North Atlantic Basin Scale Modelling Activities 10.Jan.2006

Background

The goal of this project would be to build upon existing work that has been done on coupling zooplankton dynamics at the basin scale. There has been some limited modeling of regional basin zooplankton dynamics (Bryant *et al.* 1998, Tittensor *et al.* 2004) but more recently there has been some innovative modeling at the full basin scale (Speirs *et al. 2005a).* The work of Speirs *et al.* (2005a and 2005b) focuses on the climatology from a single year, 1997, that being the year of a major field effort on the Northeast Atlantic under the umbrella of the Trans Atlantic Studies of Calanus (TASC) program. The group (D. Speirs, M. Heath and W. Gurney) working in the UK Marine Productivity (MarProd) program have developed techniques for optimising certain parameters of the model to explore the goodness of fit of the model to the available observations. They have been able to address various hypotheses concerning the regulation of the important diapause phase of the *C. finmarchicus* life cycle. Their simulations of North Atlantic *Calanus finmarchicus* population dynamics are based on the following components:

- Circulation and temperature fields from OCCAM
- Blended SeaWIFS and water bottle fields of chlorophyll (*Calanus* food)
- A discrete-time-space method of simulation giving large gains in computational speed
- A compilation of *Calanus* stage abundance data from CPR and field surveys

In the MarProd work to date, the model has been run to a quasi-stationary state with a repeating annual cycle of temperature and circulation data, however, the obvious next step is to examine the sensitivity of the population demography to changes in the annual cycle of temperature and circulation such as might be representative of the climate fluctuations over the past fifty years.

There are two possible scientific questions that could be addressed in the modeling of North Atlantic zooplankton populations. The first is to explore the interannual variability of *Calanus finmarchicus* in the North Atlantic, on the basin scale, directly building upon the modelling as presented in Speirs *et al.* (2005a). The second would be to attempt to model the regime shift in zooplankton species that has been observed in the Northeast Atlantic (Beaugrand 2004).

Calanus in the North Atlantic

The first is to extend the work that has been done to model years other than the repeat 1997 runs that have already been made (Speirs *et al.* 2005a and 2005b). The extension beyond the single year that has already been explored would be of significant scientific interest but would pose some challenges. The first is that while temperature and circulation strongly influence C. finmarchicus dynamics, food supply is also an important factor. The existing model uses spatially and temporally resolved food data from a blending of 8-day climatological composite SeaWIFS data, blended with a multi-year data set of chlorophyll samples from water bottle analyses. One possible first step would be to re-use the SeaWIFS based fields, but it would be much better to seriously address the issue of simulating North Atlantic bio-geochemistry, and employ an optimization scheme to fit such a simulation to the available observations so as to constrain it to something close to reality.

Northeast Atlantic Zooplankton Regime Shift

Perhaps the best documented change in the zooplankton of the Northeast Atlantic is the northerly retreat of *C. finmarchicus* and the advance of *C. helgolandicus* latitudinal distributions (Beaugrand 2004). In response to the warming of the north-east Atlantic after the end of the 1970s, substantial biogeographical shifts in calanoid copepods have been detected in the Northeast Atlantic. Warm-water species have moved northwards with concomitant reduction in colder-water species Beaugrand (2005). A link between these large-scale biogeographical shifts and the dynamic regime of North Sea plankton ecosystems have been suggested (Beaugrand and Ibanez 2004) in addition to the more direct hydro-climatic influence of the North Atlantic Oscillation (Reid *et al.* 2003, Weijerman *et al.* 2005). The warming of sea temperature in that region has involved a northwards movement of the boundary between the Atlantic Polar and the Atlantic Westerly Winds biome, as defined by Longhurst (1998). As the boundary between the two biomes was located in the North Sea in the central part, a movement of this boundary northwards could explain the abrupt biological changes detected in the North Sea. Evidence for a biogeographical shift in this boundary has been found by looking at zooplankton data. Possible hypotheses for this shift have not yet been quantitatively tested.

A full modelling assessment of the *finmarchicus/helgolandicus* shift in distribution would require a similar approach to that described above for *C. finmarchicus* to be implemented for *C. helgolandicus.* New analyses of laboratory data on *C. helgolandicus* have revealed quite different food and temperature responses of stage development rates for the two species, so it might be possible to envisage a simpler approach by looking at the temperature and circulation forcing alone, initially neglecting food supply. Thus one could take model output for the past few decades to drive production (development rate) of the two species. One could start with a fixed annual cycle of food supply and then, if possible, add the influence of interannual changes in food supply, thus allowing some separation of the influence of food supply and temperature. This shift is both a basin-edge and shelf-sea phenomena and so the limited skill of the global coupled model on the shelf will be a serious limitation.

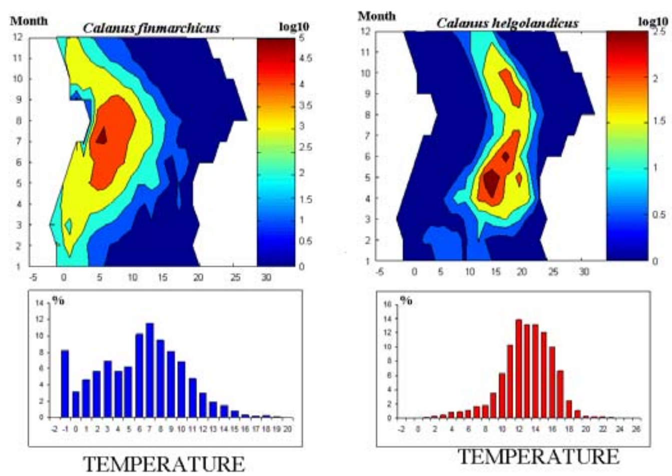

Figure 1 Thermal profiles of *Calanus finmarchicus* (left) and *Calanus helgolandicus* (right) at the seasonal scale (upper panels) and at the annual scale (lower panels). The profiles were calculated using data from the Continuous Plankton recorder (CPR) and COADS temperature. The thermal profile shows a clear separation (and complementarity) of the thermal preferences of both calanoid copepod species.

An interesting alternative approach, which we could operate in tandem to allow comparison with other data, would be to characterize the ecological niche of both species using both *in situ* and experimental data on the distribution of zooplankton and environmental conditions. This would allow us to see how their abundance and spatial distribution varies with changing environmental conditions (see Figure 1 for example). This allows us to explore the observed environmental relationship for direct comparison with the forward modeling approach. Comparing this data analysis (see Figure 1) and the modeling approach would enable an analysis of the strengths and limitations of each approach.

Approach

The development of these pilot projects would require planning to carefully frame the questions to be addressed and to determine the model structures required to answer the questions posed. The key model element in each case is the food supply model. There are ongoing research programs seeking to address this question and it may be possible to include others to assist in filling this particular gap. There are several possible investigators who could be interested in this project:

Bill Gurney – University of Strathclyde
Doug Speirs – University of Strathclyde
Mike Heath - FRS Marine Laboratory Aberdeen
Brad deYoung – Memorial University
Gregory Beaugrand - CNRS - Université des Sciences et Technologies de Lille
Francisco Werner – University of North Carolina
Jim Harrell – NCAR
Dale Haidvogel – Rutgers University

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