Plankton Phenology Workshop

by David Mackas, Rubao Ji and Martin Edwards

Ecological consequences of plankton phenologic variability have long been recognized by oceanographers and fisheries scientists (*e.g.*, Cushing's 1969 and 1990 "match-mismatch" hypothesis), but the intensity of research activity and published output has increased greatly during the GLOBEC era. A recent day-long workshop (June 23) at the 2009 GLOBEC Open Science Meeting, co-convened by authors of this article, contained 13 multi-authored talks within the general topic area "*Plankton phenology and life history in a changing climate*". Fortuitously, the numbers of presentations were almost equally balanced between results from "field observation/time series" and "numerical models" (six and seven respectively). Opportunity for close interaction and inter-comparison of the two approaches was one of the highlights of the workshop. There was also a broad geographic distribution of study areas (Fig. 1) and of target taxa (three papers on *Calanus finmarchicus*, seven on multiple zooplankton taxa, two on phytoplankton, and one on the planktonic larvae of scallops).

Fig. 1 Range of ocean regions examined by papers in the phenology workshop.

Results from the zooplankton studies indicated that annual phenology outcomes are controlled by a sequence of physiological, developmental and behavioral "choices" made at different developmental stages (Fig. 2). Water temperature during the growing season is an important regulator and cue of these choices, and can often be used to predict year-to-year variations in zooplankton timing. However, temperature dependence of timing varies among taxa, and in some regions shows non-linear thresholds or sign reversals from the "warmer implies earlier" pattern that dominates in mid-latitudes.

The two phytoplankton studies showed the zooplanktologists just how much can be learned from data that have high resolution coverage in both time and space. For example, Thomas and Weatherbee (Fig. 3) partitioned total interannual variability of satellite-sensed chlorophyll among three components: variability of annual mean, variability of seasonal amplitude, and variability of seasonal phase. They found that phase variation (*i.e.*, peak timing) is the largest component for most locations in the California Current System.

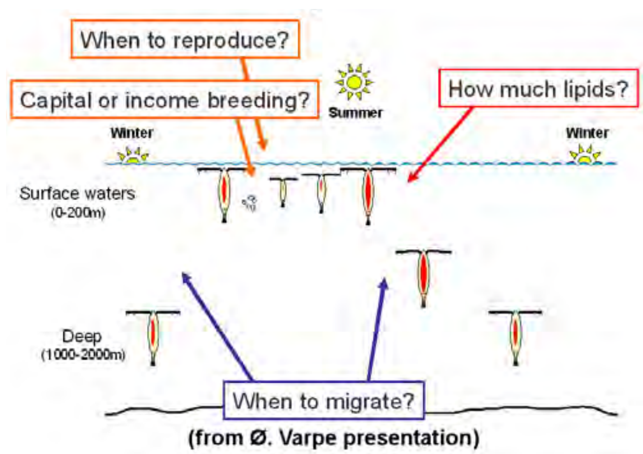

Fig. 2 For many zooplankton taxa, annual phenology is controlled by choices among life history (red boxes) or behavioral (blue box) strategies made during relatively brief portions of the life cycle. Models can be used to evaluate the adaptive fitness of these choices under differing environmental scenarios. Figure courtesy of Ø. Varpe (The University Centre in Svalbard, Norway).

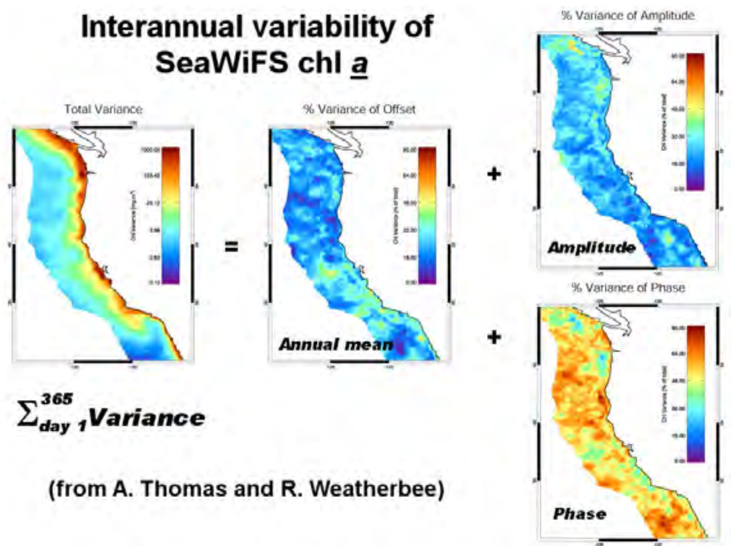

Fig. 3 Partitioning of total interannual variability of satellite-sensed chlorophyll in the California Current System (left panel) among three contributing components: variability of the annual mean (middle panel), variability of amplitude of harmonic components (top right), and variability of phase (i.e., timing) of the harmonic components (bottom right). Figure courtesy of A. Thomas and R. Weatherbee (University of Main, U.S.A.).

The workshop included a plenary discussion time-block during which participants identified knowledge gaps within present data and modeling approaches. The following were flagged as important areas for future research:

- Physiological, behavioral, and predator–prey mechanisms that cause phenologic variability;
- Climate drivers of phenologic variability (direct forcing *vs*. triggering cues, proxy *vs*. causal associations);
- Finer resolution of age/stage structure in observational time series;
- Broader attention in models to roles of transport, migration, age-dependent changes in distribution, and exchange with other populations;
- Spatial/temporal scales and potential for spatial/temporal separation of driver and response (closely linked to the previous topic); and
- Broadening the range of modeled life history patterns.

GLOBEC has agreed to fund a small follow-up workshop next autumn at which these and other observations will be fleshed out for publication as a "Horizons" article in the *Journal of Plankton Research*.



Dr. David Mackas (Dave.Mackas@dfo-mpo.gc.ca) is a biological oceanographer at the Institute of Ocean Sciences (Fisheries and Oceans Canada). His research focuses on zooplankton spatial distributions, and (especially lately) on how low-frequency zooplankton temporal variability is linked to ocean climate. He recently co-chaired (with Hans Verheye) SCOR Working Group 125 on Comparisons of Zooplankton Time Series. Although his personal and scientific homes are firmly in the Pacific, he confesses to a fondness for Mediterranean climate, diet, and lifestyles. Photo (taken near Marseille) courtesy Hal Batchelder.

Dr. Rubao Ji (rji@whoi.edu) is a biological oceanographer at Woods Hole Oceanographic Institution. His research is focused on understanding biological–physical interactions in coastal/shelf ecosystems using numerical modeling approaches. He has been involved with GLOBEC since 1999, and is currently a principal investigator on a US GLOBEC Phase 4B project and a Pan-regional GLOBEC project. He is also active in modeling phytoplankton bloom dynamics and copepod population dynamics in the North Atlantic and Arctic Oceans. Ji is currently a member of an ICES Working Group on Modeling Biological-Physical Interactions.

Dr. Martin Edwards (maed@sahfos.ac.uk) is based at the Sir Alistair Hardy Foundation for Ocean Science in Plymouth, U.K. His primary research interest is in marine macroecology, recently focusing on large-scale biogeographical shifts, phenology, harmful algal blooms, climate change impacts on marine ecosystems, biodiversity and regime shifts. In addition to numerous peer-reviewed journal articles and book chapters, he was recently a contributing author for the IPCC Fourth Assessment Report on climate change impacts on marine ecosystems and marine fisheries.