

## Theme Session D

### Trends in Chlorophyll and Primary Production in a warmer North Atlantic

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The trend in the North Atlantic in the past decade has been one of warming. Predictions throughout the 21st century forecast continued rise in temperature of 0.2°C per decade. Warmer sea temperatures have already caused shifts in phytoplankton populations, including change in abundance and distributions. These changes in primary production will certainly manifest themselves in higher trophic levels and are an important pathway for climate change to affect resource species and ecosystems. The trophic pathways of phytoplankton and microbes to zooplankton were reviewed during the session and direct links to larval fishes and overall ecosystem productivity were brought up during discussion.

Papers identified at the theme session identified several key elements of change. First, temperatures are warming; this has been documented by the WGOH and the most recent results of the WG were presented during the session (D:01). This paper also provided guidance to the ICES community as how to use standard gridded data products of ocean temperatures. Many of the other papers included evidence of a warming North Atlantic particularly in the last 10 years (D:04, D:11, D:13) while this is not evident for other regions, as in the Norwegian Sea (D:07)

Second, changes in overall chlorophyll and primary productivity were indicated in several regions. Such changes revealed a variety of patterns among regions ranging from no significant long-term change to increases or decreases of values. For instance, on the northeast US shelf these trends were documented based on satellite data (D:04) and indicated an increase in phytoplankton biomass and production in most shelf regions except in Georges Bank. Changes in chlorophyll concentration were also linked to changes in the bacterioplankton and these relationships indicate complex interactions between primary producers and the microbial loop (D:02). Temporal changes in phytoplankton indicators were also linked to changes in the zooplankton community indicating links to higher trophic levels (D:05). Together, these papers indicate that changes in the smallest size fractions of organisms in the ocean could have important consequences for overall fishery and ecosystem production.

Third, changes in size and species composition were demonstrated that were associated with warming, stratification, and nutrient availability. Picophytoplankton increased dominance with temperature in the Bay of Biscay (D:03) and were coherent with changes observed off the eastern Canadian coast (D:03 and D:02). Changes in the magnitude, timing, and species composition were found in the northeast US and these were related to temperature and the inflow of water from the north (D:05). However, not all studies found a relationship between changing phytoplankton and changing temperatures. A study from the Bay of Biscay found an increase in temperature, but not an

increase in chlorophyll levels (D:11). Additionally, changes in bloom dynamics of several species of diatoms were presented and linked to changes in nutrient concentrations, stratification and day length but not to temperature (D:09). Temperature was also not the dominant factor identified in changes primary production and phytoplankton biomass off the northwest coast of Spain; these changes were linked to multi-annual cycles of nutrient concentrations (D:13). The compilation of these studies indicates that temperature is but one of several factors that influence phytoplankton dynamics.

Fourth, several papers during the session supported the concept of a heterogeneous response of phytoplankton in the North Atlantic owing to spatially and temporally varying influence of different control factors (temperature, nutrients, stratification, day-length). Changes in the timing of the spring bloom are not coherent over the North Atlantic indicating regional differences (D:14). A finer-scale study in the Norwegian Sea indicated a different response of phytoplankton in two water masses and these spatially differences resulted from differences in stratification (D:07). Similarly, differences in the phytoplankton community off the Portuguese coast were related to upwelling processes. On the northeast US changes in chlorophyll over time were identified in some areas, but in well mixed areas, little change in chlorophyll concentration was found (D:04) and in the Barents Sea the relationship between near bottom oxygen saturation in the Barents Sea relative to primary production was reviewed (D:12). These studies suggest that regional differences in chemical and physical oceanography will affect phytoplankton and microbial dynamics independent and in concert with warming oceans.

Finally, the issue of scale was raised in several studies and directly addressed in an integration of measurements made over minutes to anomalies calculated over years (D:02). To document changes in phytoplankton and microbial dynamics observations are required over years – over the scale of temperature changes in the system. However, microbial and phytoplankton dynamics are dependent on processes acting on much shorter scales. A challenge remaining to the community is the need for fine-scale observations over long-periods and then integrating these observations to scales that are relevant for addressing issues such as climate change and ecosystem function.

Despite this challenge, the results of the theme session are clear. Phytoplankton and microbial communities are changing throughout the North Atlantic region. Bloom times are shifting, overall chlorophyll concentrations are changing, and size and species composition are changing. Most of these changes are related to changing temperature, but result from a more complex interaction of processes. These changes will affect resource species and ecosystem productivity and understanding these effects is a major challenge for the ICES community.

Based on continued interest in phytoplankton and microbial ecology within the ICES community and the fundamental importance of this group of organisms to the ICES Science Plan, a proposal for a new ICES WG was developed by theme session participants and attendees.