

Is there a decline in marine phytoplankton?

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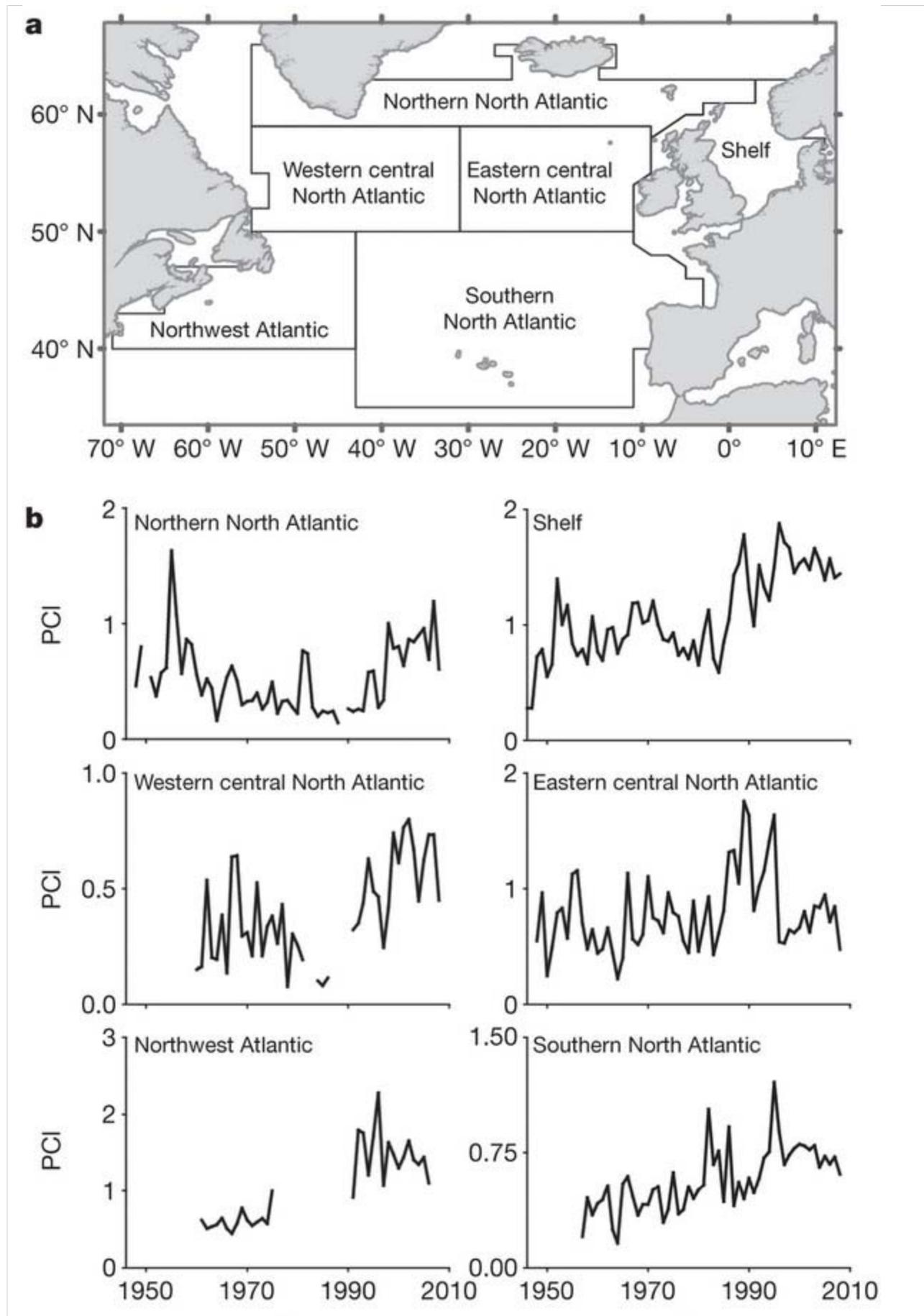
Phytoplankton account for approximately 50% of global primary production, form the trophic base of nearly all marine ecosystems, are fundamental in trophic energy transfer and have key roles in climate regulation, carbon sequestration and oxygen production. Boyce *et al.*¹ compiled a chlorophyll index by combining *in situ* chlorophyll and Secchi disk depth measurements that spanned a more than 100-year time period and showed a decrease in marine phytoplankton biomass of approximately 1% of the global median per year over the past century. Eight decades of data on phytoplankton biomass collected in the North Atlantic by the Continuous Plankton Recorder (CPR) survey², however, show an increase in an index of chlorophyll (Phytoplankton Colour Index) in both the Northeast and Northwest Atlantic basins^{3, 4, 5, 6, 7} (Fig. 1), and other long-term time series, including the Hawaii Ocean Time-series (HOT)⁸, the Bermuda Atlantic Time Series (BATS)⁸ and the California Cooperative Oceanic Fisheries Investigations (CalCOFI)⁹ also indicate increased phytoplankton biomass over the last 20–50 years. These findings, which were not discussed by Boyce *et al.*¹, are not in accordance with their conclusions and illustrate the importance of using consistent observations when estimating long-term trends.

Subject terms: Ecology Climate science Planetary sciences

Since 1931 more than 5 million nautical miles of ocean have been sampled by ships of opportunity towing the CPR and more than 250,000 phyto- and zooplankton samples, including the Phytoplankton Colour Index (PCI), analysed using a virtually unchanged methodology¹⁰. Although the CPR's mesh size is 270 μm , the device consistently collects small cells—such as coccolithophores—on the silk¹⁰; with recent work indicating that the relative contribution of smaller size fractions to the PCI is increasing in some regions¹¹. The PCI also accounts for fragile, broken and fragmented cells that contribute to phytoplankton biomass but are not morphologically identifiable. PCI has repeatedly been successfully intercalibrated with measurements of chlorophyll from the SeaWiFS^{6, 7} satellite sensor and, in contrast to the findings of Boyce *et al.*¹, shows an increase in phytoplankton biomass throughout much of the North Atlantic (Fig. 1).

Figure 1: Results from the CPR survey show increased phytoplankton in most regions of the North Atlantic.





Year

Year

a, Sub-regions, based on CPR Standard Areas, used to illustrate long-term regional variability of phytoplankton trends. **b**, Trends in the PCI in the North Atlantic from 1946–2008. Only years with >7 months of data were used in trend calculation. The reduction in the PCI after 1995 in the eastern central North Atlantic is attributed to changes in the strength and extent of the subpolar gyre¹⁵.

For the first 50 years of the Boyce *et al.*¹ time series, the majority of the chlorophyll estimates were derived from Secchi measurements; later, chlorophyll sampling became a standard oceanographic procedure and after 1980 most of the data were from *in situ* chlorophyll measurements. The 'mixed' data set of Boyce *et al.*¹ does not take into account the fact that the relationship between Secchi depth visibility and chlorophyll concentration may not be spatially or temporally uniform¹², and may therefore be biased. Boyce *et al.*¹ use chlorophyll measurements (and presumably Secchi depth readings, although this is unclear) from the top 20 m of the water column. This coincides well with the CPR sampling depth, but does not take into account the high levels of chlorophyll found in the deep chlorophyll maximum. The Secchi–chlorophyll relationship is debatable for another reason: everywhere, even in oligotrophic ocean regions, Secchi disk visibility is influenced by non-living suspended particles and by 'gilvin' (dissolved organic matter), not only by phytoplankton-containing pigments—of which chlorophyll is only one. The high chlorophyll values at the beginning of the time series in figure 4a in ref. 1 are derived mostly from Secchi observations. If these are excluded, the trend in the chlorophyll index changes to positive in the North Atlantic, Equatorial Atlantic, South Atlantic, North Pacific and South Pacific. These post-1980 trends are consistent with results from other sustained monitoring programmes such as HOT⁸, BATS⁸ and CalCOFI⁹, as well as the CPR survey. The increasing trend in chlorophyll in the 1980s for the North Atlantic is also clear in the satellite observation records cited by Boyce *et al.*¹ (see figure 2 in ref. 13 and figure 7 in ref. 14).

On the basis of the data from the CPR survey and the BATS programme, chlorophyll in the North Atlantic is shown to be increasing, especially after 1980. This increase is also seen in long-term time series from the North Pacific (HOT, CalCOFI). This considerable body of data contrasts with the results presented by Boyce *et al.*¹; it indicates that there is no strong evidence for a marked decline in global marine phytoplankton.

Methods

CPR samples are collected by a high-speed plankton recorder (~9–23 knots) towed in the mixed surface layer of the ocean (~10 m depth); one sample represents 18 km of tow. Water passes through the recorder, and plankton are filtered by a slow moving silk band (mesh size 270 µm). A second layer of silk covers the first and both are reeled into a tank containing 4% formaldehyde. The PCI is based on a relative scale of greenness caused by accumulation of phytoplankton cells on the silk, and determined by reference to a standard colour chart¹⁰.

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Competing financial interests

The authors declare no competing financial interests.

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