# GLOBEC
RESEARCH HIGHLIGHTS 2007

The aim of GLOBEC is to advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change.

Since 2002 the GLOBEC IPO selects a number of research highlights from GLOBEC publications appearing in the literature over the last 12 months. The GLOBEC publication list can be interactively searched at www.globec.org. Since 2000 the list includes a total of 2,820 publications (2,463 refereed).

1. **Applying the NEMURO 3-D ecosystem-biogeochemical model to predict the effects of global warming on ecosystem dynamics** (Hashioka, T. and Y. Yamanaka. 2007. Ecosystem change in the western North Pacific associated with global warming using 3-D NEMURO. Ecological Modelling 202: 151-204)
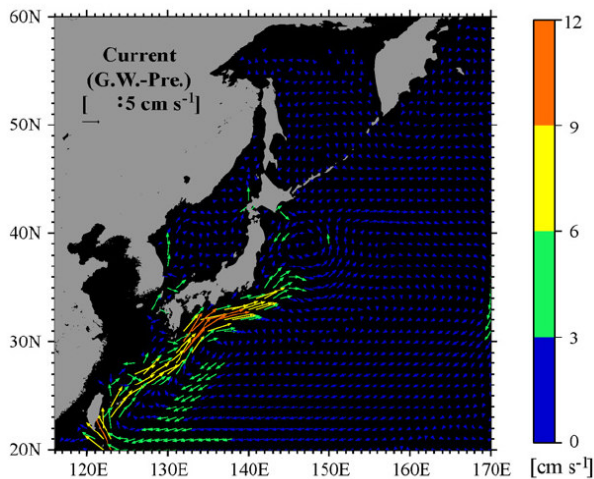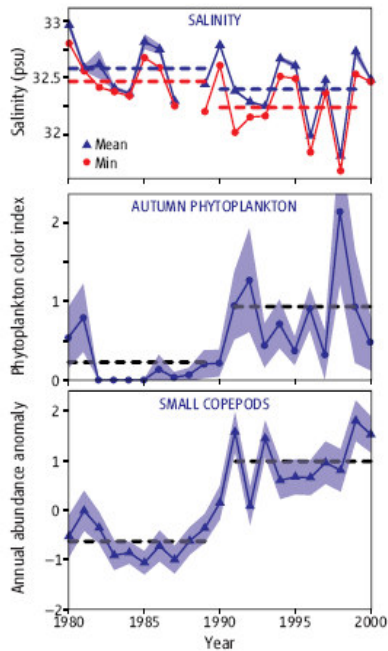

Annually averaged changes in 100 m water flows from the present-day (Pre.) to a global warming scenario (G.W.). The Kuroshio is a western boundary current, driven by wind stress in the entire Pacific Ocean, and the separation latitude between the Kuroshio and the cold, south-bound Oyashio current is roughly determined by the latitude of wind stress curl equal to zero in the course resolution model. Since the wind stress is strengthened by global warming, the separation latitude is shifted northward and the maximum Kuroshio current is strengthened from 40 to $50 cms^{-1}$.

The scenario used is the IS92a, and the model is set to predict conditions at the end of the 21st century. Among other results the model predicts a decrease in nutrient and chlorophyll *a* concentrations, a shift in dominant phytoplankton group from diatoms to smaller organisms, and a slight increase in P/B ratios. The diatom spring bloom is predicted to occur 1.5 months earlier due to strengthened stratification, but a similar shift is not observed for smaller phytoplankton. The changes do not occur uniformly throughout the year but are particularly important at the end of the spring and in the autumn.

2. **Changes in Arctic climate have contributed to shifts in abundance and seasonality of NW Atlantic species** (Greene, C.H. and A.J. Pershing. 2007. Climate drives sea change. Science 315:1084-1085)

In recent decades the Arctic has experienced unprecedented changes, bringing increased warmer, higher salinity Atlantic water into the Arctic Ocean. Associated with this, circulation in the upper layers of the Arctic Ocean changed substantially between the late 1980s and early 1990s. From an Atlantic perspective, the most important consequence of these changes was a redirection of the shallow outflow from the Arctic Ocean, from the Fram Strait to the Canadian Archipelago. In addition, continental melting of permafrost, snow and ice has increased substantially, which, combined with increased precipitation, has led to greater river discharge into the Arctic Ocean.

Northwest Atlantic shelf ecosystems shifted rapidly during the 1990s relative to the 1980s, resulting in greater phytoplankton production and abundance during the autumn, followed by a marked increase in the abundance of smaller, shelf-associated copepods. Commercially harvested fish and crustacean populations have also undergone large changes. Of particular importance is the collapse of cod stocks in the early 1990s. Overfishing is considered the main cause of this collapse, but the cold, Arctic-derived waters in the northern part of their range have probably hampered their recovery despite a decade-long fishing moratorium in the Canadian Maritime Provinces.

The relative importance of human induced versus natural climate forcing in driving the observed changes in atmospheric and oceanic circulation has not yet been fully resolved. However, the resilience of northwest Atlantic shelf ecosystems is being tested by climate forcing from the bottom up and predator overexploitation from the top down. Predicting the fate of these ecosystems will be one of oceanography's grand challenges for the 21st century.

Salinity, phytoplankton and zooplankton data from the Gulf of Maine and Georges Bank illustrate ecosystem changes associated with regime shift. Dashed lines: mean values during 1980 to 1989 and 1990 to 1999; shaded areas: 95% confidence intervals.

Top: Decadal mean salinities, based on annual mean (blue) and annual minimum (red) salinities, decrease after the regime shift.

Middle: Decadal mean autumn phytoplankton abundances, based on annual mean phytoplankton colour index values, increase after the regime shift.

Bottom: Decadal mean copepod abundances, based on annual mean small copepod abundance anomaly values, increase after the regime shift.
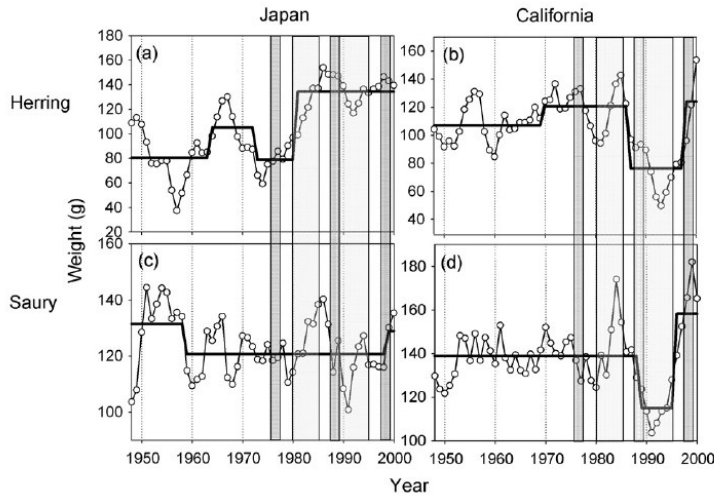
3. **Modelling reproduces in-phase and out-of-phase growth in fish species in response to changes of ecosystem regime** (Megrey, B.A., K.A. Rose, S.-I. Ito, D.E. Hay, F.E. Werner, Y. Yamanaka and M. Noguchi-Aita. 2007. North Pacific basin-scale differences in lower and higher trophic level marine ecosystem responses to climate impacts using a nutrient-phytoplankton-zooplankton model coupled to a fish bioenergetics model. Ecological Modelling 202(1-2): 196-210).

Results of a NEMURO modelling approach embedded in a three-dimensional ocean general circulation model (OGCM) and forced with a common climate forcing are presented. Results are applied to a fish bioenergetics model for two geographically distinct ocean regions off Japan and off California, and for two fish species (Pacific saury: *Cololabis saira* and Pacific herring: *Clupea harengus pallasi*) with different life histories in each region. The influence of three different "regime shift" periods was explored. One of the more intriguing results is the complicated pattern of predicted weights-at-age being out of phase in some cases and synchronous in others. Weights-at-age of herring and saury off Japan were initially out of phase and then synchronised after 1980, whilst being synchronous off California. Saury weights-at-age were generally synchronous between Japan and California, while herring weights-at-age were out of phase between Japan and California. The other was driven by time series temperature and climatological zooplankton. Results of simulation runs to explore possible reasons for this (not reported here) were suggestive of bottom-up control, as they indicated that the importance of temperature versus zooplankton in driving the responses in weight-at-age differed between species and regions.
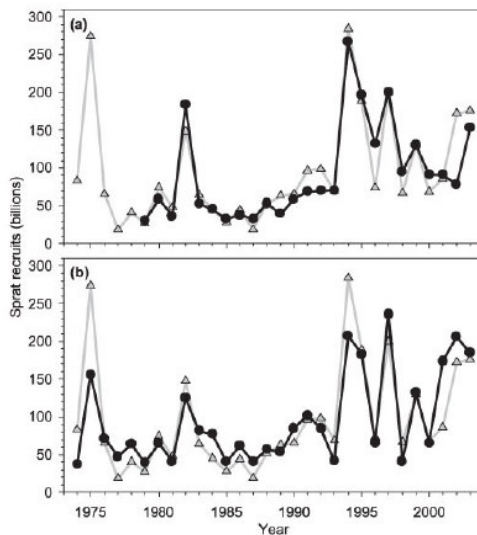
Simulated growth (g wet wt) of (a) herring in the Oyashio subregion of the Japan region (b) herring in the subarctic subregion of the California region (c) saury in the Oyashio subregion of the Japan region and (d) saury at the subarctic subregion of the California region for 1948-2002. Predicted growth from the model is shown with circles; the heavy solid lines are average values between statistically identified shifts in mean values. Grey vertical bars highlight the 1976-1977, 1988-1989 and 1998-1999 regime shifts. Light grey vertical bars identify periods of major ecological shifts (1980-1985 and 1988-1995) not corresponding to the three regime shift periods mentioned earlier.

4. Understanding the dependency of Baltic Sea sprat recruitment on larval and juvenile transport (Baumann, H., H.-H. Hinrichsen, C. Møllmann, F.W. Køster, A.M. Malzahn and A. Temming. 2006. Recruitment variability in Baltic Sea sprat (*Sprattus sprattus)* is tightly coupled to temperature and transport patterns affecting the larval and early juvenile stages. Canadian Journal of Fisheries and Aquatic Science 63: 2191-2201).

The recruitment patterns of Baltic sea sprat are correlated to time series of (i) month and depth-specific temperature conditions and (ii) larval drift patterns inferred from Lagrangian

particle simulations. From the latter, an index that reflects the degree of annual larval transport from the central, deep spawning basins to the shallow coastal areas of the Baltic was derived. The drift index, together with spawning stock biomass, explains 82% of the recruitment variability. Years of strong larval displacement towards southern and eastern Baltic coasts correspond to relative recruitment failure, while years of retention in the central basin result in relative recruitment success. In addition to patterns in temperature conditions, it is concluded that new year classes of sprat are predominantly composed of individuals born late in the season, and the recruitment strength is determined by processes acting at the larval stage. The biological mechanisms behind these patterns, however, are not fully understood.

Time series of observed (triangles, shaded line) and predicted (circles, solid line) Baltic Sea sprat recruitment. (a) Bottom depth anomaly plus spawning stock biomass model (explaining 82% of the recruitment variability) and (b) temperature model (in August, 0-10 m depth), explaining 73% of the recruitment variability.

5. **Comparing MOCNESS and video plankton zooplankton abundance: developing new tools for GLOBEC research** (Broughton, E.A. and R.G. Lough 2006. A direct comparison of MOCNESS and Video Plankton Recorder zooplankton abundance estimates: Possible applications for augmenting net sampling with video systems. Deep-Sea Research II 53: 2789-2807).
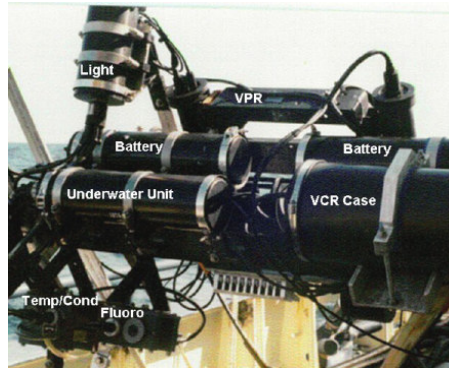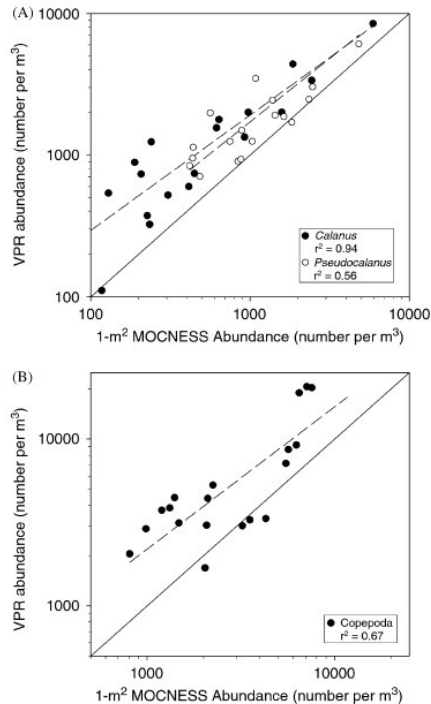
Left: (a) Abundance comparisons of the two dominant copepod species and (b) all copepoda species from the 1 m^2 MOCNESS and VPR. Each data point represents one net sampling interval. The solid lines represent a one to one relationship and the dashed lines are first order regressions.
Right: The rear view of the 1 m^2 MOCNESS mounted Video Plankton Recorder system.

A Video Plankton Recorder (VPR) was mounted on the frame of a 1 m^2 Multiple Opening and Closing Environmental Sensing System (MOCNESS) with 333 mm mesh nets during May 1997 on a cruise to the southern flank of Georges Bank. Comparison of data from the two gears used a series of sampling hauls taken along a hydrographic mooring line encompassing the tidal front. To maximize species sampling overlap, a second study compared data from the VPR to data from a ¼ m^2 MOCNESS with 64-mm mesh nets. Taxa proportional contribution to the total Copepoda abundance was not affected by differing gear. Mean proportional differences ranged from 7% for *Calanus* to 15% for *Pseudocalanus* and the other Copepoda taxa categories. The VPR produced standardised abundances that averaged two times higher than the MOCNESS nets. The differences in abundance may be decreased by a more accurate calibration of the VPR or adjusted by a calibration factor. Consideration was given to the improvements possible to plankton surveys, larval feeding studies, and coupled bio-physical modeling, from VPR integration with net samplers.

6. **Climate change and harmful algal blooms in the NE Atlantic** (Edwards, M., D.G. Johns, S.C. Leterme, E. Svendsen and A.J. Richardson 2006. Regional climate change and harmful algal blooms in the northeast Atlantic Limnology and Oceanography 51(2): 820–829).

The long-term spatial variability in a number of Harmful Algal Blooms (HABs) in the NE Atlantic and North Sea was investigated using data from the Continuous Plankton Recorder. Over the last four decades, some dinoflagellate taxa showed pronounced variation in the south and east of the North Sea, with the most significant increases being restricted to the adjacent waters off Norway. There was also a general decrease along the eastern coast of the United Kingdom. The most prominent feature was the anomalously high values recorded in the late 1980s in the northern and central North Sea areas. The only mesoscale area in the northeast Atlantic to show a significant increase in bloom formation over the last decade was the Norwegian coastal region. The changing spatial patterns of HAB taxa and the frequency of bloom formation are

discussed in relation to regional climate change, in particular, changes in temperature, salinity, and the North Atlantic Oscillation (NAO). Areas highly vulnerable to the effects of regional climate change on HABs are Norwegian coastal waters and the Skagerrak. Other vulnerable areas include Danish coastal waters, and to a lesser extent, the German and Dutch Bight and the northern Irish Sea. Quite apart from eutrophication, our results give a preview of what might happen to certain HAB genera under changing climatic conditions in temperate environments and their responses to variability of climate oscillations such as the NAO.


-0.7   -0.3   0.1   0.5   0.9
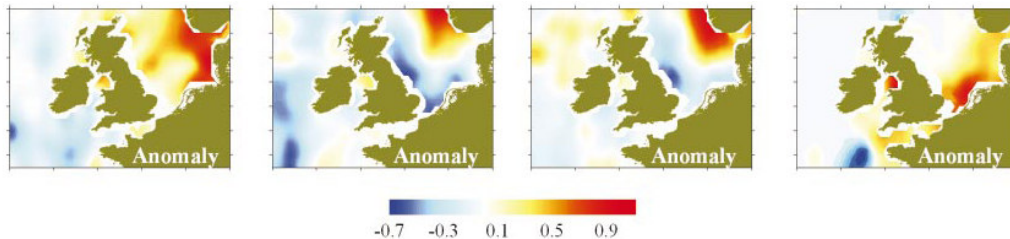
Anomaly (difference between long-term average and post 90s)

Geostatistical estimates of the decadal mean spatial distribution of four dinoflagellate taxa in the northeast Atlantic (from left to right: Prorocentrum spp., Ceratium furca, Dinophysis spp. and Noctiluca spp.). Estimated cell counts were log(x+1) transformed. Anomaly maps signify the difference between the long-term mean (1960-1989) and post-1990s (1990-2002) distributions. Shades of red signify values above the long-term mean and shades of blue signify values below the long-term mean. Zero-mean values are in white.
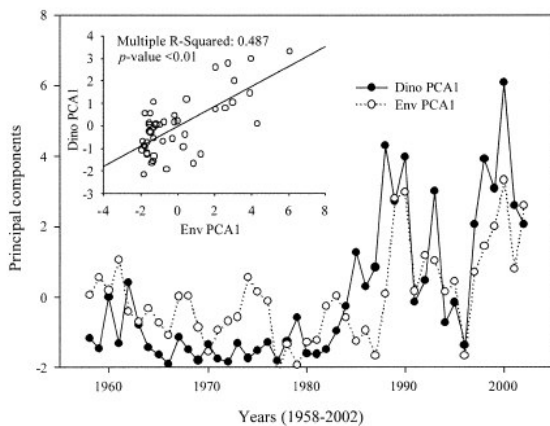
Interannual changes in the abundance of the dinoflagellate taxa and environmental variability represented by the first PCA (PC1) for standard CPR area B1 (NE North Sea) from 1958 to 2002 and resultant regression. Dinoflagellate PC1 included dinoflagellate taxa that occurred more than 1% by frequency of samples from 1958 to 2002 (including six species of the Ceratium genus, Dinophysis spp. Prorocentrum spp. and Protoperidinium spp.). Environmental PC1 included Atlantic inflow, salinity, sea-surface temperature, and wind speed. Correlation was adjusted for temporal autocorrelation using the modified Chelton method (Pyper and Peterman, 1998).

7. **Quantifying enrichment, concentration and retention in the Humboldt upwelling area (**Lett, C., P. Penven, P. Ayon and P. Freon 2006. Enrichment, concentration and retention processes in relation to anchovy (*Engraulis ringens*) eggs and larvae distributions in the northern Humboldt upwelling ecosystem. Journal of Marine Systems 64: 189-200).
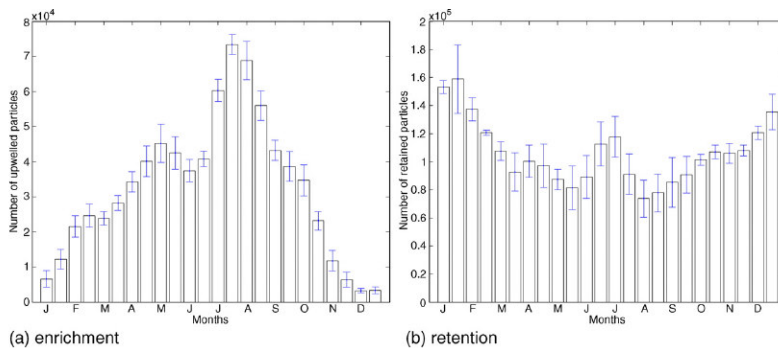
Seasonal variability in the number of (a) upwelled particles and (b) retained particles in some of the experiments conducted. Particles are summed over the domain and over depth 0-100 m for retention. The yearly means and standard deviations are shown.

A Lagrangian model was used to simulate and quantify the processes of enrichment, concentration and retention in the northern Humboldt upwelling ecosystem as these processes are important for the survival and recruitment of early life stages of pelagic fish. The method relies on tracking the positions of particles within water velocity fields generated by a three-dimensional hydrodynamic model. Simple criteria for considering particles as participating in enrichment, concentration or retention are used to derive indices of the three processes. The spatial distribution of and seasonal variability were analysed in these indices. The results were discussed in relation to anchovy (*Engraulis ringens*) eggs and larvae distributions off Peru, and to a comparable study conducted in the southern Benguela upwelling ecosystem.

8. **Quantifying enrichment, concentration and retention in the Humboldt upwelling area** (Pitois, S. and C.J. Fox. 2006. Long-term changes in zooplankton biomass concentration and mean size over the Northwest European shelf inferred from Continuous Plankton Recorder data. ICES Journal of Marine Science 63: 785-798).
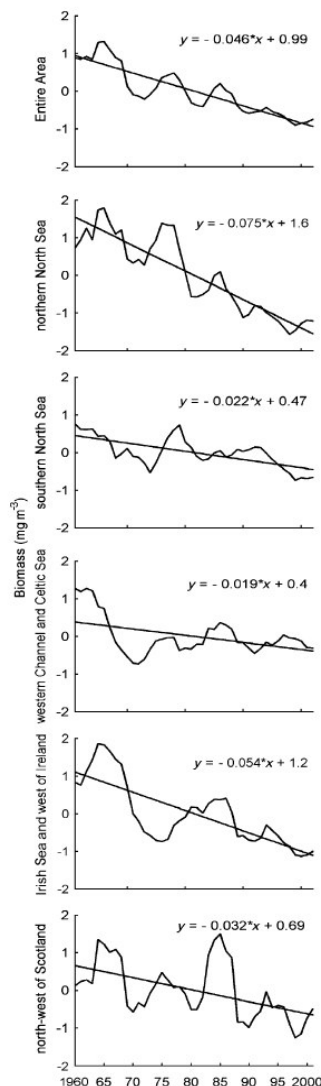
Data from the Continuous Plankton Recorder (CPR) survey over the past 40 years have shown that the abundance of copepods in many parts of the North Atlantic has declined, indicating geographical shifts in the plankton communities. Because the CPR does not sample all zooplankton species with equal efficiency, CPR undersampling was compensated for by using previously published species-specific correction factors derived from comparisons of catches made with WP-2 ring-nets and the CPR. Trend analysis confirmed the previously reported general decrease of total biomass. There has also been a general decrease in the mean size of zooplankton over time in the northern North Sea, but this has not been observed elsewhere. The results indicate the importance of smaller zooplankton species in the ecology of the Northwest European shelf. The changes in community structure may have general implications for energy transfer efficiency to higher trophic levels and for the sustainability of fisheries resources.

Evolution of annual average biomass concentration (mg m^{-3}) trend anomalies for 29 major species/taxa of copepods and cladocerans over the entire area and each of the five subareas. Annual average values were smoothed using a 5-year running window, for the period 1960-2001. Plots for uncorrected biomass values are displayed.

Details of these and other highlights can be found on the GLOBEC website, www.globec.org, under GLOBEC Publications.

_____

Manuel Barange, GLOBEC International Project Office, Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK, Globec@pml.ac.uk, www.globec.org