The Continuous Plankton Recorder (CPR) Survey in the NW Atlantic

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Continuous Plankton Recorders (CPRs) have been towed along routes between Iceland and Newfoundland (the Z route) and between Newfoundland and the NE coast of the United States (the E route) since the early 1960s. The data are analysed each year as a component of the Canadian Atlantic Zone Monitoring Programme (see http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html). The routes are divided into eight regions, four in the shallow waters of the Canadian continental shelf and four in the deep waters of the NW Atlantic sub-polar gyre (Fig. 1). Results are reported annually in Research Documents published by Fisheries and Oceans Canada (see http://www.dfo-mpo.gc.ca/csas-sccs/index.htm).

The aim of the NW Atlantic CPR survey is to have sampling at monthly intervals, but this has not always been achieved, especially before 1991. Because of the irregular sampling and because seasonal cycles are pronounced and variable, it has not been possible to calculate annual abundance indices for CPR taxa for every year and region in order to investigate long-term inter-annual trends and variability. Instead, decadal annual average values have been used, which are calculated in the following way. Firstly, the $\log_{10}(N+1)$ transformed data values are averaged over each region for each individual month and year. Next, for each region monthly values are averaged over each decade, and finally these regional decadal monthly values are averaged to give decadal annual averages. The term decade is used loosely here, since data from the Z line from 1957-1959 are included in the decade of the 1960s (otherwise 1960-1969), and since there was no sampling between 1976 and 1979 along the E line (nor in the 1980s), and no sampling between 1987 and 1989 on the Z line. Using this approach, however, Head and Pepin (2010) showed that between 1958 and 2006 phytoplankton abundance increased in shelf regions between the 1970s and 1990s, mainly in winter, as the contribution of Arctic-derived freshwater increased, and that in the sub-polar gyre, as temperatures increased over the 1990s and early 2000s, phytoplankton levels increased during the normal growth season. In both areas, the changes could be explained by increased stratification.

The most recent analysis, carried out in March 2011, included data from 1958 to 2010. In this analysis, decadal annual average abundance indices for selected taxa from the decades between the 1960s to the 2000s were compared with annual average values for 2010, a year for which sampling coverage was good in most regions and for which values for missing months could be reasonably estimated by linear interpolation. The comparison could not be made for the Newfoundland Shelf (NLS) region, however, because in 2010 the shipping route followed a more northerly path between June and October (Fig. 1).

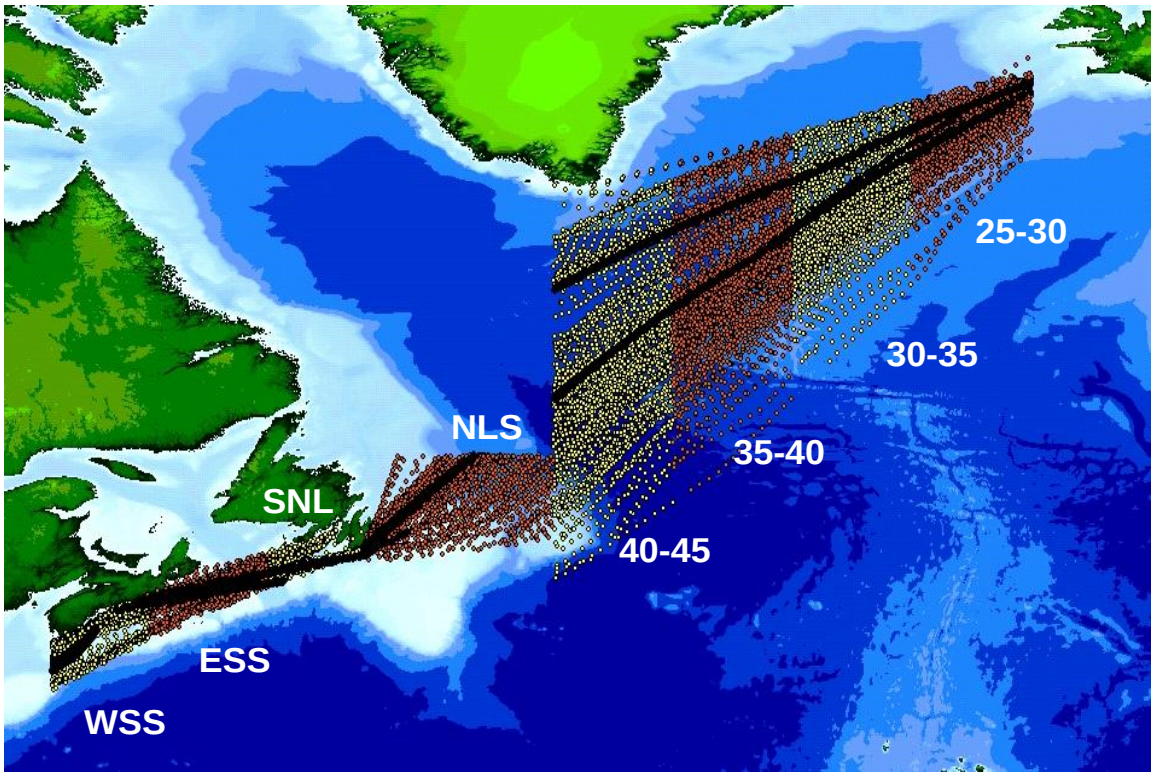

Figure 1. Continuous Plankton Recorder (CPR) lines and stations 1957 to 2010. Only stations that are included in the analysis are shown, with adjacent regions delineated alternately by colour (yellow and orange) in the years preceding 2010. Stations sampled in 2010 are shown in black. Shelf regions are the Western Scotian Shelf – WSS, the Eastern Scotian Shelf – ESS, the South Newfoundland Shelf – SNL and the Newfoundland Shelf – NLS. Regions of the sub-polar gyre are divided by longitude, e.g. between longitudes 40-45°W - 40-45, etc.

For the other three shelf regions, however, the phytoplankton colour index (PCI) and diatom abundance remained at the high levels of the 1990s and 2000s in 2010, while dinoflagellate abundance returned to the low levels of the 1960s and 1970s on the Western Scotian Shelf (WSS), but remained at the high levels of the 1990s and 2000s on the Eastern Scotian Shelf (ESS, data not shown) and the South Newfoundland Shelf (SNL) (Fig. 2). The four regions in the sub-polar gyre showed similar patterns of change for all three phytoplankton indices, with gradual increases after low values the 1980s, which were sustained in 2010 (Fig. 2). The abundance of young *Calanus* (*Calanus I-IV*) and late stage *Calanus finmarchicus* (*C. finmarchicus V-VI*) has remained relatively stable over the decades on the WSS and in the sub-polar gyre (40-45°W), although both taxa showed slightly reduced levels on the WSS and higher levels in the sub-polar gyre in 2010 (Fig. 2). On the SNL (and ESS) both *Calanus* groups were at their lowest levels in the 90s and 00s, but both increased in 2010. Three categories of small copepods (copepod nauplii, the *Pseudo/Paracalanus* group, *Oithona* spp.) are generally more abundant in shelf regions than in the sub-polar gyre. On the WSS (and ESS) copepod nauplii were most abundant in the 90s and 00s, and decreased in abundance in 2010. On the SNL, however, increases in the 90s and 00s were sustained in 2010.

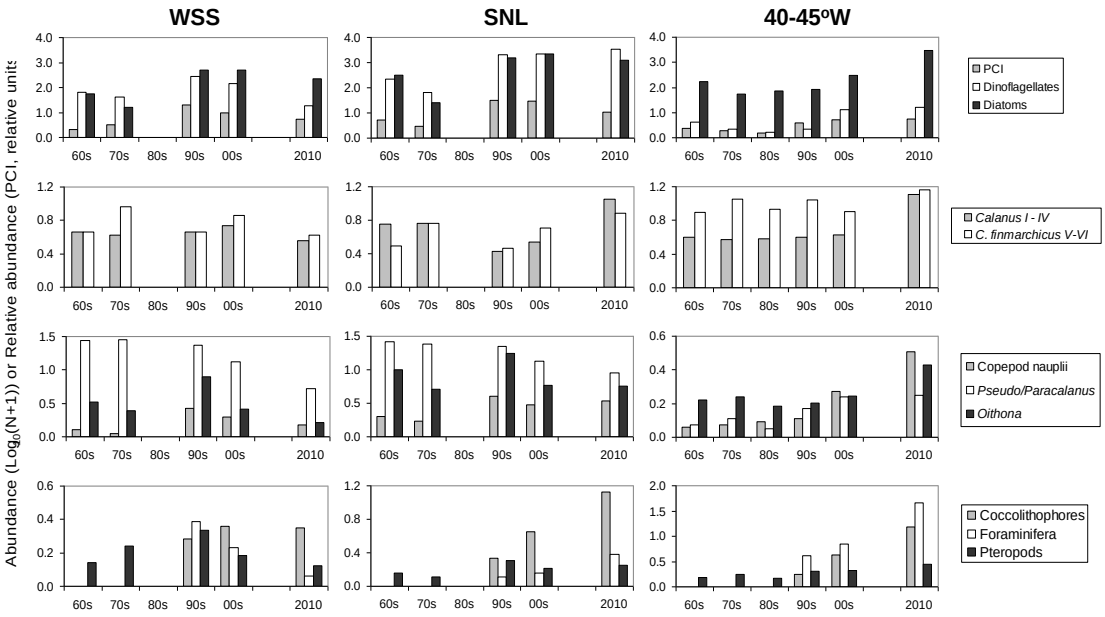

Figure 2. Annual average abundances by decade of selected phytoplankton and zooplankton taxa on the Western Scotian Shelf (WSS) and the South Newfoundland Shelf (SNL) and in the region of the sub-polar gyre between 40 and 45 degrees west (40-45°W) for the decades since the 1960s and for 2010.

The abundance of the *Pseudo/Paracalanus* group, which includes other small unidentified copepods, was high in all shelf regions throughout the 60s-90s, decreasing in the 00s and 2010. Changes in abundances of *Oithona* spp. were similar in all shelf regions, with elevated values in the 1990s. In the sub-polar gyre all three small copepod categories have increased in abundance since the 1980s. Three taxa, Coccolithophores, Foraminifera and Pteropods, are used to monitor potential effects of increasing acidification in the NW Atlantic. The two former taxa have only been counted consistently since the 1990s and since then abundances of Coccolithophores have increased in all regions, while abundances of foraminifera have either decreased (WSS, ESS), or increased (SNL, sub-polar gyre). Pteropods, which have been counted for all decades, had their highest levels in the 90s in shelf regions, while in the sub-polar gyre levels have slightly increased over the decades.

No detailed comparison of plankton abundances and environmental conditions has been made since 2006, but in 2010 the North Atlantic Oscillation (NAO) index dropped to its lowest level since 1969. When this index of atmospheric conditions is low, air and water temperatures in the Labrador Sea region are relatively warm and winter-time convective vertical mixing is relatively shallow. As expected, sea-surface temperatures (from http://poet.jpl.nasa.gov/) were relatively warm in the sub-polar gyre in 2010. As discussed by Head and Pepin (2010), rising temperatures in this region since the early 1990s have led to increasing levels of stratification, and this effect would have been

augmented in 2010 by the reduced winter vertical mixing. This appears to have led to increased primary production, which was accompanied by increases in the levels of zooplankton grazers. On the Scotian Shelf, stratification is driven by both salinity and temperature, so that interpretation of the plankton abundances observed in 2010 is not straightforward: it has not yet been accomplished.

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