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Above :
Mud shrimp *Solenocera membranacea* larva, caught in the western Bay of Biscay. - Juan Bueno, Instituto Español de Oceanografía (IEO)

Cover image:
Assorted copepods and a decapod caught in the Mallorca Channel. - María Luz Fernández de Puelles, Instituto Español de Oceanografía (IEO)

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The time-series analyses and figures used in this report were created using COPEPODITE:
http://www.st.nmfs.noaa.gov/copepodite

10. ZOOPLANKTON OF THE NORTH ATLANTIC BASIN

Priscilla Licandro, Claudia Castellani, Martin Edwards, and Rowena Stern

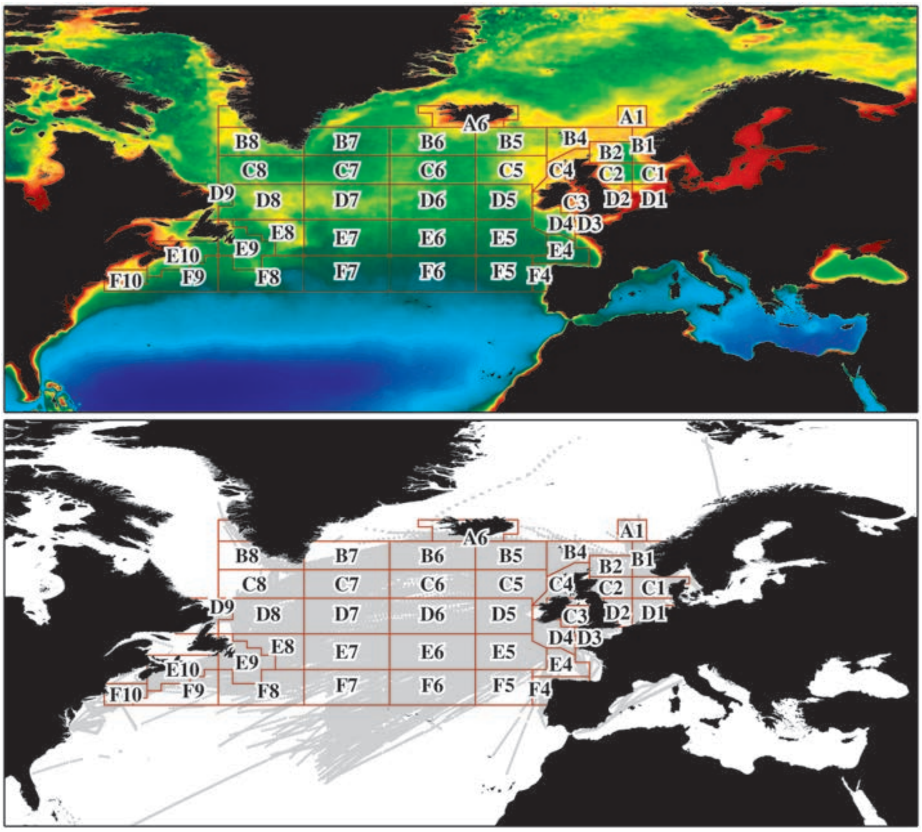

Figure 10.1
Locations of Continuous Plankton Recorder (CPR) standard areas (outlined in red). The top panel shows these areas on a map of average chlorophyll concentrations (see Section 2.3.2). The bottom panel shows the CPR transect and sampling coverage (grey dots) available within each of these areas.

The CPR survey is a long-term subsurface marine plankton monitoring programme consisting of a network of CPR transects towed monthly across the major geographical regions of the North Atlantic. It has been operated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS; http://www.SAHFOS.org) in the North Sea since 1931, with some standard routes existing with virtually unbroken monthly coverage back to 1946.

The CPR instrument is towed just below the surface behind volunteer-operated vessels (ships of opportunity), sampling plankton onto a moving 270 µm band of net silk as the vessel and CPR unit traverse the North Atlantic and/or North Sea. Within the CPR instrument, the net silk and its captured plankton are preserved in formalin until they are returned to the SAHFOS laboratory. During processing, the net silk is divided into sections representing 10 nautical miles of towing, and each section, which represents ~3 m^3 of filtered seawater, is analysed for plankton composition and abundance and other routine analyses including the estimation of the greenness of the silk (i.e. Phytoplankton Colour Index, PCI). The identification of up to 500 different phytoplankton and zooplankton taxa is part of the analysis (Warner and Hays, 1994). The greenness of the silk is determined by the chloroplasts of unbroken and broken cells as well as small, unarmoured flagellates, which tend to disintegrate on contact with the net. Direct comparisons between the phytoplankton colour index and other chlorophyll *a* estimates, including SeaWiFS satellite estimates, indicate strong positive correlations (Batten *et al.*, 2003; Raitsos *et al.*, 2005). The PCI, thereby, is considered a good index of total phytoplankton biomass.

The North Atlantic CPR database contains more than 5 million plankton observations analysed from more than 200 000 silk sections. By representing the midpoint of each silk section with a grey dot, the spatial coverage of the North Atlantic area of the CPR survey is shown in Figure 10.1. For the purpose of the assessment in this report, the North Atlantic basin has been geographically subdivided into different spatial regions (Figure 10.1; red boxes). The forty geographical regions shown in the figures are known as CPR standard areas and are referenced by their alphanumeric identifiers (e.g. "B2", "D8").

The CPR data from the standard areas were processed using standard report methods (see Section 2.1) as applied to the other plankton time-series presented in this report. For the purpose of viewing the long-term CPR trends in a spatial context, the standard report graphics (see Section 2.2) were truncated into the graphical forms described in Figure 10.2 and used in the "Spatial Trends Plots" of this section (Figures 10.3–10.8).

Basin-scale trends in zooplankton

In inshore and offshore waters of the Northeast Atlantic, total copepod abundance (Figure 10.3) has been significantly decreasing since the beginning of the time-series ($p \leq 0.05$). A similar trend was also observed in the central part of the western North Sea (e.g. C2 and D2), while in the western North Atlantic, copepod abundance has remained relatively stable.

To understand long-term changes in zooplankton populations, it is essential to consider the changes occurring in the lower trophic levels and in the regional marine environment. Indices of phytoplankton, such as the PCI and the sum of the abundance of all counted diatoms and dinoflagellates, help to represent the general functional response of phytoplankton to the changing environment. Sea surface temperature (SST) is considered to be a good proxy for hydroclimatic variability.

Overall, Figures 10.4 and 10.5 show a general increase in SST and PCI along the western and eastern boundaries. It is worth noting that phytoplankton biomass (based on PCI) mainly increased in the Northeast Atlantic and around the Newfoundland Shelf, where the increase in temperature was particularly significant ($p < 0.01$). In contrast Figures 10.3 and 10.6–10.8 show a clear west–east difference in the decadal trends of total copepods, diatoms, dinoflagellates, and tintinnids. In the western North Atlantic, diatoms, dinoflagellates, and tintinnids have increased, whereas copepod abundance has remained more or less the same. In contrast, in the eastern North Atlantic, diatoms, dinoflagellates, and copepods have generally decreased. Hence, the basin-wide trend increase in PCI suggests that the phytoplankton increase in the eastern Atlantic may be due to an increase in small photosynthetic organisms such as flagellates, which are less nutritious than diatoms and dinoflagellates for copepods. Thus, the observed decadal decline in copepod abundance appears to be driven by a decline in prey availability in the eastern North Atlantic (Figures 10.6–10.8) compared to the western North Atlantic. Although the basin-scale increase in SST alone cannot explain the difference in total copepod abundance between the western and eastern North Atlantic, temperature does exert an important effect on copepod physiology and metabolic rates. Hence, it is possible that the SST increase also contributed to the decline in total copepod abundance, particularly in the eastern Atlantic, where copepods might have been more food-deprived.

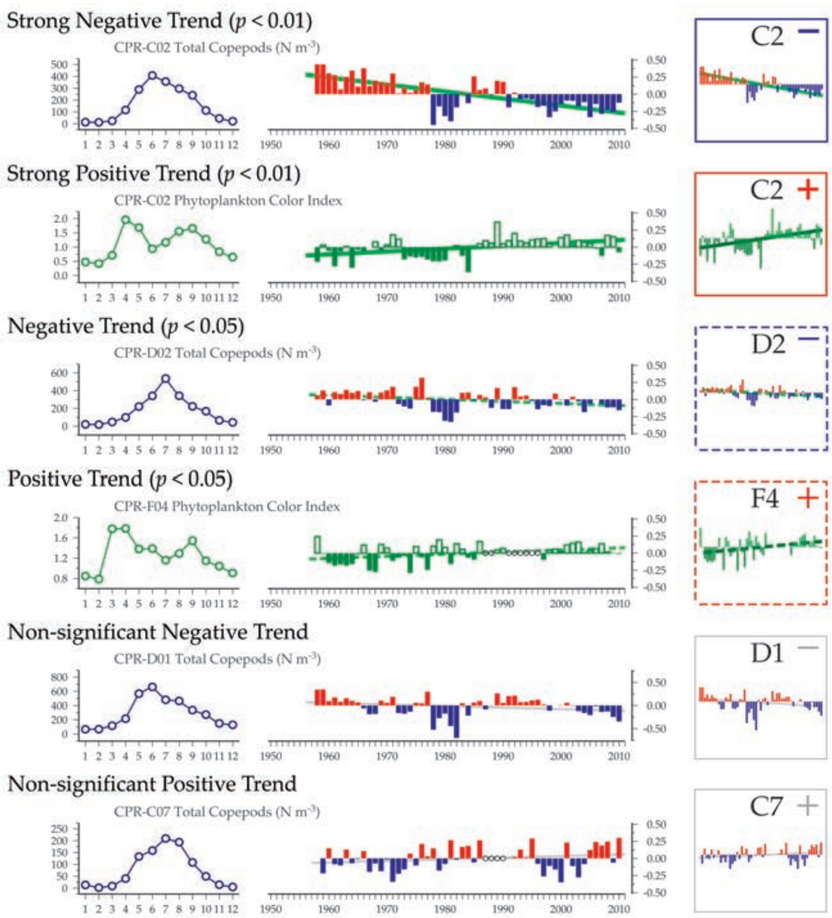

Figure 10.2
Examples of CPR standard area data shown in the standard report plot format (left column, see Section 2.2.2) and their corresponding truncated forms (right column) as presented in the "Spatial Trends Plots" shown later in this section.

The truncated form incorporates the standard annual anomaly trend representation (e.g. the green and grey slope lines) as described in Section 2.2. Positive significant trends ($p < 0.01$ or $p < 0.05$) are indicated with a red box outline, negative significant trends are indicated with blue box outline. Solid box outlines indicate $p < 0.01$, dashed boxed outlines indicate $p < 0.05$. Non-significant trends are outlined in grey. Trend directions ("+", "-") are also indicated in all cases.

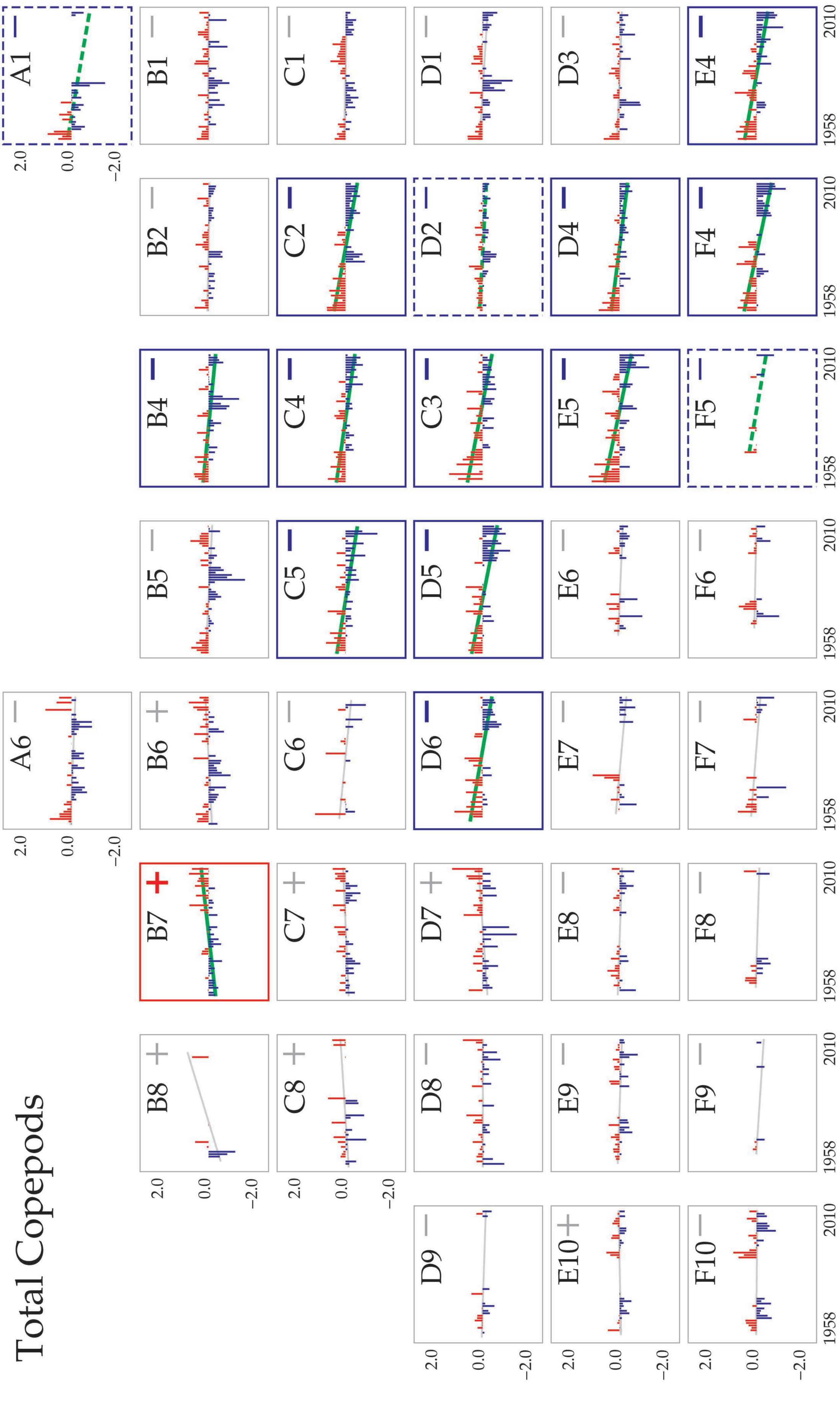

Figure 10.3
Spatio-temporal trends plot for Total Copepods time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1958 to 2010.

Phytoplankton Colour Index

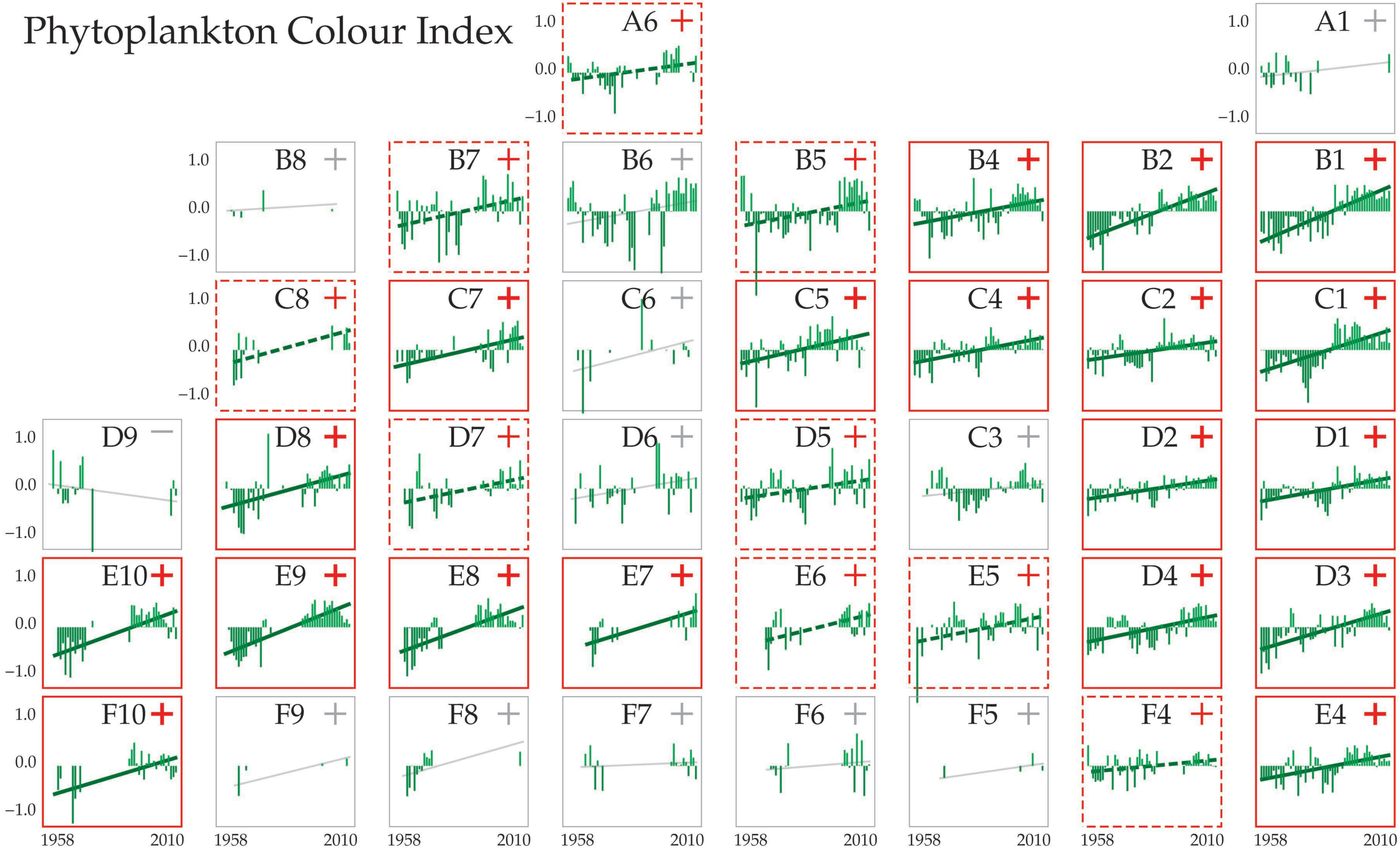

Figure 10.4
Spatio-temporal trends plot for Phytoplankton Colour Index time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1958 to 2010.

Sea Surface Temperature

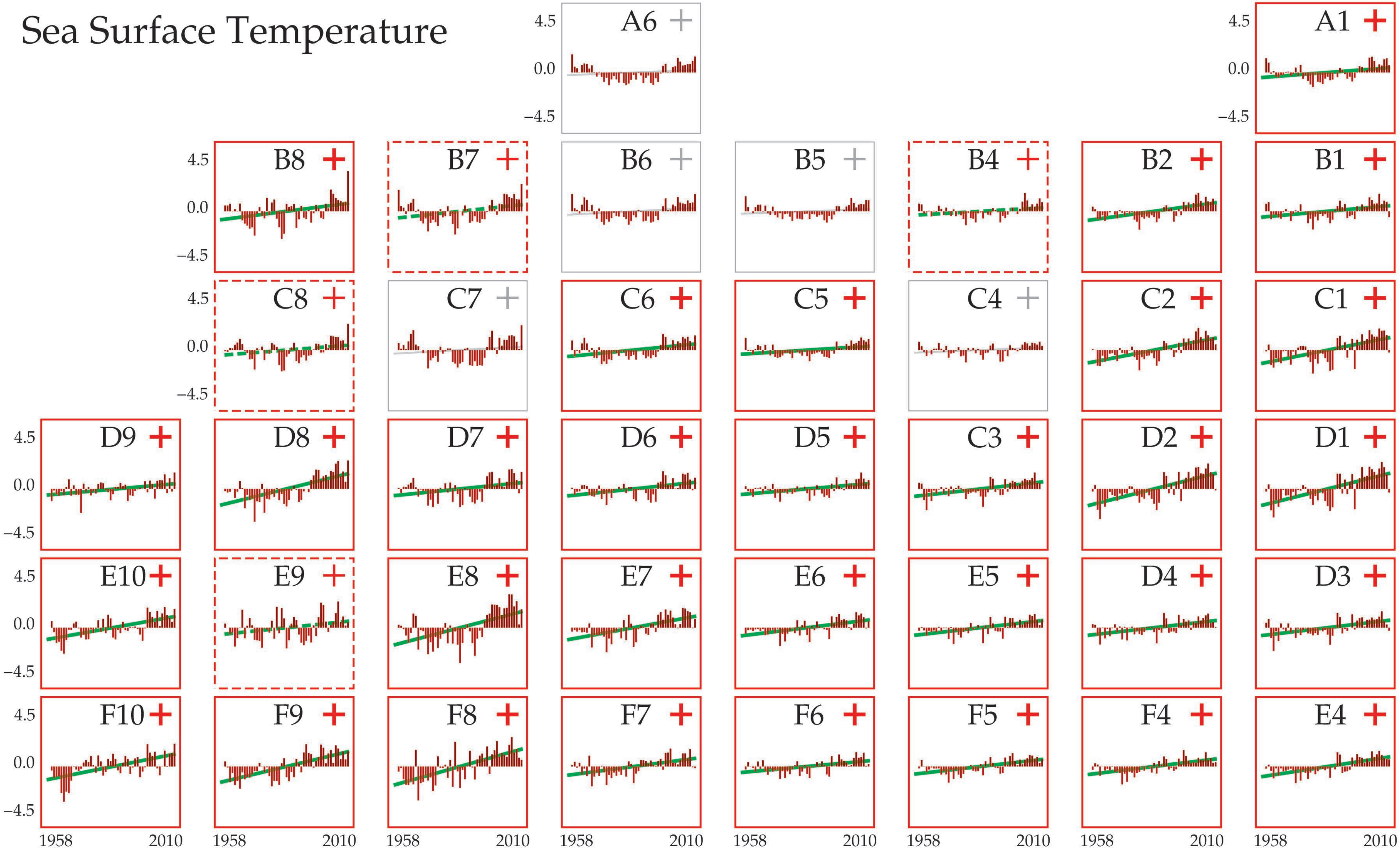

Figure 10.5
Spatio-temporal trends plot for Sea Surface Temperature time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1958 to 2010.

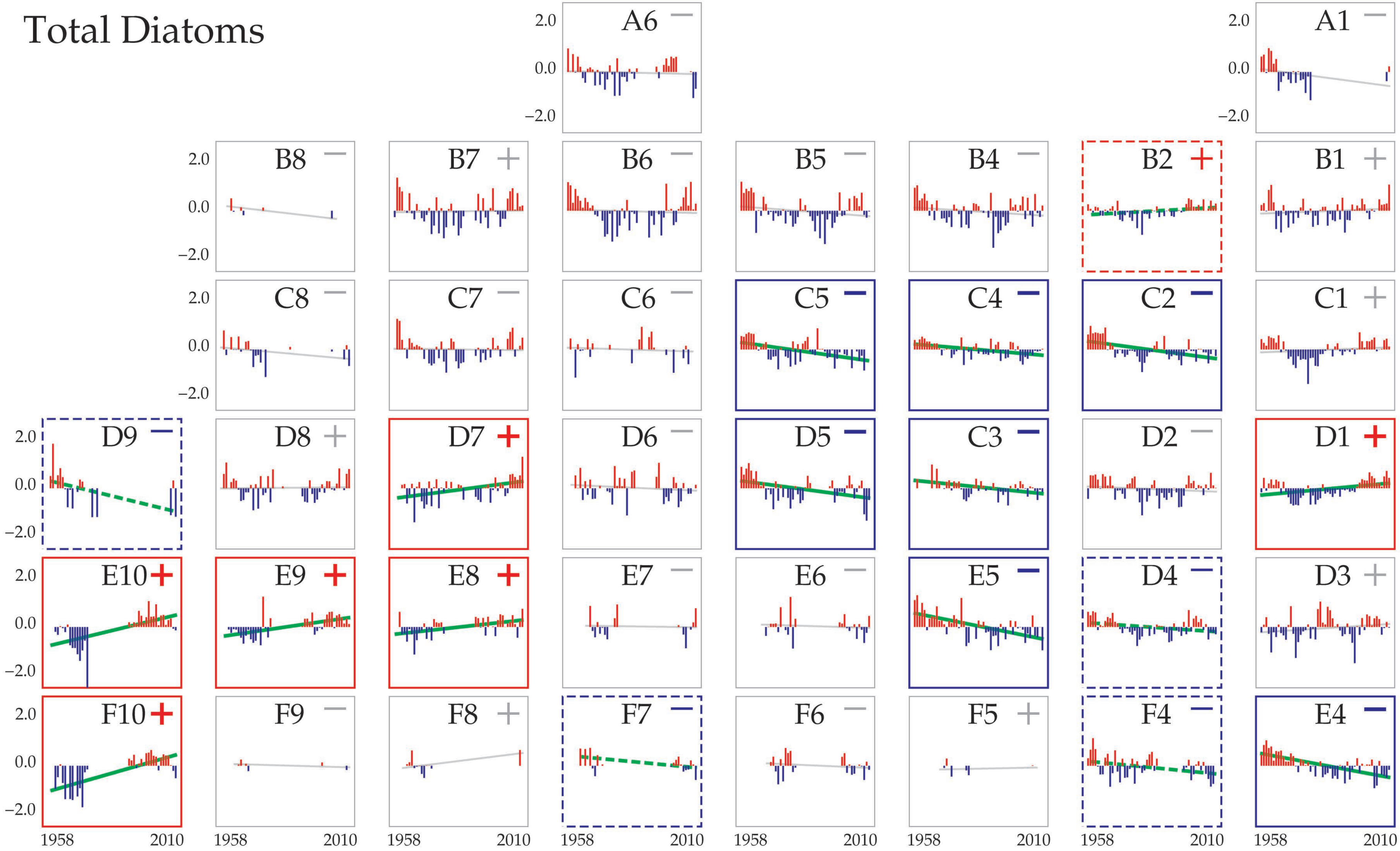

Figure 10.6
Spatio-temporal trends plot for Total Diatoms time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1958 to 2010. (Adapted from O'Brien et al.*, 2012.)*

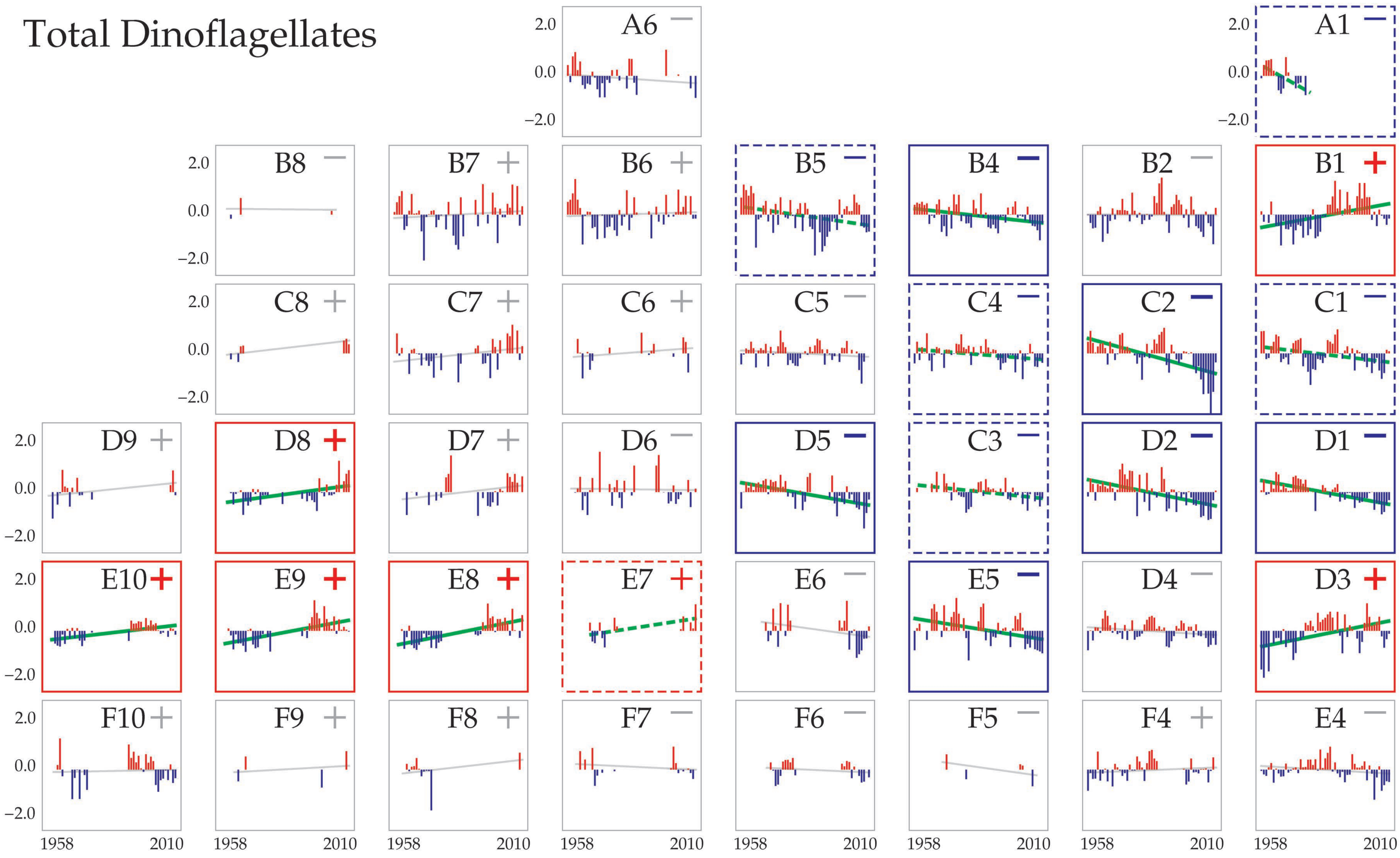

Figure 10.7
Spatio-temporal trends plot for Total Dinoflagellates time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1958 to 2010. (Adapted from O'Brien et al.*, 2012.)*

Total Tintinnids

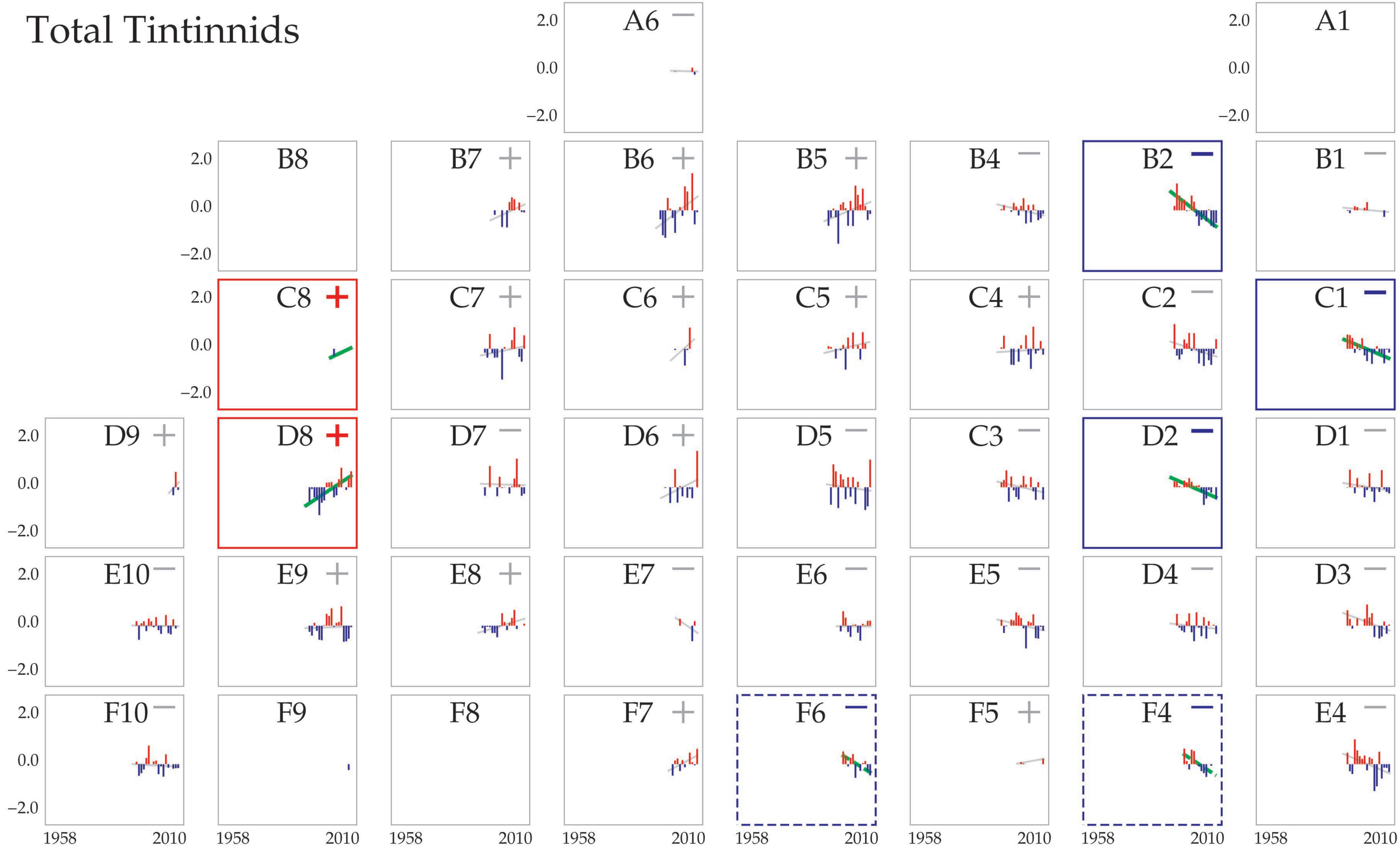

Figure 10.8
Spatio-temporal trends plot for Total Tintinnids time-series in the CPR standard areas of the North Atlantic Basin, based on data from 1993 to 2010. (Adapted from O'Brien et al.*, 2012.)*