

Patterns and ecological implications of historical marine phytoplankton change

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Data Sources and Methods

All data used in this were extracted from publicly available sources (Table S1). Publication statistics used to produce Fig. 1 were extracted from SciVerse Scopus (www.info.sciverse.com/scopus) and the Thomsom ISI Web of Science (www.apps.webofknowledge.com), which represent two of the largest abstract and citation data bases for peer-reviewed scientific literature. To standardize the proportion of publications for each marine taxa, the number of articles published in each year was divided by the total number of published articles in the same year and multiplied by 100. Time trends in the scientific literature on phytoplankton were estimated using generalized additive models (GAMs; Hastie & Tibshirani 1986, Wood 2006).

Phytoplankton abundance as indicated by chlorophyll *a* (Chl; mg m^{-3}) was derived from remotely-sensed ocean-leaving radiances measured by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS; McClain et al. 2004). Climatological surface nitrate concentrations (N ; $\mu\text{mol l}^{-1}$) were extracted from the NODC World Ocean Atlas (2009) and are available as global 1° by 1° objectively analyzed measurements. Zooplankton biomass measurements (mg C m^{-3}) were extracted from the COPEPOD database (O'Brien 2005) and are available at a near-global 1° by 1° resolution

Standardized time series of westerly weather, phytoplankton, zooplankton, herring, and kittiwake breeding success as reported by Aebischer et al. (1990) were extracted as yearly averages using data digitization software (www.getdata-graph-digitizer.com). Indices of the North Atlantic Oscillation Index (NAO), and the Atlantic Multidecadal Oscillation (AMO) were extracted from the sources listed in Table S1. The NAO represents the first principle component from a rotated principle components analysis (RPCA) applied to monthly standardized pressure anomalies across the North Atlantic (20° to 90°N ; ref. Barnston & Livezey 1987). The AMO represents the area-weighted SST average over the North Atlantic (0° to 70°N). To remove high-frequency temporal variability, all series were smoothed using GAMs. Following this smoothing procedure, all series were re-scaled such that they were represented on the same scale (between -1 and 1).

Variance estimate for phytoplankton trends

The standard deviation was used as an estimate of phytoplankton trend variability within each $5^\circ \times 5^\circ$ degree cell. This statistic is appropriate since the estimates of change were all standardized to common units of percent of the initial time-series value per year. Following this procedure the standard deviation was positively correlated to the mean rate of phytoplankton change per cell. We attempted to correct for this by using alternate variance statistics such as the relative coefficient of variation (RCV) and the coefficient of L-variation (CLV), but these appeared to be biased in instances where the average rate of change was close to 0.

Table S1. Data sources

Parameter	Source	Webpage	Reference
Chlorophyll	NASA	www.oceandata.sci.gsfc.nasa.gov	McClain & Signorini (2004)
Zooplankton	COPEPOD	www.st.nmfs.noaa.gov/plankton/biomass/index.html	O'Brien (2005)
Nitrate	WOA09	www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html	Boyer et al. (2009)
North Atlantic Oscillation	NOAA	www.cpc.noaa.gov/products/precip/Cwlink	Barnston & Livezey (1987), van den Dool et al. (2000), Chen & van den Dool (2003)
Atlantic multidecadal oscillation	NOAA	www.esrl.noaa.gov/psd/data/timeseries/AMO/	Enfield et al. (2001)

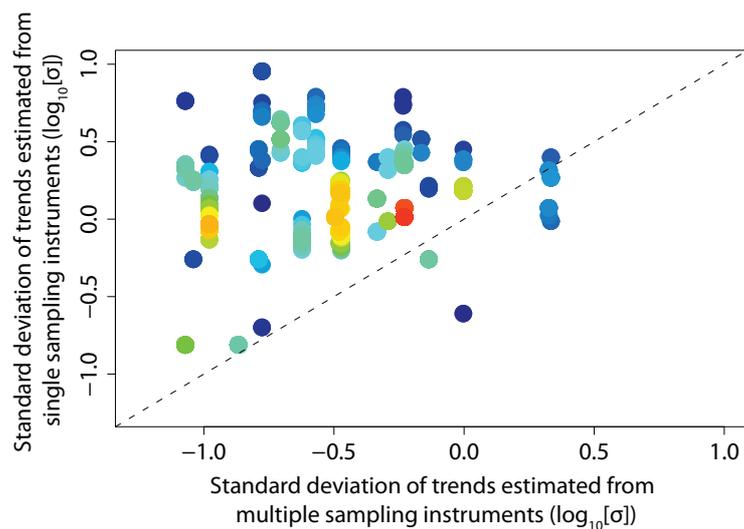


Figure S1. Variance of available phytoplankton time trends within each $5^\circ \times 5^\circ$ cell estimated using data from multiple sampling instruments (x-axis) and from single sampling instruments (y-axis). The colours depict the density of the points, where blue are few and red are many points per pixel. Dashed line depicts an intercept of 0 and slope of 1.

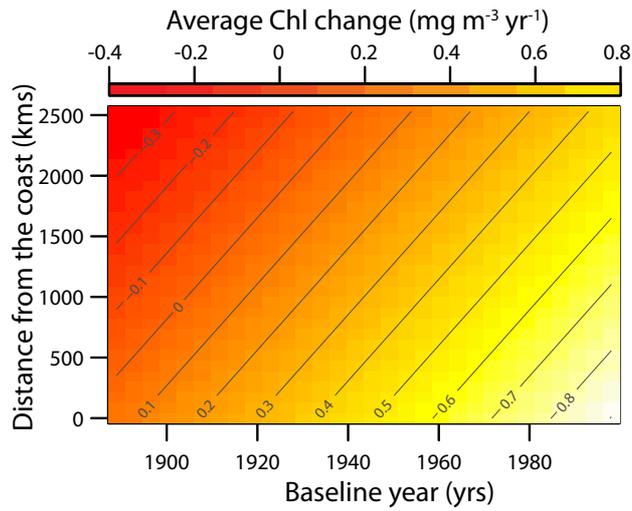


Figure S2. Effects of location and baseline year on phytoplankton trends. Shown are the modelled effects of distance from the nearest coastline and baseline year of time series on all extracted rates of phytoplankton change. Color depicts the magnitude of the mean rate of phytoplankton change.

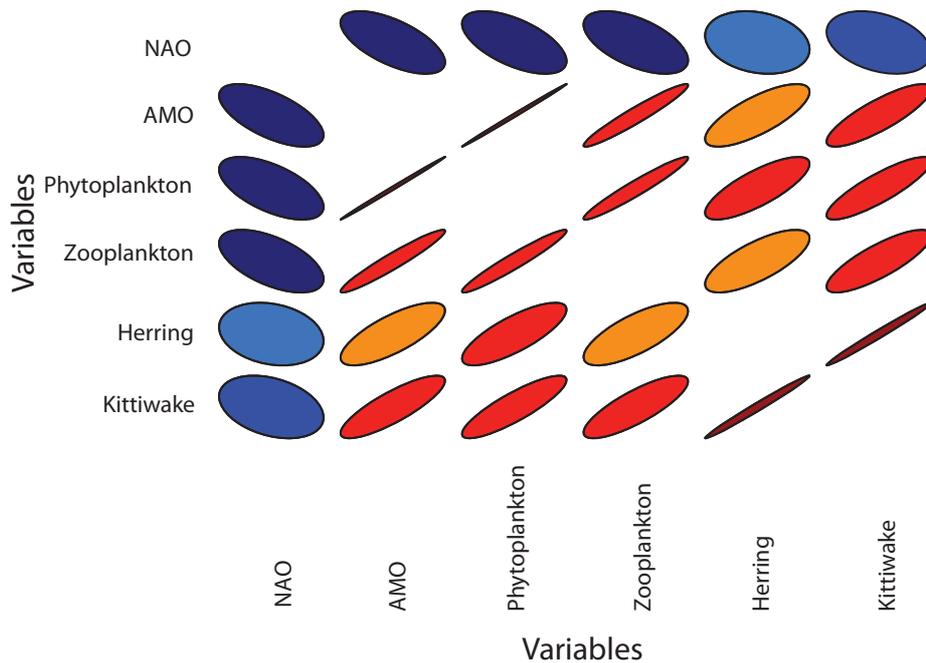


Figure S3. Linear correlation between time series of climate and abundance. The shape and color of the ellipses represent the strength and direction of the relationships. Blue depicts negative relationships and red depicts positive relationships. Flatter ellipses represent stronger relationships. White represents correlations of 1.

Supplementary References

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