. The main results of our analysis are as follows:

- **Figure 2**: Re-analysis of potential early warning signals compiled from the diatom community in Lake Erhai. The trends in diatom composition and diversity based on detrended correspondence analysis (DCA) of diatom composition are shown in panel (a), while panel (b) shows the HDI diversity index (HDI) with a LOESS smoothing function used for detrending.

**Methods**

We simulated time series (n = 1,000) with an annual resolution of a process that resembles the characteristics of DCA. The trend decreases slowly before 1960 and faster thereafter, and the standard deviation of the uncorrelated noise is 0.25. The time series were aggregated to mimic the observed samples spacing. The remaining analysis follows ref. 1.

To repeat the analysis of early warning signals with more robust methods, we detrended the non-interpolated DCA and HDI values before 2001 (Fig. 1 in ref. 1) with a LOESS smoothing function. Residuals from the detrending were standardized by the square root of the period, and the values represent a count of the differences in temporal aggregation. Autocorrelation is calculated from the data with missing values, calculation of early warning signals otherwise follows ref. 1.

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Notethattheresultsdonotreplicatethefullrangeofourtests.Theydonotseemtoaddressthesizeofwindowsize,thesensitivitytothe fullrangeofinformations,ortheformofinformations(including correspondence analysis). Their assumption that “Greater temporal aggregation in the deeper profile reduces the temporal variation in diatom composition” has to be countered by the observation that among the samples dating back to 1885 (n = 49), two of the seven larger temporal aggregations (≈3.4 years per sample compared to the mean of 2.4 ± 0.9 years per sample) are in fact recent samples, dated to 1986 and 1998 (Supplementary Fig. 2 in ref. 1).

The new simulation method proposed by Carstensen et al. does not test the hypothesis of interest, but again does not fully account for the temporal aggregation in the actual DCA data. Instead, it resembles our DCA data. The model does not use the real time periods in the sediment data derived from the dating model and does not account for the real errors in the dating model. Therefore, the simulation demonstrates a general principle for testing a model but does not itself overturn the findings from the analysis of our paper.
In conclusion, given the sensitivity of residual growth functions and the choice of parameters (for example, window size and span value), the main implication of the work by Carstensen et al. is that future studies of sediment data should evaluate the results from a wider range of smoothing-function options. In any case, we do not advocate the use of time-series analysis of sediment data online to infer early warning signals. At Lake Erhai, China, our test included a wealth of real-time observations (for example, algal blooms) that amounted to prima facie evidence for increased ecosystem instability before a critical transition. In our view, the new results do not make a case for overturning the main findings of the paper.

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