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Contents

Editorial

Dawn Ashby, GLOBEC IPO, Plymouth, UK (d.ashby@pml.ac.uk)

This has been a busy summer for GLOBEC. Firstly there was there was the Eastern Boundary Upwelling Ecosystems symposium held in Las Palmas, Gran Canaria in June, this was a hugely successful event with over 350 participants from nearly 40 countries attending. This was followed by the Coping with Global Change in Marine Social-Ecological Systems symposia which was held in Rome in July at the FAO Headquarters. I was fortunate to attend and help with the organisation of this symposium and I would like to say a special thank you to all the staff at FAO who made my job so much easier. In August the Linking Herring symposium was held in Galway, Ireland, further details of this and the other meetings can be found in the special GLOBEC Symposia section of this newsletter starting on page 21.

GLOBEC is also busy preparing a book entitled Marine Ecosystems and Global Change to be published by Oxford University Press next year. A meeting of the editors will be held in Halifax, Nova Scotia shortly after this newsletter goes to press and I would like to thank all of the members of the GLOBEC community who have contributed work or given their time and expertise to review book chapters.

A final word of thanks goes to Tim Baumgartner and his Mexican colleagues for their excellent article on the achievements of the IMECOCAL programme, the Mexican contribution to GLOBEC, for further details see pages 43-54 of this issue.

Looking forward to next year, registration for the third (and final) GLOBEC OSM is now open (see page 63 for further details), I hope to see many of you there.

Bertha Lavaniegos recovering a bongo net on the fantail of the R/V Francisco de Ulloa during an IMECOCAL cruise (see page 43 of this issue for further details).

A CORE PROJECT OF THE GLOBAL IGBP CHANGE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME
Co-sponsored by: The Scientific Committee for Oceanic Research (SCOR)
and The Intergovernmental Oceanographic Commission of UNESCO (IOC)

International Council for Science
Scientific Committee on Oceanic Research

GLOBEC-IMBER Transition Task Team

John Field
Marine Research Institute, University of Cape Town, Cape Town, South Africa

A Transition Task Team has been set up to recommend to SCOR and IGBP on how the second phase of the IMBER programme (Integrated Marine Biogeochemistry and Ecosystem Research) should proceed to accommodate new developments in marine ecosystem research that need addressing after the completion of the GLOBEC research programme at the end of 2009. The Task Team met in Reading, UK from 30 July – 1 August. Its terms of reference are summarised as:

To make recommendations to SCOR and IGBP for a second phase of IMBER after 2009, bearing in mind:

1. New developments in marine ecosystem science
2. Key new scientific questions arising from GLOBEC
3. Scientific results of IMBER to date
4. Projects currently within GLOBEC that are planned to continue after 2009 (especially CLIOTOP, ESSAS)
5. Recommendations for mechanisms to facilitate the transition, including representation in programmatic structures (to be done at the final meeting)

The SCOR-IGBP Ocean Vision (2002; http://www.igbp.net/documents/OceanVision-15Jan04.pdf) summarises the role of the ocean in the earth system and focuses on i) understanding the role of the ocean in earth system biogeochemistry and ii) predicting the consequences of global change for ocean biogeochemistry and biology, as a means to investigate pathways towards sustainability. We can view in this context, the vision of IMBER:

> *"To provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the earth system and human society."*

Leading to the IMBER Goal:

> *"To investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades."*

The broad nature of ecosystems has led to a spectrum of approaches to studying ecosystems ranging from a biogeochemical approach emphasising fluxes of carbon and nutrients and the role micro-organisms on the one hand, to the approach of population dynamics, biological communities, and animal behaviour on the other. These approaches are exemplified in the marine environment by the approaches of JGOFS and GLOBEC, respectively. IMBER is aimed at bringing these approaches together and integrating them in the modern framework of Earth System Science. Hence it is important to use the term "ecosystem" in its integrative sense, realising that ecosystems incorporate physical factors, biogeochemical cycles and living populations.

The task team has already identified several areas that now need emphasis in order to achieve the IMBER vision: in particular, we emphasise 1) integrating the human dimensions of marine global change, 2) regional research programmes, and 3) comparative analyses within and among regional programmes including ecosystem models incorporating the human dimension, and 4) emerging scientific issues.

It would be premature to discuss the Task Team's initial thoughts further, except to mention that several regional programmes are being considered, these include: ICED (Southern Ocean) and SIBER (Indian Ocean) that have already been accepted by the IMBER SSC. Further potential regional programmes are being considered, should their SSCs wish to have them included within IMBER: CLIOTOP (focus on top predators in the open ocean), ESSAS (sub-arctic ecosystems) and BASIN (proposed North Atlantic comparative studies).

The Task Team has drafted an interim report for feedback from the sponsors and respective SSCs of GLOBEC and IMBER, and an Implementation Strategy document will probably be drafted for Phase 2 of IMBER to implement the changes that are recommended after consultation. The Task Team calls upon members of the programmes and interested marine scientists to submit their ideas on what might be added to IMBER, for incorporation into Phase 2 of IMBER from 2010-2014. These ideas should address the vision and goals of IMBER as indicated above and should be submitted by the end of October 2008, in time for drafting into the final meeting of the team in December 2008. They should be submitted to both the GLOBEC (globec@pml.ac.uk) and IMBER IPOs (imber@univ-brest.fr) for transmission to the Transition Task Team.

There will be a report-back on the Task Team's recommendations at the GLOBEC Open Science Meeting in June 2009, after the report has been reviewed by the main sponsors of IMBER and GLOBEC: SCOR and IGBP during the first months of 2009.

Members of the Transition Task Team are:

- Hugh Ducklow
- Ken Drinkwater
- John Field (chair)
- Roger Harris
- Eileen Hofmann
- Olivier Maury
- Kathleen Miller
- Mike Roman
- Qisheng Tang

Seasonal abundance and various stages of *Pseudodiaptomus annandalei* (Copepoda: Calanoida) in Muttukadu backwater

J. Chitra and R. Ramanibai

University of Madras, Chennai, India (chitra_copepod@yahoo.co.in)

The seasonal abundance of the calanoid copepod *Pseudodiaptomus annandalei* was investigated from February 2004 to May 2006 in the Muttukadu backwater (Fig. 1), located 36 km from Chennai city surrounded by many aquaculture industries.

Figure 1. Muttukadu backwater.

Copepods are an excellent food with high nutritional value for zooplanktivorous fishes and shrimps (Watanabe *et al.*, 1983a,b; Bulkowski *et al.*, 1985; Kraul *et al.*, 1991; McLand *et al.*, 2000) and are used as a nutritionally significant live food for fishes and prawns (Altaff and Chandran, 1995). Increasing attraction in commercial culture of various marine fish species has led to recent improvements in copepod culture technology (Stottrup and Norsker, 1997; Schipp *et al.*, 1999). The use of copepod nauplii as prey during the early larval rearing of groupers has shown considerable promise in improving larval growth and survival (Doi *et al.*, 1997). Provision of calanoid nauplii (mainly *P. annandalei* and *Acartia tsuensis*) in rearing tanks resulted in higher survival and faster growth in *Epinephelus cocoides* compared with the use of rotifer (Doi *et al.*, 1997; Toledo *et al.*, 1999). It has already been reported that temperate estuarine species are amenable to high-density culture (Rippingale and MacShane, 1991) and may contain desirable ratios of essential fatty acids (Payne *et al.*, 1998). Planktonic copepods of the *Pseudodiaptomus* genus are distributed worldwide and commonly found in estuarine waters (Walter, 1986).

The aim of the present work is to study the abundance patterns of free-living calanoid copepods (*P. annandalei*) and their various stages of life cycle in the Muttukadu backwater. Muttukadu (Kovalam) backwater (12°47'N, 80°15'E) is located 36 km south of Chennai and forms a complex system of shallow estuarine waters spread over an area of 215 acres used primarily for fishing and boating activities by the Tamilnadu Tourism Development Corporation. The backwater extends north and south for about 15 km and opens into the Bay of Bengal at its southern end. It receives a considerable amount of sewage, industrial effluents, hazardous wastes, human influences and urban runoff (Fig. 1).

Bimonthly sampling was carried out from February 2004 to May 2006 and the sampling was done between 7.30 am and 9.30 am throughout the study. Four locations were selected at 100 m intervals from the mouth of the estuary and towards the boat house along the Muttukadu backwater. Copepods were collected in 100 L of surface water filtered using a plankton net (mesh size 250 μm) and preserved using 5% buffered formalin for further analysis. Zooplankton were identified following Sars (1921); Wilson (1932); Edmondson (1959) and Kasturirangan (1963) and enumerated using a Sedgewick Rafter cell counter. The values were expressed as ind.m^{-3} for zooplankton (Santhanam, 1989).

Among the 224 samples collected, the calanoid copepod (*P. annandalei*) occurred in almost all the four locations throughout the study period. Copepod abundance was estimated for various stages such as adult males, adult females, brood females, nauplii and copepodite. The abundance values of *P. annandalei* ranged from 237 to 2,667 ind.m^{-3} for nauplii, copepodites (108-3,358 ind.m^{-3}); adult male (0-4,510 ind.m^{-3}); adult female (108-4,638 ind.m^{-3}) and brood female (0-333 ind.m^{-3}).

Among the various stages of the copepod, the adult female showed the highest mean density (4,638 ind.m^{-3}). Brood females were observed least in the collections from monsoon 2004 to summer 2006. Adult male and female abundance was higher in the post monsoon 2004, naupliar density was found to be dominant during post monsoon 2005 and contrastingly the copepodites played a major role in production during post monsoon 2006. Comparatively higher abundance was recorded during the post monsoon seasons throughout the study period which appears to be the fertile period of *P. annandalei* (Fig. 2).

The copepods were cultured in the laboratory using mixed algal feed (*Chaetoceros wighami*, *Tetraselmis gracilis*, *Chlorella vulgaris*, *Chlamydomonas globosa* and *Skeletonema costatum*; Fig. 3). In the present study, the abundance was measured for all the stages from naupliar to adult stages. Prevalence of adults was already reported for various copepod species, although more specifically for Calanoida, from numerous estuaries, lagoons and neritic zones located worldwide (Heinle, 1966; Burkill and Kendall, 1982). Salinity may also be an important factor when regulating the composition, density and distribution of *Pseudodiaptomus* species in estuaries (Collins and Williams, 1981; Mitra and Patra, 1990; Sarkar and Choudhury, 1998).

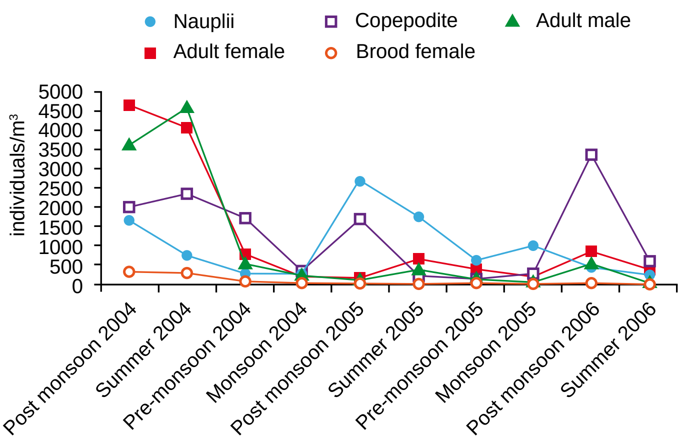

Figure 2. Seasonal abundance of the Pseudodiaptomus annandalei *community in Muttukadu backwater.*

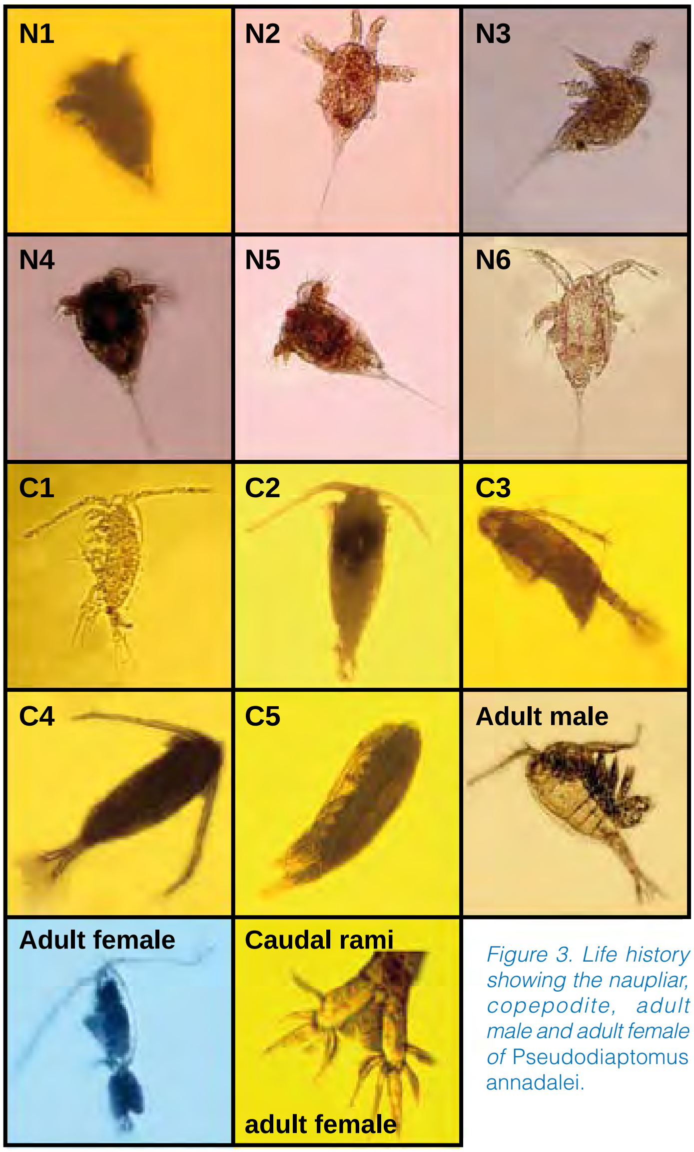

Figure 3. Life history showing the naupliar, copepodite, adult male and adult female of Pseudodiaptomus annadalei.

In the case of species of the *Pseudodiaptomus* genus, dominance of adult individuals in the populations was confirmed by Uye *et al*. (1983) and Uye and Sano (1995). However, the data obtained in terms of abundance from the investigations could be used to estimate the ecological role of the populations studied in the Muttukadu backwater. Biomass values for *Pseudodiaptomus* species in the studied area were lower than those reported in other regions (Liang and Uye, 1997; Eskinazi-Santánna, 2000). The relatively higher values registered in the Muttukadu backwater could be explained by the mesh size (250 μm) of the plankton net used in this study that should have predominantly captured individuals of large sizes and smaller sized nauplii and copepodites. The naupliar and the copepodite stages may have influenced the overall population biomass and play an important role in the aquaculture system. The complete scenario on the abundance and distribution of *P. annandalei* depicts the role as a live feed for fishes and shrimps in Muttukadu backwater and as may be used as the major feed in aquaculture industries surrounded by this backwater in the future.

The results demonstrate that the contribution of *P. annandalei* plays an important role in secondary production of the Muttukadu backwater and is one of the dominant copepods found throughout the study period.

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The zooplankton community of the Agadir Bay during spring season

Fatima El Aamri[1], Aziz Regragui[2] and Hassan El Ouizgani[1]
[1]Université IBN ZOHR, Agadir, Morocco (hassan.elouizgani@oceamar.org)
[2]Institut Spécialisé de Technologie des Pêches Maritimes, Agadir, Morocco

The zooplankton community was studied in the Atlantic waters of Agadir Bay over a period of seven years (1999-2006), the purpose of the study was to survey the spring evolution of the composition and distribution of zooplankton (specifically copepods). The systematic survey of the samples revealed the presence of 37 species of zooplankton with a predominance of the copepods which represented 22 species grouped in 12 families and was dominated by 5 species: *Acartia clausi*, *A. discaudata*, *Paracalanus parvus*, *Labidocera wollastoni* and *Centropages chierchia*.

Agadir Bay extends from Cape Ghir (30°37'N, 9°54'W) to Cape Aglou (29°40'N, 10°W) and is situated between two cells of upwelling to the north between Cape Ghir and Cape Sim and to the south between Sidi Ifni and the Cape Juby. The upwellings along the Atlantic Moroccan coast are weak or nonexistent in winter, develop in spring, increase in summer and are attenuated in autumn (Furnestin, 1957; Bélveze, 1984; Agoumi and Orbi, 1992).

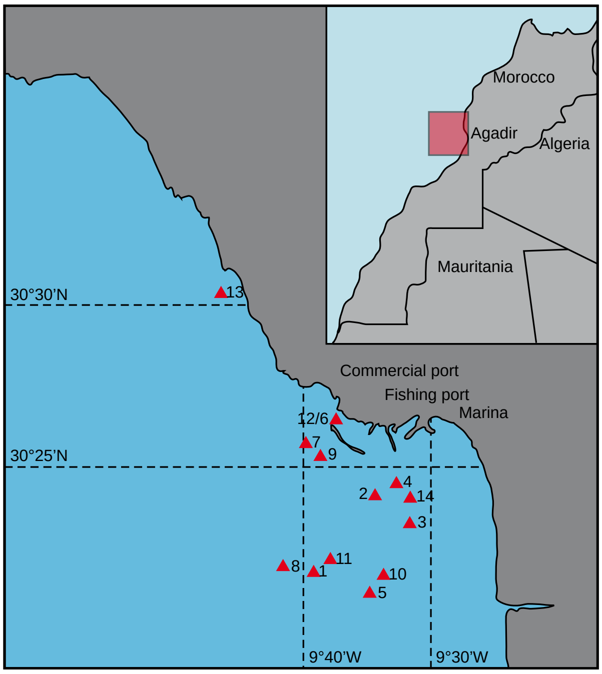

Figure 1. Study area and sampling sites in Agadir Bay.

Zooplankton were collected from the stations shown in Figure 1 using a Yakuma 180 µm plankton net and stored in formalin for analysis in the laboratory. Plankton were identified to gender for the copepods and to taxa for the other zooplankton. 37 species were identified, including three orders (Fig. 2a) and several species (Fig. 2b) of copepods.

The Shannon Index (H') varied between 0.75 (station 1) and 2.2 bits ind^{-1} (station 4; Fig. 3) and nearly all stations have diversity values of between 1.4 and 1.6 bits ind^{-1}. The weak values of H' noted here testify the dominance of a few species. Indeed, more than 96% of the total abundance was due to the five dominant species (Figs. 2 and 4). These values for the Agadir Bay are compared with other results for the area and for other bays worldwide in Table 1.

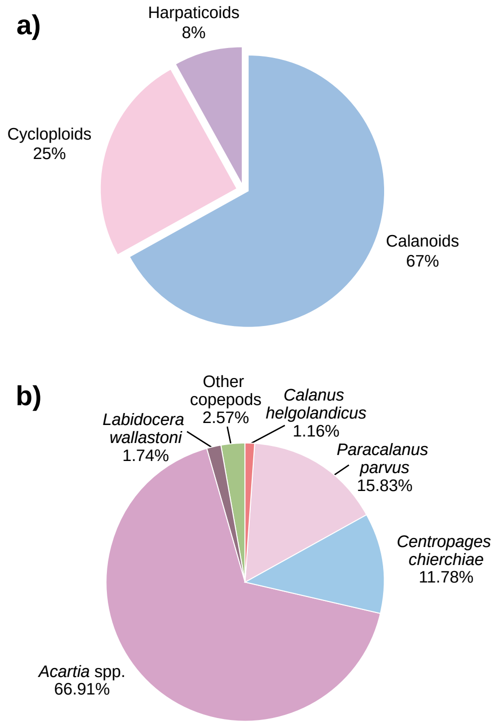

Figure 2. a) Distribution by order of the copepods from Agadir Bay and b) relative abundance of the different copepod species in Agadir Bay

Table 1. Shannon index variation expressed by study area

Authors	Area of study	Shannon Index
Elayaraja *et al.* (2007)	Bay of Bengal, Indian Ocean	1.3-2
Somoue (2005)	Atlantic coast of Morocco	2.5 and 4
Osore *et al.* (2004)	Mida Creek, Kenya	0.8-1
Youssara (2002)	Agadir Bay, Morocco	1 and 3.5
Jamet *et al.* (2001)	Toulon Bay, France	0.97 and 1.56
This study	Agadir Bay, Morocco	0.75-2.2

In our survey, copepods represented 59% of the zooplankton diversity and abundance hence demonstrating their importance in the trophic chain. A description of the most abundant species follows:

Acartia clausi is the most abundant species showing a peak of 1098 ind.m^{-3} at station 1, it was also found to be the most abundant copepod in the Bay of Biscay by Valdés *et al.* (1991). *Acartia clausi* is an epiplanktonic omnivorous species (Conover, 1956; Petipa, 1959; Anraku, 1964; Gaudy, 1970) which is able to adapt to any available food, this behaviour means that *A. clausi* can live throughout the year in Agadir Bay (Paulmier, 1969; Youssara, 2002; Belfquih, 1980).

Paracalanus parvus is an exclusive herbivore (Timonim, 1971; Binet, 1973; Belfquih, 1980) present throughout our survey (except 2006), with a strong abundance at station S6 (450 ind.m^{-3}).

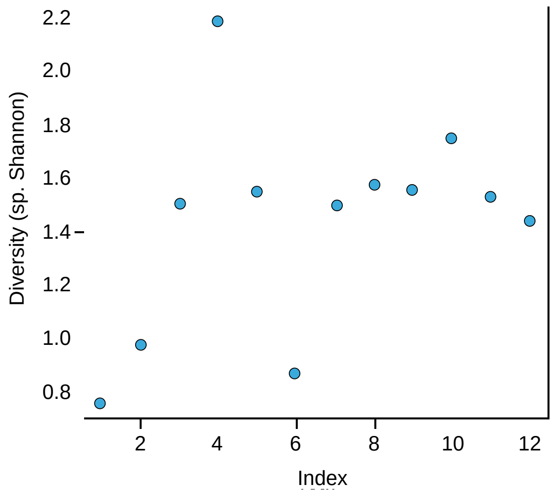

Figure 3. Variation of the Shannon diversity index for every station.

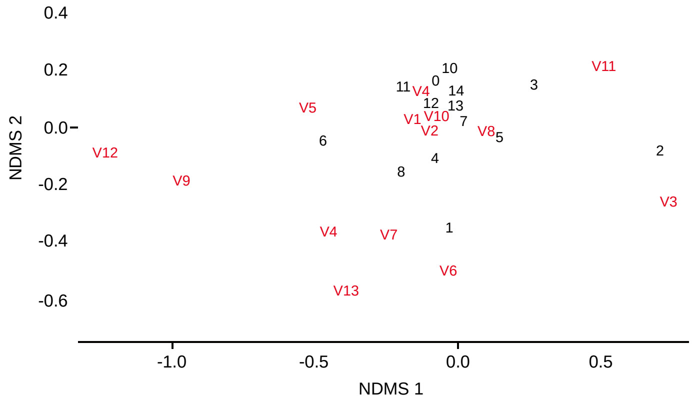

Figure 4. Non-metric multi-dimensional scaling (NDMS) plot of dominant species in Agadir Bay. V1: Calanus helgolandicus, *V2:* Paracalanus parvus, *V4:* Centropages chierchiae, *V8:* Acartia *spp., V10:* Labidocera wollastoni.

According to Belfquih (1980) and Somoue (2005), this copepod has a maximal abundance in both spring and summer. Furnestin (1960) found this species particularly abundant at the shore, and its distribution is limited by the local hydrological and meteorological conditions. *Paracalanus parvus* was the second most abundant copepod in the Bay of Biscay (Valdés *et al.*, 1991). The absence of this species in 2006 samples may be due to the high number of *Euterpina acutifrons* due to a high salinity.

Centropages chierchia is an omnivorous species which was found at all stations with a maximal abundance at station S11 (584 ind.m^{-3}), this high abundance has already been observed by Youssara (2002).

According to Belfquih (1980) and Somoue et al. (2005) *C. chierchiae* abundance varies with temperature and an inverse relationship is shown with *C. typicus*. In this survey we found the interrelationship of *C. chierchia* with temperature, but the absence of *C. typicus* remains to explained. In the literature, it has been suggested that *C. typicus* and *C. cheirchiae* could be used as key species for the surveillance of the climatic changes in the North Sea and the Gulf of Gascogne (Lindley and Reid, 2002; Lindley and Daykin, 2005).

Labidocera wollastoni dominated our samples (28 ind.m^{-3}) in the stations: S7, S8 and S11. Belfquih (1980) found *L. wollastoni* to be omnipresent in the Moroccan Atlantic, it is an omnivore (Conley and Turner, 1985) and shows a high abundance in both spring and summer, both in our survey and the survey by Chiahou (1990).

Calanus helgolandicus is a herbivorous copepod that was present in our samples with a weak abundance (S4 = 18 ind.m^{-3}) although it has been reported to be one of the most abundant Calanoidae on the Moroccan coast (Belfquih, 1980), after *A. clausi*. However, in the spring it is less well represented in the coastal zone which explains the weak abundance in our samples.

Cladocerans are a group of zooplankton which show a high abundance during warm seasons in Agadir Bay (Youssara, 2002).

Appendicularia were represented by *Oikopleura dioica* in our study. This species is abundant along the Moroccan coast. It is a neritic species which shows a maximum abundance in both spring and summer (Furnestin, 1957; Thiriot, 1978) which is in agreement with our samples.

Chaetognatha were abundant in our samples which is confirmed by Youssara (2002).

Dolioles, Siphonophores, Ctenophores and Leptomedusae are rare in our samples as their development is usually focused on the autumnal season.

Meroplankton were represented by four taxa, and the most abundant were the crustacean larvae (euphausiids and Decapoda) and fish eggs.

A similarity analysis of the sampled stations by species richness showed three distinct groups.

Group 1: High species richness. 5 stations (S6, S7, S12, S13, and S14).

Group 2: Moderate species richness. 6 stations (S1, S5, S8, S9, S10, and S11).

Group 3: Weak species richness. 3 stations (S2, S3, and S4).

These three groups are distributed according to their position in the bay: one close to the port, the second in the centre of the bay and the third further to the south. This distribution can be explained by a spatio-temporal evolution conditioned by the hydrological and physico-chemical parameters of Agadir Bay.

Acknowledgements

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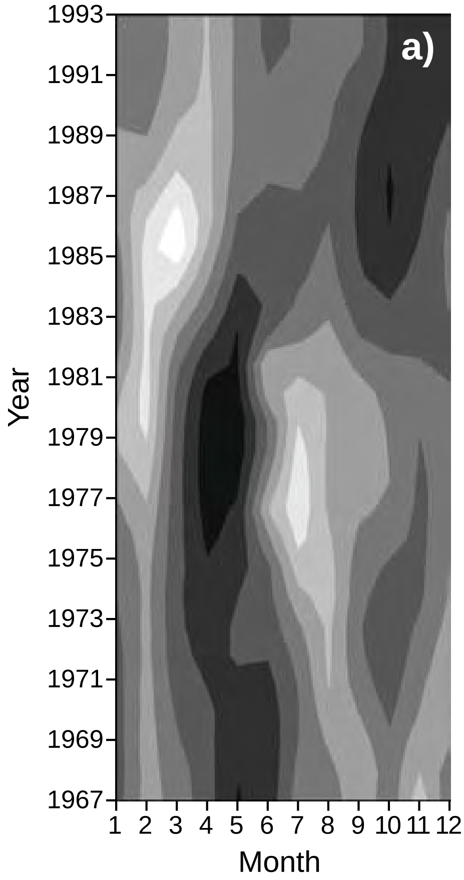
Connecting climate variability and the long-term changes of gelatinous carnivore populations in the northwestern Mediterranean

Juan Carlos Molinero[1], Michele Casini[2] and Emmanuelle Buecher[3]

[1]Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, Kiel, Germany (jmolinero@ifm-geomar.de)
[2]Swedish Board of Fisheries, Institute of Marine Research, Lysekil, Sweden
[3]University of the Western Cape, Bellville, South Africa

One of the main questions at the centre of the current debate on global change is the impact that modifications in climate patterns could have on marine ecosystems. Of significant importance are the potential effects in global geochemical cycles and fisheries. In recent years, particular awareness has focused on the upward trends documented for gelatinous carnivore populations in temperate ecosystems, which may have important implications on the population size of mesozooplankton, including fish eggs and larvae (Purcell and Arai, 2001), as well as on the alteration of matter fluxes in food webs (i.e. by channelling the energy flow away from fish). Indeed, the effects these organisms may have on fisheries are extensively documented for a number of ecosystems (e.g. North and Baltic Seas, British Columbia, Bering Sea). Hence, the frequent outbreaks of gelatinous carnivores reported in the last few decades in some temperate coastal areas may be indicative of ongoing modifications in marine ecosystems (Hay, 2006).

Here, we introduce results from retrospective analysis on the abundance variability of gelatinous carnivore populations (i.e. siphonophores, hydromedusae, ctenophores) during the period 1967-1993 in the northwestern Mediterranean. The species investigated show a holoplanktonic life cycle for which significant modifications in the water column features may affect survival and abundances of these species. The interannual changes in gelatinous carnivore populations during these years showed a noticeable shift (i.e. from spring to summer-autumn) in their peak of abundance *ca.* 1985 (Fig. 1a). The percentage of spring and summer-autumn species showed marked modifications that were also reflected in the species-specific abundances. For instance,



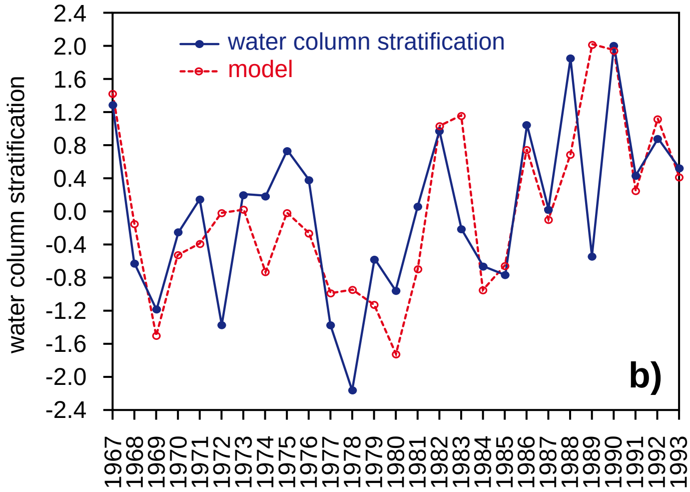


Figure 1. a) Month–year map of the seasonal peak. It was bimodal during the period ranging from 1967 to the mid-1970s and became unimodal during the late-1970s through early-1980s and was characterised by a spring peak. Afterwards the seasonal peak shifted to a summer–autumn annual peak; b) Observed interannual variability of the thermal stratification of the water column (anomalies: blue line) and that predicted by downscaling modelling (red line) during the period ranging from 1967 to 1993. Correlation of cross-validation is 0.64, and the model skill (β) is 0.57. Figure modified from Molinero et al., 2008.

the calycophoran siphonophores, *Chelophyes appendiculata* and *Abylopsis tetragona*, doubled their mean abundances between the years 1967-1974 and 1986-1993. Also, a higher increase was generally noticed in hydromedusae. *Rhopalonera velatum* and *Solmundella bitentaculata* reached abundances 4-fold higher in the years 1986-1993, and *Liriope tetraphylla* doubled its mean abundance compared to the years 1967-1974. The ctenophore *Pleurobrachia rhodopis*, however, showed major mean abundances (4-fold higher) during the years 1975-1985 (cold years). With the exception of *P. rhodopis*, the population size of gelatinous carnivores substantially increased during years with higher water temperatures and low wind stress that characterised the northwestern Mediterranean in middle-late 1980s.

Examination of local hydro-climatic factors (i.e. precipitation, irradiance, thermal stratification of the water column) potentially affecting survival of gelatinous carnivores and their larvae (Goy *et al*., 1989; Buecher, 1999) showed a tight link with regional and North Atlantic climates. In particular, the variability of thermal stratification over the period 1967-1993 is captured when using regional and North Atlantic climate variability as predictors (Fig. 1b). Briefly, the downscaling approach used consisted of an evaluation of the interrelations between climate (i.e. Atlantic climate and regional climate) and the local environmental conditions. Factors identified were included in a Principal Component Analysis (PCA) to pick up the main climate signals related to local conditions. Then, Canonical Correlation Analysis (CCA) was performed between the leading principal components of climate (predictors) and local conditions (thermal stratification) at the study site (for details see Molinero *et al*., 2008).

The statistical downscaling approach allows identification of significant links between the Atlantic climate and the timing in the annual peak of gelatinous carnivores. Specifically thermal stratification used as a proxy of local environmental conditions relevant for gelatinous carnivore populations emerges as a potential mediator between climate and the phenology of gelatinous carnivores. Species-specific sensitivity was also pointed out by the downscaling approach, which allows identification of links between the abundance of gelatinous carnivores and the North Atlantic climate, hydro-climate in the Ligurian region, and thermal stratification of the water column.

Figure 2 displays the predicted interannual changes of calycophorans, siphonophores and hydromedusae by dowscaling models. The correlations displayed are significant with respect to the 99% confidence level. In addition, it is worth noting that downscaling models (including for the ctenophore *P. rhodophis* and the hydromedusae *L. tetraphylla*) were substantially improved when considering only the years in which the North Atlantic climate anomalies were higher than 0.5 SD. These results suggest threshold values from which climate effects become noticeable and the relationship between climate forcing and gelatinous carnivore abundance increases with the strength of the climate signal.

A novel result is the sensitivity shown by gelatinous carnivore species to environmental forcing related to their seasonal appearance and peak of abundance. For instance, the spring peak species (i.e. *A. tetragona*, *C. appendiculata* and *P. rhodophis*) were found to be more sensitive to winter and spring environmental conditions, whereas the summer peak species (i.e. *R. velatum*, *S. bitentaculata* and *L. tetraphylla*) were more sensitive to spring and summer environmental conditions. These

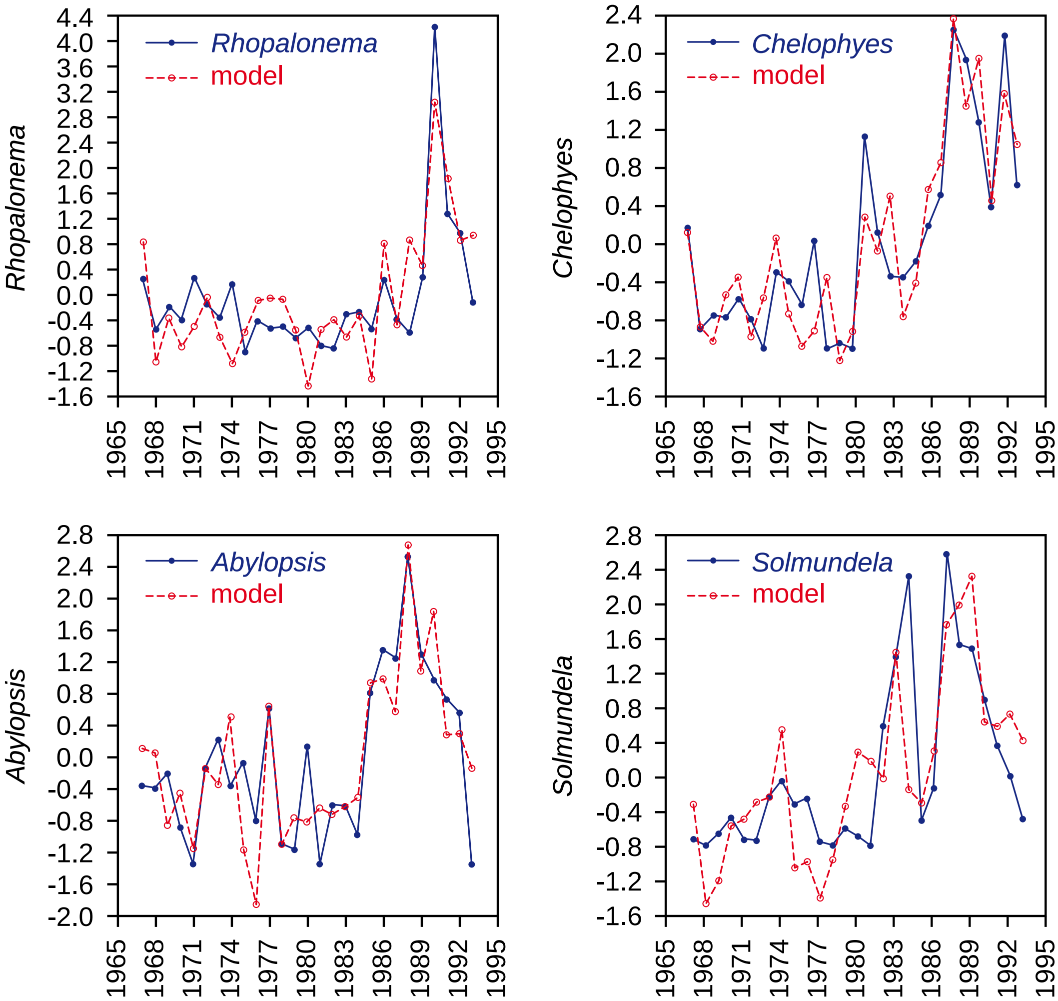


Figure 2. Observed interannual variability of gelatinous carnivore species (anomalies: blue line) and that predicted by downscaling models (red line) during the period ranging from 1967 to 1993. Correlation of cross validation (CC) and the model skill (β) are as follows: a) Rhopalonema *(CC = 0.61, β = 0.57); b)* Chelophyes *(CC = 0.69, β = 0.48); c)* Abylopsis *(CC = 0.54, β = 0.65); and (d)* Solmundela *(CC = 0.55, β = 0.66). Figure modified from Molinero et al., 2008.*

results strongly emphasise the occurrence of short time windows where gelatinous carnivores appear to be more sensitive to environmental conditions, and favourable conditions may therefore substantially enhance their annual peaks. The possibility therefore emerges of assessing and perhaps predicting the main patterns of interannual variations in gelatinous carnivore abundance according to the patterns of variability of the North Atlantic climate; particularly if threshold values are considered (e.g. anomalies of climate > 0.5 SD). Also, these results alert us to the likelihood that large populations of gelatinous carnivores may become more frequent in the northwestern Mediterranean if projections of NAO scenarios and higher temperatures in the Northern Hemisphere are confirmed. In fact, among global climate projections none of the analysed models suggest a decrease of the dominance of the positive phases of the NAO (IPCC, 2007). This means that high atmospheric pressure, low precipitation, high temperatures and low wind stress in the northwestern Mediterranean may be more recurrent, which points toward enhanced water column stratification and possible favourable environments for gelatinous carnivore growth. In this framework, owing to the ecological importance of gelatinous carnivores (i.e. modification in matter fluxes and top-down control of mesozooplankton) these results constitute ecological warning indicators of changes in the pelagic ecosystem of the northwestern Mediterranean.

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Mnemiopsis leidyi, the new invader of the Baltic Sea: seasonal changes and population dynamics

Jamileh Javidpour (jjavid@ifm-geomar.de), Juan Carlos Molinero, Jesco Peschutter and Ulrich Sommer
Leibniz-Institute of Marine Sciences, Kiel, Germany

Invasions by alien species represent one of the major threats to the functioning of natural ecosystems (Sala *et al*., 2000; Wolters *et al*., 2000). The global increase of species invasions is thought to be driven mainly by two factors: ecosystem homogenisation due to intensified human transport vectors (e.g. ballast water of ship traffic) and weakening of invasion resistance of recipient ecosystems due to overexploitation, species removal and environmental change (Carlton, 1999; Jackson *et al*., 2001). While biological resistance by indigenous communities in the poor ecosystems like the Baltic Sea may play a minimum role controlling a generalist invader, the success or failure of invasions may depend crucially on the physical and chemical conditions of the recipient ecosystem.

Recent invasion of the ctenophore *Mnemiopsis leidyi* (Fig. 1) and its potential impact on the plankton community of the Baltic Sea became a matter of current concern. This species is widely recognised as a harmful invader and ranked among the world's 100 worst invasive species (http://www.issg.org/). Its original home range comprises coastal and estuarine habitats of the North and South American Atlantic coasts. *M. leidyi* became particularly infamous for causing the strong ecological impact on marine food webs, which stems from both the direct feeding on fish larvae and eggs and resource competition with zooplanktivorous fish. While its invasion to the Baltic Sea opens a question of its ecosystem wide impact in an overexploited system, a prior understanding of the seasonal variations and population dynamics of *M. leidyi* is required. Here we introduce the first data on the seasonal dynamics and population size of *M. leidyi* in the southwestern Baltic Sea after its first occurrence, and discuss the possible mechanisms underlying its establishment in the Baltic ecosystem.

Figure 1. The comb jelly Mnemiopsis leidyi *(A. Agassiz, 1965).*

Annual cycle and population dynamics – the weekly sampling of different plankton communities of the Kiel Fjord, western Baltic Sea, allowed us to follow the annual cycle of each group which is presented in Figure 2. The phytoplankton-copepod-ichthyoplankton pattern of abundance considered as a regular sequence of the plankton pulse of this area in which the sharp decrease of copepod density corresponds to the increase of fish larvae (Javidpour *et al*., 2008). *M. leidyi* was always present in the plankton samples during the period from October 2006 to December 2007, however it had short time scale fluctuations in density. *M. leidyi's* annual cycle was characterised by a main peak in late summer-early autumn. The single peak of July was associated with high water exchange with the Kiel Bight. The simultaneous outbreak of *M. leidyi* with the peak of microzooplankton, suggests a primary predation on microzooplankton (i.e. ciliates) which can

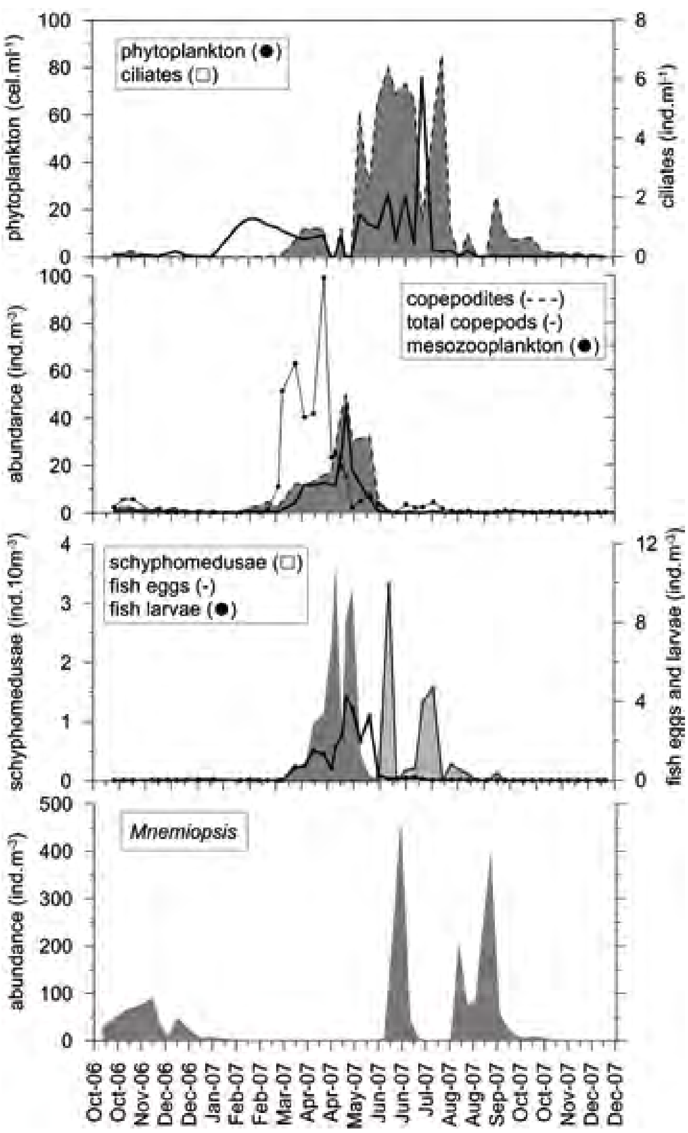

Figure 2. Annual cycle of plankton communities' succession in Kiel Fjord, a) microplankton, b) mesozooplankton, c) ichthyioplankton and matured schyphomedusae, and d) Mnemiopsis leidyi. *© Springer 2008.*

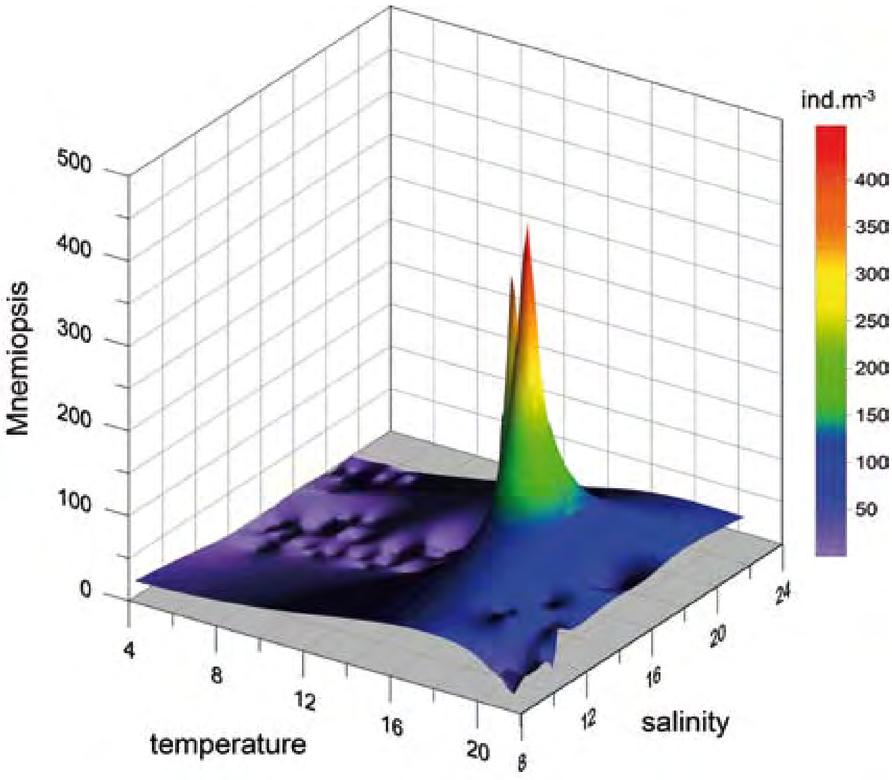

Figure 3. 3D graph of Mnemiopsis leidyi *abundance-temperature-salinity.* M. leidyi *reaches its highest density in a narrow environmental space (between 14-17°C and salinity of 16-20) that mainly corresponds to the summer season. © Springer 2008*

have important ecological implications since Pitt *et al*. (2007) indicated that high predation pressures on ciliates and changing the structure of microzooplankton assemblages may trigger red tide formation. There was no seasonal overlap between *M. leidyi* high abundance with peaks of mesozooplankton and fish larvae. During the whole period of investigation 85-90% of the population consisted of small larvae and post larvae of <10 mm. Reproduction patterns showed a period of high reproductive activity associated with warmer temperatures, which was followed by a period of low reproductive activity associated with the lowest temperatures and low population density. The vertical distribution analysis results in two contrasting situations: the bulk of the population remains in deep layers during the periods of low population density (winter-spring), whereas it appeared situated in upper layers during the proliferation of the species (summer-early fall). To emphasise the strength of the population outbreaks, we provided Figure 3 which displays the narrow environmental space in which *M. leidyi* can reach its maximum abundances more than 10-fold higher in a short time.

Ecosystem wide impact – the narrow environmental window for accelerating population growth might limit the fitness of *M. leidyi* for the whole area of the Baltic Sea, as the favourable temperature and salinity for increasing its density lies in a limited region. However, the reported warming trend in the Baltic Sea (Lehmann and Hinrichsen, 2007) and the remarkable ability of this invader to double its population size in short time periods, makes it a matter for current concern and a critical challenge in predicting future risks of the Baltic Sea ecosystem development.

Acknowledgments
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EcoANCHOA: a proposal for a significant improvement of our understanding of Bay of Biscay anchovy in the context of the ecosystem

Xabier Irigoien

AZTI-TECNALIA, Marine Research Unit, Pasaia, Spain

As far as registers exist (1940) the captures and estimated biomass of anchovy (*Engraulis encrasicolus*) in the Bay of Biscay have never been so low. The fishery collapsed in 2005 and still remains closed (Fig. 1) which was caused by a series of successive recruitment failures. However, we do not know the reason behind the high mortality of egg and larvae and consequent low recruitment during those years. This situation has prompted the demand from the administration for a deeper understanding of anchovy in the context of its ecosystem.

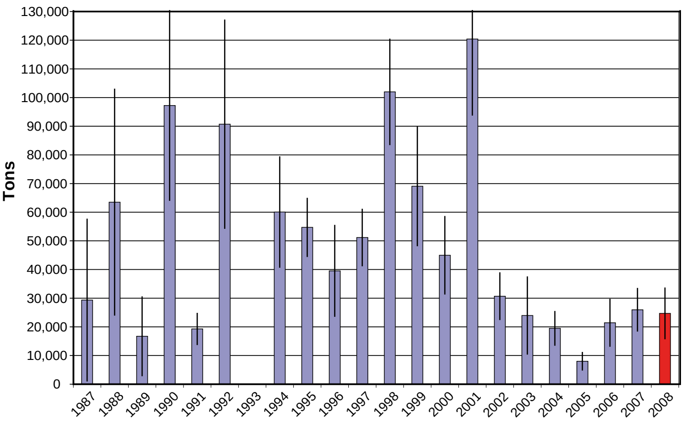

Figure 1. Time series of anchovy biomass in the Bay of Biscay.

Is it due to overfishing?

Traditional fisheries models based on single species analysis suggest that fishing mortality was not excessive (although this is being evaluated). However, there is a mechanism not considered in the applied fisheries models where the fishery could still have an effect on the recruitment: intraguild predation (IGP), species that compete for food as adults and eat the eggs and larvae of the other species. This is the case for almost all species of small pelagic fish. If such an interaction is strong, then fishing on one species has a double negative impact by favouring adult competitors and therefore increasing the number of predators of egg and larvae (Fig. 2).

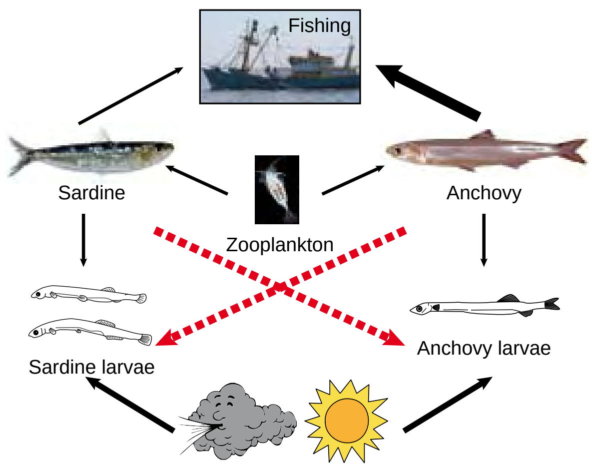

Figure 2. Simplified diagram of the relationships to be evaluated in this project. The red arrows show the interaction whose intensity must be measured in order to be able to accept or reject the proposed hypothesis.

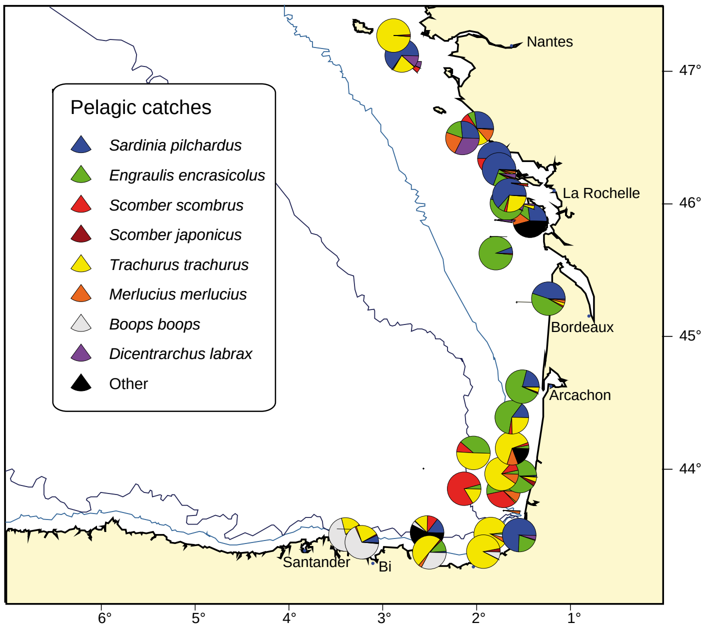

Figure 3. Composition of pelagic catches in the spawning area of anchovy in spring 2008.

It is not then related to climate or climate change?

Anchovy and other small pelagic populations oscillate naturally (Baumgartner, 1992; Chavez *et al*., 2003). It is obvious that recruitment is influenced by environmental conditions, but ignoring the mechanisms we cannot establish the cause and effect. The Bay of Biscay has been warming at a rate of about 0.5°C per decade (Koutsikopoulos *et al*., 1998). This warming is associated with changes in the frequency and timing of upwelling events and nutrient input. Anchovy populations are sensitive to temperature variations (Chavez *et al*., 2003) upwelling intensity (Borja *et al*., 1998), and probably to other processes associated with warming and transport. However, in the Bay of Biscay paradoxically we observe that the declining species is the one better adapted to warmer temperatures, whereas species spawning at lower temperatures (sardine, mackerel, horse mackerel) are more abundant at present (Fig. 3). The potential factors affecting the population could be classified in two large groups: 1) bottom up factors such as temperature, transport or food, and 2) top down factors such as fishing or predation between competitors.

Why does it matter if the environment is influenced by bottom-up or top-down mechanisms?

The two mechanisms have radically different consequences in terms of the management of short lived small pelagics. If the environment influences recruitment through bottom-up mechanisms, the factors controlling recruitment cannot be controlled and the only management possible is short term measures through the measurement of next year's recruits. If the control is top-down there is the potential to propose long term ecosystem management measures aiming to compensate pressure on the most valuable species.

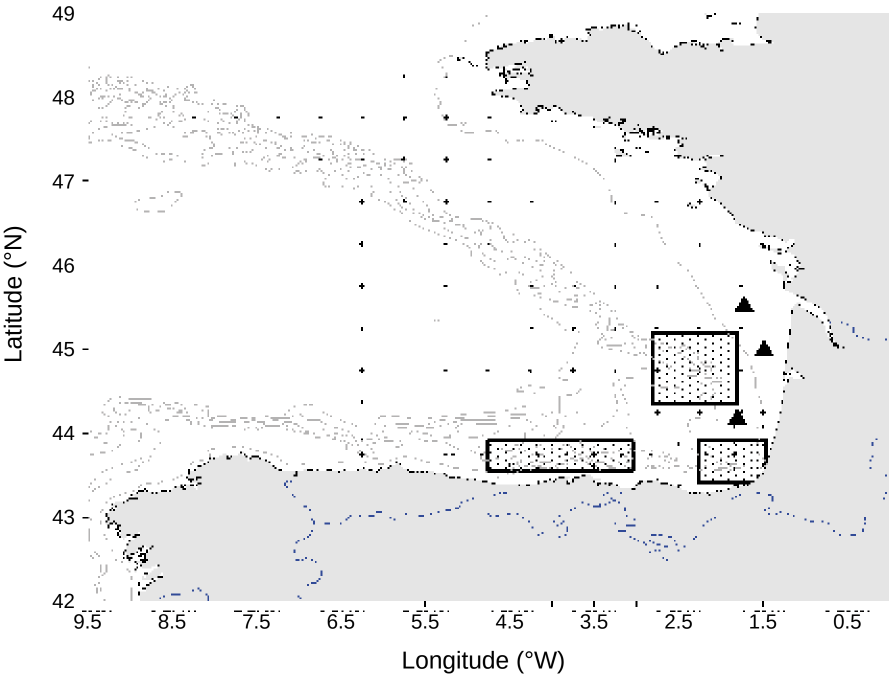

Figure 4. Map of the Bay of Biscay showing the area of interest. The crosses show the nodes to be sampled during the mapping campaigns (the northern part, >47°N, will only be sampled in one winter campaign). The triangles show approximate starting points for the mesocosm drift experiments. The boxes indicate areas of special interest for the processing studies.

How will EcoANCHOA reach these objectives?

EcoANCHOA proposes 5 activities:

1. Analysis of historical information
2. Mapping cruises (2008-2009)
3. Process cruises (2009)
4. Modelling
5. Evaluation of the socioeconomic impact

The first three activities will contribute information on the size of the population, relationship with the environment, distribution and transport of eggs and larvae, distribution of food and predators and predation rates. The main difference with usual biological oceanography cruises is that we will consider the distribution of potential predators of eggs and larvae using acoustics, trawls and gut content analysis (Fig. 4). This information will be fed into the models in order to evaluate the relative importance of the different factors and the effect of management methods. Finally, we will evaluate the socioeconomic impact of the different scenarios

What is the main objective of EcoANCHOA in this context?

The first priority of EcoANCHOA is to answer the most important question in terms of alternative management methods: Is intraguild predation an important control mechanism of the Bay of Biscay anchovy population? This is the main difference with other GLOBEC programmes because in EcoANCHOA we will make an important effort to evaluate the role of predation in the dynamics of small pelagics, not predation on adults, but predation on eggs and larvae.

This is the first question that we need to answer, as it is the one question that has important consequences in terms of changing management methods for anchovy fisheries. If the answer is negative there are remaining mechanisms for a bottom-up control of the recruitment; but in this case, whatever the mechanism, it would not have consequences in terms of management in the long term as none of the bottom-up factors can be controlled.

Is this the only objective of EcoANCHOA?

No, EcoANCHOA has three secondary objectives. The first one is to improve our understanding of the pelagic ecosystem in the Bay of Biscay in order to establish a comprehensive knowledge basis. The second, if top-down control was found to be irrelevant, will be to use the acquired knowledge to establish which bottom-up mechanisms determine recruitment. The third objective is to determine the socioeconomic impact of the anchovy fisheries and the consequences of alternative management methods.

Who will participate in EcoANCHOA?

In the first phase 8 institutions will be involved: AZTI Tecnalia, IEO, University of the Basque Country, University of Cantabria, University of Oviedo, CEP, University of Vigo and ICMAN CSIC. However, EcoANCHOA aims to establish close collaborations with other groups, both Spanish and international.

How long and who pays?

The project will run for 4 years (2008-2012). It was promoted by the Department of Agriculture and Fisheries of the Basque country government through the Interregional Committee for Cantabrian Sea and Northwest Fisheries Coordination. It has initial funding from the Basque Country, Cantabria, Asturias and Galicia autonomous regional governments.

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8th Larval Biology Symposium

Antonina dos Santos

IPIMAR-INRB, Lisbon, Portugal (antonina@ipimar.pt)

Figure 1. Participants of the 8th Larval Biology Symposium.

The 8th Larval Biology Symposium (Larval 2008) was held on 6-11 July 2008 in Lisbon, Portugal. The symposium was organised by IPIMAR-INRB with the collaboration of the Faculty of Sciences of the University of Lisbon and CESAM (Centre for Environmental and Marine Studies) of the University of Aveiro. It was a great success and all the participants very much enjoyed the high level of the scientific presentations, as well as the friendly atmosphere of Lisbon, the social programme for the free Wednesday afternoon, the welcome reception, and the conference dinner on Thursday night.

This conference aimed to promote the exchange of information and enhance international research collaboration in any field of marine larval biology (invertebrate and fish larvae) defined in its widest sense and the programme included six thematic symposia to give a more comprehensive rather than specialised approach.

The symposium was opened with a welcome address from senior scientist Carlos Vale, on behalf of the IPIMAR Director, Prof Nuno Guimarães, President of the Faculty of Sciences, the representative of CESAM and myself, Antonina dos Santos, as the chair of the organising committee. 170 participants (a record for Larval symposiums), from more than 25 countries, attended Larval 2008 (Fig. 1). 107 oral presentations and 49 posters were presented in the course of 9 sessions.

Six special half-day thematic sessions focused on subjects chosen by the organising committee. For this symposium we had the following themes: "Larval behaviour, dispersal and mortality", regarding the interaction of physical and biological aspects that act from larval hatching to settlement; "Molecular and geochemical markers for assessing larval dispersal", where the goal was to seek new ways to integrate and automate these methods; "Larval feeding strategies", regarding the role of different feeding strategies directly or indirectly affecting the dispersal potential as well as the size and stability of populations; "Larval settlement: cues, behaviour response, and possible mechanisms", which aimed to provide a platform for larval biologists to review recent progress in identification of larval settlement cues, possible sources of cues, larval settlement behaviour, and possible molecular mechanisms on how larvae perceive the cues; "Eggs, embryogenesis and early larval life" that tried to discuss all aspects of early life stages, such as morphology, ultra structure, embryology, organogenesis, etc.; and finally "Ontogenetic strategies in extreme aquatic environments" which tried to explore all aspects of all stages of development of invertebrates that live under extreme aquatic environmental conditions.

Additionally there were three sessions on general ecology, morphology and larval development, and genetics and physiology. For this conference, as plenary and invited speakers of the thematic sessions, we assembled a distinguished array of researchers and experts in the different fields. On Thursday afternoon there was a poster session joining all theme sessions (Fig. 2). Details of the abstracts for all the presentations can be obtained from the Larval 2008 website (http://larval2008.fc.ul.pt/).

Figure 2. Photographs from the poster session that was held in the Faculty of Sciences, University of Lisbon, Portugal

Prize money was donated for the best student oral communication by Dr Steve Coombs from Spartel which was won by Jorge Fontes with the presentation "Can we predict *Coris julis* recruitment success from larval growth, size and stage duration?".

Larval 2008 had fascinating communications from the invited speakers to student presentations. It turned out to be a great opportunity to discuss new scientific and technical ideas and to make contact with colleagues from all over the world.

Finally, the next Larval Biology Symposium will take place in 2010 in Wellington, New Zealand.

Climate effects on benthic interactions revealed by continuous monitoring of the North Sea meroplankton

Richard R. Kirby[1], Gregory Beaugrand[2], and John A. Lindley[3]

[1]University of Plymouth, Plymouth, UK (Richard.Kirby@plymouth.ac.uk)

[2]Université des Sciences et Technologies de Lille 1, Wimereux, France

[3]Sir Alister Hardy Foundation for Ocean Science, Plymouth, UK

Several changes have been reported recently in the distributions, abundances and seasonal cycles of the North Sea and Atlantic plankton that appear to be climate driven. However, in contrast to the Continuous Plankton Recorder (CPR) survey of the North Atlantic and North Sea plankton (Batten *et al*., 2003), there are few similarly long-term, spatially extensive studies of the benthos where sampling techniques are consistent over both temporal and spatial scales. Analyses of the long-term time series of North Sea CPR plankton samples and sea surface temperature (SST) data reveal that the annual planktonic larval abundances of three benthic phyla, Echinodermata, Arthropoda, and Mollusca each respond positively and immediately to SST (Kirby *et al*., 2008; Fig. 1a-f). Long-term outcomes for the planktonic abundance of these three phyla are different, however. While the planktonic larvae of echinoderms and decapod crustaceans have increased in abundance in CPR samples from 1958 to 2005, and especially since the mid-1980s as North Sea SST has increased (Figs. 2a and b), the abundance of bivalve larvae has declined (Fig. 2c), despite a positive year to year relationship between temperature and bivalve larval abundance continuing to hold (Fig. 1f).

Although North Sea SST is now higher throughout the year, the greatest increases have occurred in the winter and spring months. Fecundity in many poikilotherms, egg size and number, are phenotypically plastic traits influenced by temperature; warmer temperatures during gametogenesis are usually associated with smaller eggs and larger clutch sizes. In marine organisms this phenomenon is often represented by latitudinal clines or depth variation in reproductive output. In this way, increases in SST could influence reproductive output in a wide variety of benthic organisms with similar life history strategies (sea bottom temperatures are close to SST in most continental shelf waters for much of the year). Warmer winter temperatures may also favour the survival of the benthic adults.

Meroplankton abundance is also influenced by SST during the planktonic phase. Warmer SST will shorten larval development times benefiting larval survival when food is unlimited. The availability of phytoplankton food during the planktonic stage will therefore also have an effect on larval survival. Increases in the North Sea Phytoplankton Colour Index (PCI; a measure of phytoplankton chlorophyll) derived from the CPR survey (Batten *et al*., 2003) show that chlorophyll levels have increased over

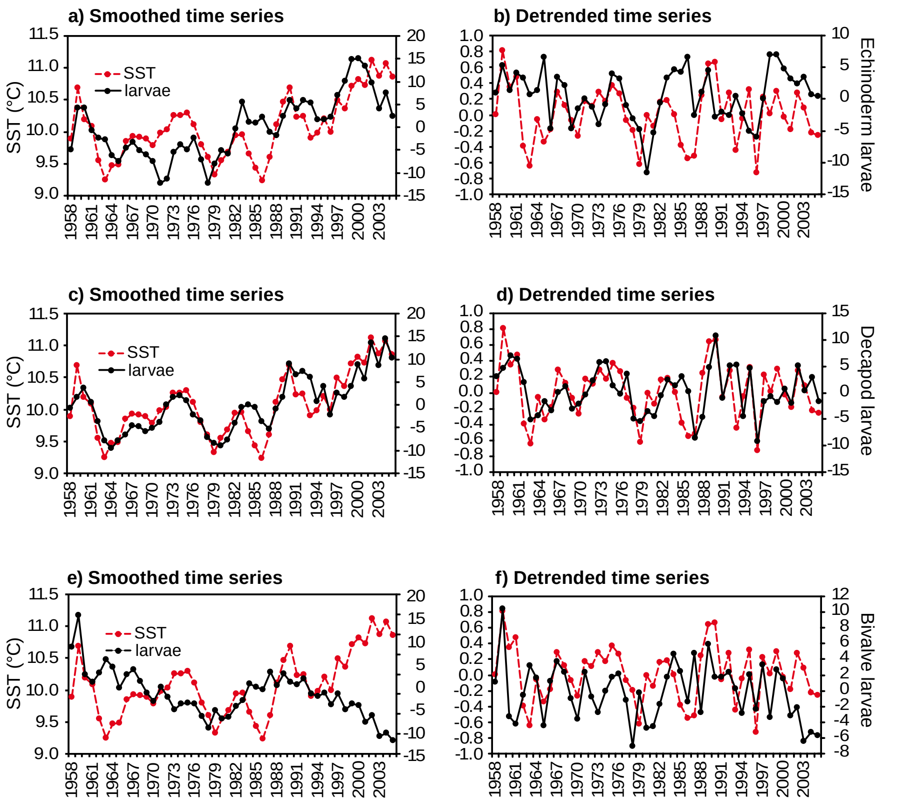

Figure 1. Correlations between echinoderm, decapod and bivalve larval abundance ($log_{10}(x+1)$) and annual averaged SST in the North Sea for the period 1958-2005. a) Smoothed time series of the first principal component of echinoderm larval abundance and SST. b) Detrended time series of the first principal component of echinoderm larval abundance and temperature. c) Smoothed time series of the first principal component of decapod larval abundance and SST. d) Detrended time series of the first principal component of decapod larval abundance and temperature. e) Smoothed time series of the first principal component of bivalve larval abundance and SST. f) Detrended time series of the first principal component of bivalve larval abundance and temperature. Temperature data were obtained from the COADS 1-degree enhanced dataset provided by the comprehensive NOAA-CIRES Climate Diagnostics Center Database (Boulder, Colorado, USA). Plankton data were obtained from the CPR survey (Batten et al., 2003). Full details of the statistical methods can be found in Kirby et al. (2008).

the whole North Sea region since the mid-1980s and are now also higher throughout the year (Fig. 3). Coincident changes in temperature and phytoplankton in the North Sea may thus act in concert to increase meroplankton abundance.

It is known that climate change can uncouple trophic interactions in aquatic ecosystems with severe consequences for resource flow. In continental shelf seas, changes in meroplankton abundance may affect the trophodynamics of the spring and summer plankton and, if their recruitment also improves, may have an effect on benthic community ecology to intimately link the benthic and pelagic environments.

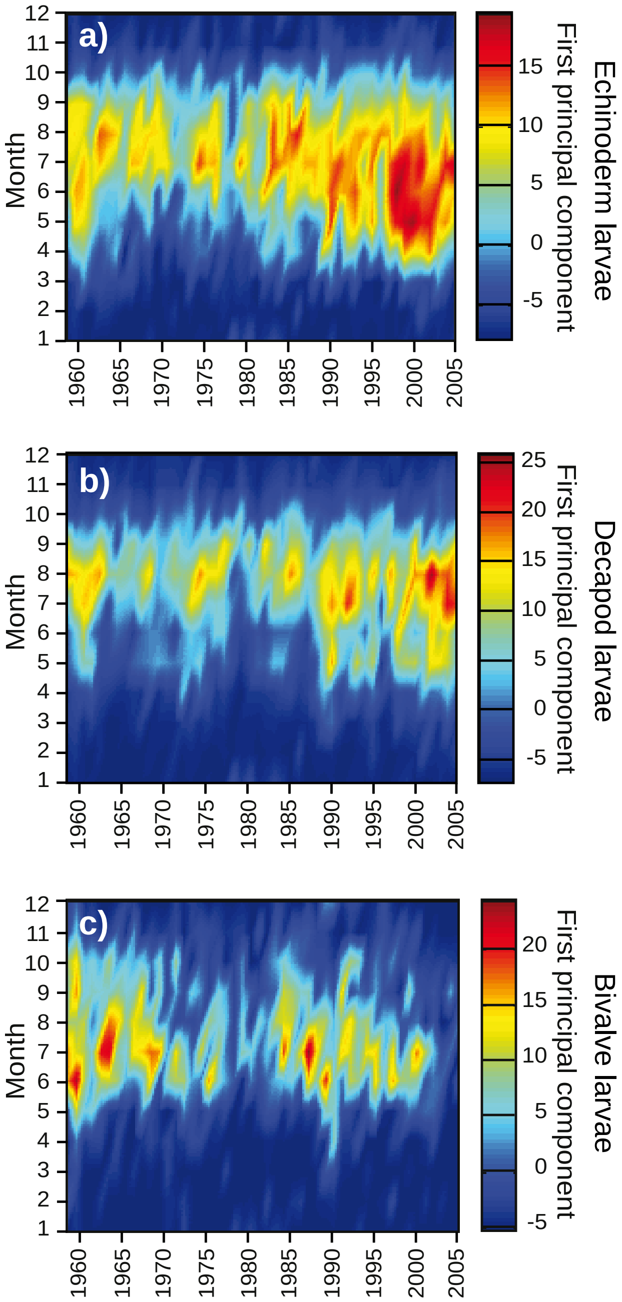

Figure 2. Three dimensional plots showing temporal changes in the first principal component of echinoderm, decapod and bivalve larval abundance ($log_{10}(x+1)$) in North Sea CPR samples for the period 1958-2005. a) Echinoderm larvae, b) Decapod larvae, c) Bivalve larvae.

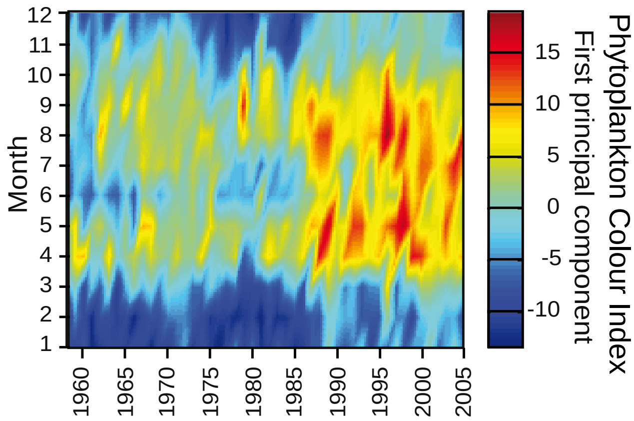

Figure 3. Three dimensional plot of temporal changes in the first principal component of the Phytoplankton Colour Index (PCI) in North Sea CPR samples. The PCI data were obtained from the CPR survey.

Despite the positive relationship between the abundance of bivalve larvae and SST, the long-term decline in abundance of bivalve larvae reveals that not all taxa benefit equally from the new North Sea hydroclimatic regime. Although the relationship between planktonic larval abundance and the size of benthic populations has not been generally established for invertebrate macrofauna, larval surveys are a long established means of estimating the spawning stocks of certain taxa e.g. decapods. North Sea fisheries data also show that landings of the predatory decapods *Pandalus* and *Nephrops*, and *Cancer* have increased markedly. Bivalve recruitment is affected deleteriously by benthic decapod predation on the newly settled bivalve larvae. The declining abundance of bivalve larvae in the North Sea may therefore represent a dwindling adult population due to poor recruitment year on year as a result of increased decapod predation.

Our analysis of a long-term plankton community dataset therefore suggests that while larval production of benthic organisms with similar life histories may respond similarly to ocean warming, the interactions among species may bring about quite different outcomes. The changes in the North Sea meroplankton may signal ecosystem-wide changes in nutrient cycling through changes in benthic-pelagic coupling. Likewise, changes in the relative abundances of the adult benthic stages, due to improved recruitment, may be restructuring the benthic community though competition, predation, and disturbance. Continued long-term monitoring of the North Sea plankton may provide new insights into the effect of climate on uncoupling the trophic linkages between species and systems.

A more detailed analysis of these results is reported by Kirby *et al.* (2008).

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The Australian Continuous Plankton Recorder (AusCPR) survey: a plankton observing system in Australian waters

Claire Davies (claire.davies@csiro.au), Frank Coman, Graham Hosie, David McLeod, Anthony J. Richardson and Anita Slotwinski
CSIRO Marine and Atmospheric Research, Cleveland, Queensland, Australia

The AusCPR survey is a joint project of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Antarctic Division (AAD, Department of the Environment, Water, Heritage and the Arts) to monitor plankton communities as a guide to the health of Australia's oceans. The AusCPR survey is part of the Integrated Marine Observing System (IMOS), an initiative of the Australian Government being conducted as part of the National Collaborative Research Infrastructure Strategy to observe Australia's marine environments.

The project will initially run for 4 years and cost A$1.69 million ($US1.47M), but it is envisaged that the survey will continue well into the future. International experience has shown that plankton respond rapidly to changes in ocean conditions making them invaluable indicators of ecosystem health and environmental change. Time series provide a baseline for answering questions concerning impacts of climate change, fisheries, eutrophication, pollution and species introductions on the abundance, distribution, phenology and composition of plankton (Fig. 1).

The AusCPR survey aims to:

- map plankton biodiversity and distribution
- develop the first long-term plankton baseline for Australian waters
- document plankton changes in response to climate change
- provide indices for fisheries management
- detect harmful algal blooms
- validate satellite remote sensing
- initialise and test ecosystem models.

Routes

Australia is unique in being bounded by warm-water poleward-flowing boundary currents off both its east (the East Australian Current, EAC) and west (Leeuwin Current) coasts. Although this results in generally low plankton and fisheries productivity, diversity is high and has affinities with the diverse tropical taxa of the Indonesian region. AusCPR will observe the plankton monthly along two routes using Continuous Plankton Recorders (CPRs).

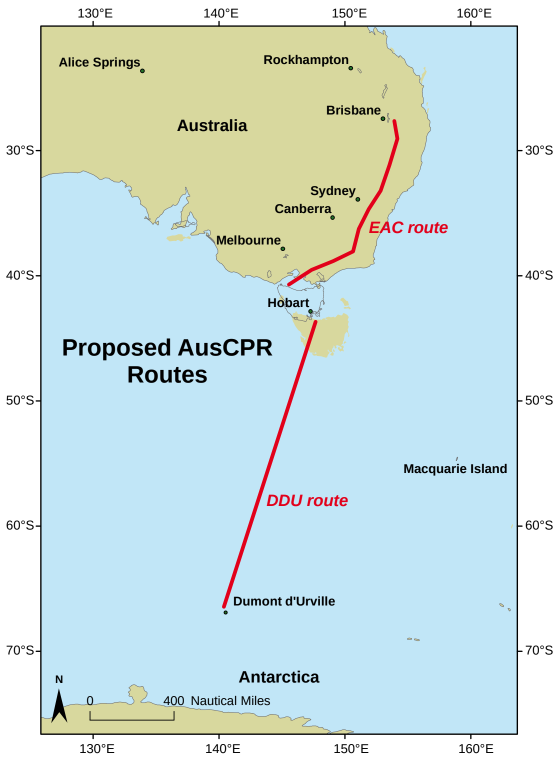

Figure 2. Map of the proposed AusCPR tow routes.

The EAC route extends from Brisbane (Queensland, latitude 27°S) to Burnie (Tasmania, latitude 41°S; Fig. 2). The EAC has intensified over the last 60 years, with a poleward advance of ~350 km, and in the south is warming at a rate of 2.28°C/century (Ridgway, 2007). This intensification has led to a southward shift in intertidal and fish species, although much of this information is anecdotal (Poloczanska *et al.*, 2007). Global climate models suggest that this region will experience the greatest warming in the southern hemisphere this century (Cai *et al.*, 2005). This CPR route will allow us to identify and understand mesoscale features that drive production and biodiversity along the Australian east coast and provide a longer-term baseline for assessing change.

Figure 1. Some organisms found in CPR samples: a) Noctiluca scintillans *can form algal blooms, b) an Oncaea, and c) a planktonic fish egg. Images courtesy of Anita Slotwinski/TAFI.*

The other route is from Hobart (Tasmania, latitude 43°S), to Dumont d'Urville (Antarctica, latitude 67°S) in the Southern Ocean (DDU route). The DDU route will run over the six austral summer months, October to March. This route will mainly use the resupply vessel, *l'Astrolabe*, to tow the CPR as well as other vessels travelling this route. Using research vessels has the advantage that physical parameters are collected continuously. This route will complement the SCAR Southern Ocean CPR survey, which has been operating since 1991 (Hosie *et al*., 2003).

Continuous plankton recorder

Today's version of the CPR is a modified form of the device first used by pioneering British marine biologist Sir Alister Hardy during a 1925-1927 *Discovery* expedition to the Antarctic. It has been used by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in the North Atlantic CPR surveys for 75 years, making it the world's longest-running marine survey. Its robust nature and simplicity of deployment and retrieval make it suitable for towing behind voluntary ships of opportunity (SOOPs), unaccompanied by research staff. Modern towed undulating plankton recorders are extremely fragile and require careful deployment and retrieval behind research vessels. More than 275 SOOPs have participated in the North Atlantic CPR surveys and over 5,000,000 nautical miles have been towed (Richardson *et al*., 2006). The CPR is towed behind ships at about 10 metres depth. Seawater and plankton enter the device through a small opening in the nose and are retained on silk mesh. Back at the AusCPR laboratory, the silk layers are unrolled and cut into sections representing 5 nautical miles of tow. Phytoplankton and zooplankton are then identified to the lowest possible taxa and counted (Fig. 3). Methods of analysis for phytoplankton and zooplankton employed by AusCPR will be very similar to those used at SAHFOS for the North Atlantic CPR survey. Data produced from the AusCPR surveys will be made freely and rapidly available to the research community.

Importance of long-term plankton monitoring programs

Our ability to understand and adapt to climate change in our oceans is hampered by the relatively few marine time series compared with the number on land (Richardson and Poloczanska, 2008). For example, the recent IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report noted 28,586 significant biological changes in terrestrial systems, but only 85 from marine and freshwater systems. Our knowledge of global climate change impacts come from terrestrial systems, although much of this understanding is not directly applicable to marine systems. We urgently need marine time series to provide baselines against which we can assess change.

The situation in Australia in terms of zooplankton time series has historically been particularly disappointing. Globally there are zooplankton time series spanning more than 15 years in no fewer than 30 countries, including many relatively small and developing nations. However, the longest ongoing zooplankton time series in Australia is 2 years and consists of a single cross-shelf transect. Given the diversity of marine habitats in Australia and the economic and social importance of fishing, Australia is clearly impoverished in long-term zooplankton observations and other datasets are urgently required to assess climate change impacts (Poloczanska *et al*., 2007). With accelerating global warming and ocean acidification, time series of plankton numbers can provide the baseline for detecting and understanding the impacts of climate change at the very base of the marine food web.

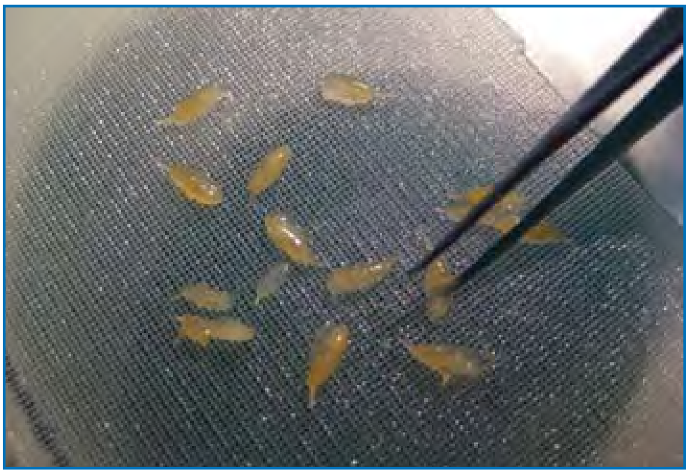

Figure 3. Zooplankton on a silk. Photograph: David McLeod.

AusCPR tows on the EAC route are scheduled to begin in November 2008. Tows on the DDU route are expected to commence this 2008/2009 austral summer when the ship resumes services to Antarctica. However, we already have tows from this route in 2007/2008 courtesy of the SO-CPR survey and the RSV *Aurora Australis*. Currently we are training four plankton analysts and are installing towing equipment on the *Kota Pemimpin* to tow the CPR along the EAC route. The initiation of the AusCPR survey now brings the number of CPR surveys in the world to five: the North Atlantic (SAHFOS), North Pacific, Southern Ocean, and western North Atlantic. Sir Alister Hardy would be astonished that more than 80 years after he first towed the CPR, it remains in operation and is still regarded as the most practical and cost effective way to gather species-level plankton information over ocean basin scales. This legacy of Sir Alister Hardy, a growing network of CPR surveys globally, provides the basis for a global zooplankton observing system in the future.

Finally, we would like to take this opportunity here to thank the staff at SAHFOS for their help and support initiating AusCPR. For further information please see our website at http://imos.org.au/auscpr.html.

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An Australian Government Initiative
National Collaborative Research Infrastructure Strategy
IMOS Integrated Marine Observing System
Australian Government
Department of the Environment, Water, Heritage and the Arts
Australian Antarctic Division
CSIRO

SCAR Southern Ocean Continuous Plankton Recorder Survey

Graham W. Hosie

Australian Antarctic Division, Department of the Environment, Water, Heritage and the Arts, Kingston, Tasmania, Australia (graham.hosie@aad.gov.au)

Antarctic plankton are expected to be particularly sensitive and vulnerable to climate change. Global warming will affect sea ice patterns and plankton distributions. Increased UV levels, ocean acidification, invasive plankton species, pollution and harvesting impacts are also potential major threats. At this stage we do not know the synergistic effects of any of the threats working in combination. The SCAR (Scientific Committee on Antarctic Research) Southern Ocean-Continuous Plankton Recorder (SO-CPR) Survey was established in 1991 by the Australian Antarctic Division to map the spatial-temporal patterns of zooplankton and then to use the sensitivity of plankton to environmental change as early warning indicators of the health of the Southern Ocean (Hosie *et al*., 2003). It can also serve as a reference for other monitoring programmes such as the Commission for Conservations of Antarctic Marine Living Resources (CCAMLR) Ecosystem Monitoring Program (C-EMP) and the developing Southern Ocean Observing System.

Seven countries have participated in the survey to date, Australia, Japan, Germany, New Zealand, United Kingdom, USA and Russia, providing a near circum-Antarctic Survey. France is expected to join in the near future. The South America consortium of Brazil, Chile, Peru, Argentina, Uruguay, Venezuela and Ecuador are participating in the international Census of Antarctic Marine Life (CAML) with their OLA CAML Survey of the Antarctic Peninsula region. They will start towing a CPR across the Drake Passage in the upcoming 2008/09 Antarctic summer.

The SO-CPR Survey is supported by the SCAR Expert Group on Continuous Plankton Research, which helps promote and develop the Survey. The CPR used by the SO-CPR Survey is a Type II Mark V unit (Reid *et al*., 2003) computer aided designed and built at the Australian Antarctic Division (AAD). The AAD units differ very little from Sir Alister Hardy's original design, other than using more modern materials in construction to make it more robust for Antarctic use (Fig. 1). The units are towed and operated in the same manner as the SAHFOS survey, although we also usually have scientists or technicians on board who can service the units and reload the CPR cassettes with new silks. This extends the sampling range to thousands of nautical miles per voyage. We also use research and resupply vessels which provide additional underway environmental data such as sea surface temperature, salinity, fluorometry, light and other oceanographic-meteorological parameters.

Figure 1. Preparing the CPR on board TS Umitaka Maru (Photograph: Graham Hosie, AAD).

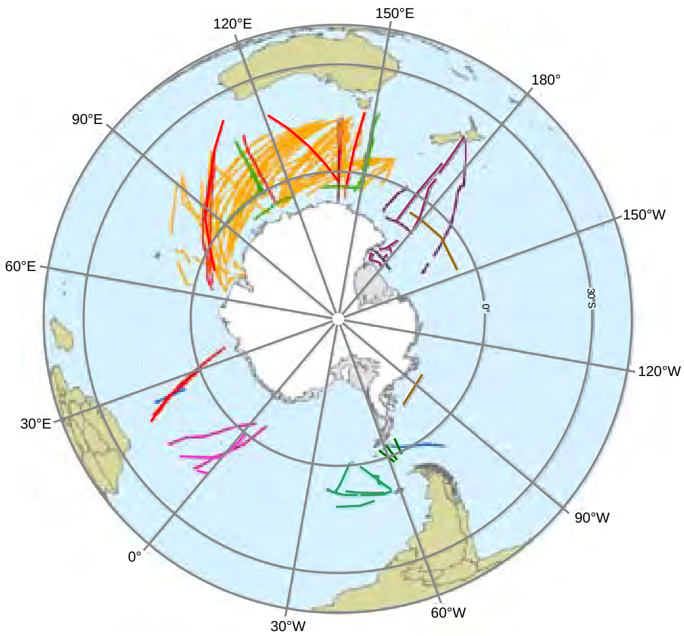

Figure 2. Continuous plankton recorder tow conducted between 1991 and 2008. Map produced by the Australian Antarctic Data Centre (No 13481).

The silks are processed in the laboratory by trained plankton taxonomists in Australia and Japan. Samples collected by the British Antarctic Survey are processed at SAHFOS. Other centres are being developed in New Zealand and in South America. All zooplankton in five nautical mile equivalent sections are identified to the lowest possible taxa, usually species, and counted. Antarctic krill and other euphausiids are identified to developmental stage. Plankton counts are combined with averaged environmental data for each 5 nmile. The Southern Ocean is noted for having several oceanographic fronts, often with sub-branches of the fronts, and the 5 nautical mile resolution is ideal for finding and monitoring changes in the zooplankton relative to these fronts (Hunt and Hosie, 2005).

Tows have been made around most of Antarctic (~70%) with new additional tows made in the Bellingshausen Sea and Drakes Passage during the 2007/08 Antarctic Season (Fig. 2). Much of the Amundsen and Bellingshausen seas, and eastern Weddell Sea have not been surveyed. Approximately 40-50 tows are made each year. More than 80 were made in the 2007-08 International Polar Year as part of the CAML. Approximately 135,000 nmiles of data have been collected since 1991 producing more than

27,000 samples for 200+ taxa coupled with environmental data. Most data comes from the October to April period. Some winter tows south of Australia have been made.

The CPR data can be used to produce plankton distribution maps. An atlas will be produced later in 2008. Subtle variations in species composition can identify and map frontal zones (Hunt and Hosie, 2005), as well as distinguishing seasonal, annual and long-term variation in plankton patterns. The SO-CPR Survey has already identified two major changes in zooplankton composition in eastern Antarctic waters. The first was in the sea ice zone (SIZ) around the year 2000 when smaller zooplankton such as the cyclopoid copepod *Oithona similis* became more dominant instead of the larger Antarctic krill *Euphausia superba*. The second change occurred in 2004/05 north of the SIZ when pelagic foraminiferans exceeded 50% of the numerical abundance instead of the 2% long term average, replacing *Oithona similis* as the dominant species. Such changes in food size and type could well have a major impact on the survival of higher predators.

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EUR-OCEANS Consortium agreement

Caroline Gernez

Institut Universitaire Européen de la Mer, Plouzané, France (caroline.gernez@univ-brest.fr)

On 12 July 2008, the agreement creating the EUR-OCEANS Consortium was signed by the official representatives of Member Organisations, during a ceremony hosted by Oceanopolis, Brest, and chaired by Dominique Le Queau, Director of the National Institute of Science of the Universe (INSU/CNRS).

Building on the achievements and successes of the EUR-OCEANS Network of Excellence (2005-2008), the Consortium aims at facilitating the long-term harmonisation of the efforts of European marine research institutes and universities on ocean ecosystem research under anthropogenic and natural forcings. The overall objectives of the EUR-OCEANS Consortium are to facilitate the promotion of: 1) top-level scientific research on the impacts of anthropogenic and natural forcings on ocean ecosystems, and foster collaborations across the European Research Area; 2) optimal use of any shared technical infrastructures and scientific facilities, and 3) activities to spread excellence that include training of scientific personnel and students, and dissemination of knowledge to a large public and to socio-economic users.

The EUR-OCEANS Consortium's activities, which will officially begin on 1 January 2009, include: activities implemented by the EUR-OCEANS Flagship Institutions, which are selected on a competitive basis by the Scientific Steering Committee (SSC) of the Consortium, and Cluster activities, which are initiated by the SSC and coordinated by the Project Office.

Introduced by Julie Hall, Chair of the Scientific Steering Committee of the IMBER project, a first discussion about the scientific priorities of the Consortium for the first actions to be launched in 2009 (Flagship Institutions, Gordon-like Conferences) was initiated after the signing ceremony, and will be continued among the Members in the coming months.

Preceding the signing ceremony, the delegations of the Member Organisations were invited to a visit and a lunch on board the *RV Marion Dufresne* of the French Polar Institute (IPEV), present in the Brest harbour at the occasion of a large maritime festival, "Brest 2008". Hosted by J. Borg and M. Wallström, European Commissioners, and the 27 European Ministers in charge of European Affairs, a celebration ceremony was also held at the end of the afternoon at the European Commission Pavilion.

Table 1 lists the 20 institutes/universities that committed to the EUR-OCEANS Consortium on 12 July 2008.

Table 1. Institutes committed to the EUR-OCEANS Consortium

Denmark	• National Institute of Aquatic Resources (DTU Aqua)
Finland	• Finnish Institute of Marine Research (FIMR)
France	• Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer) • Institut National des Sciences de l'Univers (INSU/CNRS) • Institut de Recherche pour le Développement (IRD) • Université de Bretagne Occidentale (UBO) • Océanopolis, Université Pierre et Marie Curie (Paris 6) • Université du Littoral de la Côte d'Opale (ULCO) • Université des Sciences et Techniques de Lille (Lille 1)
Germany	• Alfred Wegener Institut (AWI) • Universität Bremen • Universität Hamburg
Greece	• Hellenic Centre for Marine Research (HCMR)
Italy	• Consiglio Nationale delle Ricerche (CNR) • National Inter-University Consortium for Marine Sciences (CoNISMA)
Norway	• Norwegian University of Science and Technology (NTNU)
Spain	• Fundacion AZTI
United Kingdom	• British Antarctic Survey (BAS) • Plymouth Marine Laboratory (PML)

Please note that this list will remain open until the end of 2008. If you wish to become a Member, or for any information about the Consortium, do not hesitate to contact the EUR-OCEANS Network of Excellence office (Caroline Gernez, gernez@univ-brest.fr).

Linking Herring, Galway 2008

Mark Dickey-Collas[1], Maurice Clarke[2] and Aril Slotte[3]
[1]Wageningen IMARES, IJmuiden,
The Netherlands (mark.dickeycollas@wur.nl)
[2]Marine Institute, Rinville, Oranmore, Co. Galway, Ireland
[3]Institute of Marine Research, Nordnes, Bergen, Norway

Are herring really important in northern ecosystems? This was one of many questions that over 100 participants of the ICES/PICES/GLOBEC symposium Linking Herring considered in Galway this August. The symposium was designed to update, synthesise and move forward our current understanding of herring and the role it plays in both the Pacific and Atlantic systems. The majority of the participants were scientists, but the symposium was also well attended by fishers and those involved in the fisheries advisory process. Galway again proved itself a great location for conferences, especially as the weather encouraged people to remain indoors and enjoy the Irish fare.

The study and management of herring has been an important innovator in fisheries science and the institutions that provide advice. The conference keynote by Mike Sinclair (Canada) illustrated many of the paradigm shifts that have occurred as a result of studies on herring. There was a need for an update on the assessment of herring and recent developments in herring biology. These two subjects were introduced by John Simmonds (Scotland) who gave a thorough overview of counting herring through surveys and assessments and by Audrey Geffen (Norway) who gave a very interesting talk on advances in herring biology. It was clear that if you study herring, you should expect plasticity and change. Audrey commented that she liked studying herring "because there were no wrong answers" and her talk certainly showed that populations of herring are very adaptive through their large phenotypic plasticity. John commented that you should survey herring when "the abundance is high and the flux is low" and after a talk by Claude LeBlanc (Canada) the symposium discussed the use of commercially derived acoustic surveys to assess trends in herring populations. This developing research area requires much more work. The issue of disease and parasitism in the regulation of herring populations was raised and it was agreed that it should be considered by population ecologists.

After the first day of talks the conference was keen to talk about variable production and population integrity/connectivity as these issues kept arising in the earlier sessions. The session keynote David Secor (USA) showed that different patterns in connectivity will result in different perceptions of populations than the reality. This was also highlighted by Laurie Kell (UK). Considering the variable but ubiquitous mixing at various life stages, and the mating behaviour of herring, it was not surprising that stock identification through current genetic methods was poor and the estimates of effective population size in herring was extremely large when compared to other fish. It appeared that no global model for life history closure and population integrity was applicable to herring. Many talks illustrated changes in growth, fecundity, condition, recruitment that thus impact on the intrinsic population production of herring. As stated above, when working with herring expect change.

Participants at the Linking Herring conference, 26-29 August 2008 in Galway, Ireland.

The final sessions flowed well from the previous talks as they considered the role of herring and the management of herring in the system. Andrew Bakun (USA) showed that the complexity of the system meant that understanding the impact of herring in even simple systems was going to be difficult. The role of herring as a "wasp waist" organism meant that it interacts in many different ways and it was like studying an African savanna "where the zebra also eat lion cubs". It was folly to consider stationarity in either rates of processes or in the ranking of relevant processes that determine the position of herring in an ecosystem. The session showed that herring not only impact on but are impacted by salmon, whales, seals, cod, capelin, plankton and many other organisms. Thus managing herring fisheries was also complex and this was highlighted by the final keynote speaker Martin Pastoors (ICES). He commented that advisory and management structures must change to allow effective communication, trust and transparency especially when moving from single species management to the management of fisheries that exploit components of the ecosystem.

The symposium was viewed as a success as it allowed debate and synthesis to occur on many factors that are current when thinking about herring in the ecosystem. The proceedings will be reviewed and published in the ICES Journal of Marine Science in 2009.

Coping with global change in marine social-ecological systems: an international symposium

Rosemary Ommer[1] and Ian Perry[2]

[1]Co-Chair, GLOBEC Focus 4, and Director, Institute for Coastal and Oceans Research, University of Victoria, Victoria, BC, Canada (ommer@uvic.ca)

[2]Co-Chair GLOBEC Focus 4, Fisheries & Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada (Ian.Perry@dfo-mpo.gc.ca)

An international symposium on "Coping with global change in marine social-ecological systems", co-sponsored by GLOBEC's Focus 4 Working Group on the human dimensions of marine ecological changes, the European Network of Excellence for Oceans Ecosystem Analysis (EUR-OCEANS), and the Food and Agriculture Organization of the United Nations (FAO), was held 8-11 July 2008 at FAO Headquarters in Rome, Italy. The meeting was convened by Ian Perry, Rosemary Ommer, and Philippe Cury. The meeting was supported by GLOBEC, EUR-OCEANS, FAO, the Institut de Recherche pour le Développement (IRD), Institut français de recherche pour l'exploitation de la mer (IFREMER), Scientific Committee for Oceanic Research (SCOR), the North Pacific Marine Science Organisation (PICES), the International Council for the Exploration of the Seas (ICES), the Integrated Marine Biogeochemistry and Ecosystem Research programme (IMBER), the Social Sciences and Humanities Research Council of Canada (SSHRC), the WorldFish Centre, and was endorsed by the International Human Dimensions Program (IHDP).

The background materials to the meeting noted that humans are integral components of social-ecological systems. Such systems have marine (including physical-biological) and human (including cultural, management, economic, and socio-political) components which are highly inter-connected and interactive. Changes in marine ecosystems have impacts on, and consequences for, the human communities that depend on these systems, but how these human communities respond to these changes can have reciprocal impacts on marine ecosystems. However, "natural" marine ecosystems are usually studied independently from their human components, and by different scientific disciplines with different scientific traditions ("natural" scientists; "social"` scientists and humanists). Understanding the important issues and collaborating with other disciplines is essential for correctly interpreting the causes and dealing with the consequences of global changes in marine social-ecological systems.

Small fishing vessels in Nanaimo harbour, BC, Canada.

The central goals of the symposium were to share experiences across disciplines and to identify key next steps and common elements and approaches that promote resilience of marine social-ecological systems in the face of global changes. This involved:

1. exploring conceptual issues relating to social-ecological responses in marine systems to global changes;
2. analysing case studies of specific examples of social-ecological responses in marine systems to significant environmental changes manifested locally;
3. synthesising the work of natural and social scientists and building comparisons of social-ecological responses in marine ecosystems subjected to major environmental variability;
4. developing innovative approaches to the use of science and knowledge in management, policy and advice;
5. identifying lessons for governance for building resilient social-ecological systems.

The symposium was felt by all to be fun and highly successful, and to have achieved these goals. Over 150 people participated in the symposium, from 38 countries. FAO Headquarters was an ideal location for this meeting, and several of the meeting outcomes were felt to be highly relevant to the work of FAO. The presentations and posters dealt with issues of economics, society, environment, and technology as these relate to coastal and ocean issues in the face of both social (e.g. globalisation) and natural (e.g. climate) global changes. It was noted that wild capture fisheries are fundamentally different to other food production systems, and therefore their responses to environmental and climate changes must be considered separately from those of terrestrial food production systems.

Many questions were asked and lessons learned, and there was much discussion about the positive way forward to create and sustain healthy future global communities of fish and fishers. Keynote presentations (by Fikret Berkes, Bonnie McCay, Katrina Brown, and Judith Kildow) emphasised that fisheries are linked social-ecological systems which require a humans-in-ecosystems approach. Including people leads us to recognise larger and more complex "communities" (e.g. of fish and fishers) which include exploiters, drivers, and disrupters. The interactions among multiple social, economic, and environmental stressors are particular challenges (as underlined by recent rises in fuel prices) and suggest that a resilience perspective focused on adaptive capacity would be a useful approach. There was also discussion that we should move from the narrowly-defined government regulatory approach to include broader concepts of governance to deal with these complex systems.

The final panel and summary session concluded that the range and breadth of the participants was extraordinary, with a wonderful collection of presentations, all excellent. The panel pointed out that not all global changes will be negative, that there will be winners and losers, and that we must always proceed with caution since some industrial development strategies, intended to reduce poverty in fishing communities, may inadvertently undermine their economic basis and make their poverty worse. It was also recognised that "one size does not fit all", that exposure, susceptibility and resilience vary immensely, and that one framework and policy response may not apply to all situations. In which case, the important question is how do we develop policies which are flexible and support a wide range of adaptation situations? Fisheries stock assessments, it was noted, have yet to fully integrate the environment, climate change, ecology and human behaviour into their models and management recommendations. This is a critical step in the implementation of science-based ecosystem approaches and should be a priority. Thus, continued development of models will remain very important, as will continued synthesis and integration of the work of natural and social scientists. Such inter-disciplinary teams will have to think outside the box of their disciplinary expertise and work together cooperatively, creatively, and imaginatively to address these challenging problems. In that respect, one scientist from Hawaii noted that he was extremely pleased to see how much progress has been made on the social science side of conceptualising marine ecosystems, and that there is a firm foundation for moving ahead on ecosystem approaches to natural marine resource conservation and management now that human beings have been brought into the equation.

We are nearing agreement concerning what we mean by, and how we will formalise and operationalise, such concepts as resiliency, adaptability, flexibility and capacity. We must, however, always keep in mind that fisheries are a human phenomenon in which human activities interact with natural ecosystems. We should therefore never think of a fishery as just a particular stock in a particular geographic region. Moreover, the politics or political economy of fisheries remains under-developed, particularly with regard to the metropolitan countries while, despite the small size of many fisheries in national economies, they continue to be politically troublesome. Understanding the interests, values, and practices of those involved in fisheries issues from within the broader political economy would be valuable. We need to make sure that government, business and managers get to experience what one participant described as "the wonderful sweep of ideas that characterised this conference" in order to "do justice to the ideas expressed over the past four days". We need to turn the strong insights gained at this meeting into the kind of pragmatic policy guidelines in fisheries management practice that are needed to prevent future over-fishing, including new guidelines for the application of stock assessment science which will reduce data errors. We should, it was suggested, work on these ideas with fishers and others in fishing and coastal communities, and others using marine ecosystems, and we should enhance our communication of the significance of global changes on marine ecological systems to the general public.

That said, although life is mostly lived locally, we must continue to think globally, while remembering that most fishers' perspectives are decidedly local, and their lives are embedded in the particular local environment in which they live, upon which they depend, and from which they derive important aspects of their individual and cultural identities. Their long-term and intimate embedding in these environments gives local people insights and specialised knowledge from which the visiting expert can always learn. Finally, we must promote international cooperation and support to help humanity face the challenges posed by global change. A coordinated worldwide system to monitor global changes needs much additional development. New conventions may also be needed to help the world's nations to cooperatively engage in problem solving and coping with global change - in particular as it impacts marine environments. Organisations and programmes such as FAO, UNEP, GLOBEC, and others can play important leadership roles to bring about this enhanced international cooperation.

Overall, we learned a lot about the relationships between global (in particular, climate) changes and marine ecosystems, made them more visible, generating models to help us understand and model the future and starting to build humans and social and economic impacts into these models. We are beginning to provide a common language across disciplines, increasingly more sophisticated conceptual frameworks, with a strong focus on drivers and system dynamics, couplings/interactivities, scale (spatial, temporal, organisational), complexity, coping and adaptation, and governance including contributions of traditional and local knowledge. In terms of gaps and weaknesses, we saw that in systems theory there is a tendency towards teleological or circular thinking (are we really getting at cause and effect?), blunt distinctions (i.e. between things that are functional and nonfunctional for systems), stretched concepts (do we really mean the same thing by drivers?) and paradigmatic stasis.

Building the social into the ecological requires more than adding on a couple of variables, because social power is multi-dimensional and operates at multiple scales, especially during periods of rapid change. The Closing Panel also noted that there were no systematic gender-based analyses in the presentations, that more attention could have been paid to human as well as environmental health, and that aquaculture was not featured as prominently as it might have been. The success of the presentations, posters, and discussions (to facilitate communication amongst the many disciplines present, all presentations were conduced in plenary) and the questions and gaps remaining, point to the need for further meetings of this nature, perhaps focused on specific topics.

Further information about the symposium, including links to the presentations and posters, is available on the symposium website at http://www.peopleandfish.org. Publication of the symposium proceedings is planned for the near future.

Coping with global change in marine social-ecological systems

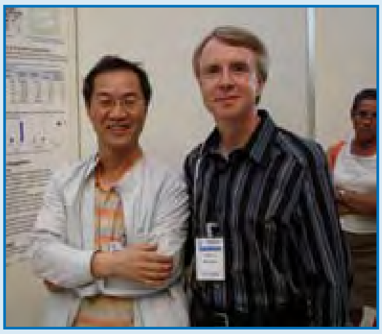
The distinguished closing panel: Poul Degnbol, Mitsutaku Makino, James McGoodwin, Barbara Neis, Samuel Pooley and Jurgenne Primavera, chaired by Rosemary Ommer.

Rodica Sirbu and Michel Lamboeuf (FAO) who organised the poster session.

Philippe Cury and Christian Mullon.

The Mexican contingent: Pablo del Monte Luna, Mauricio Ramírez Rodríguez and Francisco Arreguín Sánchez.

Tim Daw deep in discussion with Natalie Bown.



Suam Kim and Ian Perry.

FAO headquarters.

Poster session in the FAO Atrium.

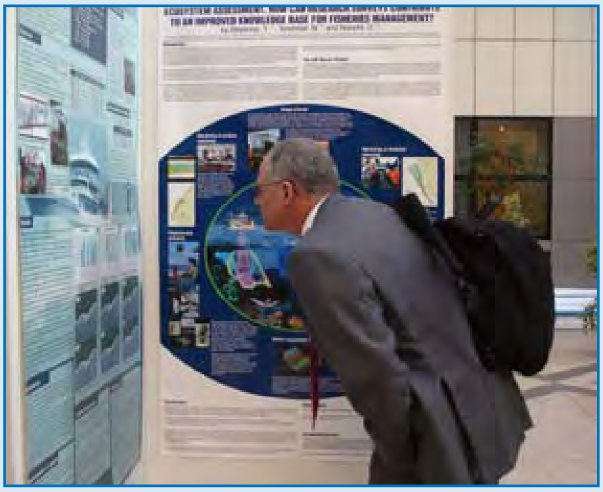
Mauro Fabiano discussing his poster.

Kevern Cochrane (FAO) studying the abstracts book.

Maria Gasalla and Simone Libralato.

Suam Kim.

Symposium participants.



A poster being carefully scrutinised.

International symposium on Eastern Boundary Upwelling Ecosystems

Pierre Freon[1], Manuel Barange[2] and Javier Arístegui[3]

[1]Institut de Recherche pour le Développement, Sète, France (pierre.freon@ird.fr)
[2]Plymouth Marine Laboratory, Plymouth, UK
[3]Universidad de Las Palmas de Gran Canaria, Gran Canaria, Spain

From the 2nd to 6th June 2008, an international symposium on Eastern Boundary Upwelling Ecosystems (EBUEs) was held in Las Palmas de Gran Canaria, Spain. EBUEs are some of the most productive marine ecosystems of the world; the four main EBUEs, the Canary, California, Humboldt and Benguela Currents provide over a fifth of the marine fish global catch, significantly contributing to securing livelihood strategies and food in many countries. EBUEs are narrow strips of the ocean (10 to 300 km wide but extending latitudinally in excess of 1,000 km), located on the western margin of the continents (eastern parts of the oceans), on each side of the equator. In these regions, intense trade winds combined with the earth's rotation generate coastal upwelling, bringing cold, nutrient-rich waters from the deep ocean to the surface. The arrival of this water to the sunlight-exposed surface layer fuels production and supports a complex and highly dynamic food web. It also contributes very significantly to gas exchanges between the ocean and the atmosphere, particularly CO_2.

The dependency of EBUEs on environmental drivers makes them particularly relevant to anthropogenic climate change research. How climate change will affect EBUEs is crucial, not just in terms of the biochemical balance of the planet, but also in terms of the social and economic consequences of potential changes in global fish production. This symposium was an international effort to present the state-of-the-art in our understanding of EBUEs, with particular emphasis on both integrating our knowledge from climate processes all the way to fisheries dynamics, and comparing the dynamics of EBUEs across the world. The ultimate goal was to identify climate change impacts on EBUEs and pave the way for adequate adaptations to these.

Geographical coverage and challenges. The symposium covered the four major eastern boundary upwelling ecosystems: the Canary and Benguela Current ecosystems in the Atlantic Ocean and the California and Humboldt Current ecosystems in the Pacific Ocean (Fig. 1). The countries bordering these ecosystems are Spain (from its NW corner to the Canary Islands), Portugal, Morocco, Mauritania, Senegal and Gambia for the Canary ecosystem; Angola, Namibia and South Africa for the Benguela ecosystem; USA and Mexico for the California ecosystem and finally Peru and Chile for the Humboldt ecosystem. The coastal zones of these countries host the most productive marine areas but this productivity is highly variable from year to year and from decade to decade due to strong forcing factors like *El Niño* events, decadal climate oscillations and fisheries exploitation. Collaboration and cooperation between countries and ecosystems is needed to face new challenges represented by climate change, generalised overexploitation of marine resources, economic globalisation and food security.

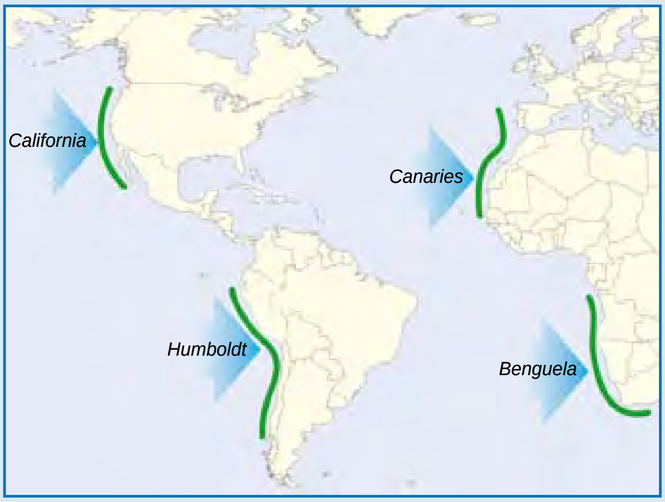


Figure 1. The four major eastern boundary upwelling ecosystems.

Scientific focus. In the past, a number of international symposia and conferences have focused on one or more eastern boundary upwelling ecosystems, but none of these explicitly covered the four main EBUEs and considered all aspects of their dynamics, structure and functioning. These aspects include climate and ocean dynamics, climate change, physics of the ocean and atmosphere, biogeochemistry, ecosystem production, ecology, food web structure and dynamics, trophic interactions, fisheries assessment and management. Furthermore, the comparative emphasis of this symposium allowed a better understanding of the key processes responsible for the productivity and dynamics of the four main EBUEs.

Partnership. The symposium was supported and organised by the European network of excellence EUR-OCEANS, the French Institute of Research for Development (IRD), the Global Ocean Ecosystem Dynamics (GLOBEC) programme and the University of Las Palmas, Gran Canaria (ULPGC). Additional sponsorship was provided by IMBER (Integrated Marine Biogeochemistry and Ecosystem Research project), SOLAS (Surface Ocean Lower Atmosphere Study), BENEFIT (Benguela, Environment, Fisheries, Interactions, Training programme), GTZ (German Society for Technical Cooperation), SCOR (Scientific Committee on Oceanic Research) and various Spanish national and regional authorities. These grants allowed us to sponsor 26 scientists and students, mostly from developing countries, and to partially support 20 keynote speakers. In total the programme included 144 oral presentations and 170 posters were on display.

Audience. More than 350 people, coming from almost 40 countries from the five continents, attended the event.

Research highlights

Numerous presentations demonstrated the benefit of using regional physical models with high spatial resolution, embedded in basin scale models. This was particularly the case to show the specificity of EBUEs and their export of nutrients, organic mater and plankton toward offshore regions. The role of mesoscale features, such as eddies, filaments and fronts, was underlined by the use of such models, and the ability of these models to reproduce mesoscale features was demonstrated through satellite tracking of drift buoys. Results from a new generation of autonomous observing devices (gliders), helped characterise the whole water column, both physically and chemically, providing new information on the functioning of EBUEs and their links with the open ocean. Concurrent biological information also contributed to the validation of physical models, through model coupling, allowing a realistic reproduction of the fate of fish early stages after long distance transport. This is, for instance, the case of the transport of larvae of several pelagic species from the North African coast to the Canary Islands, where they support fish stocks that are exploited away from their spawning grounds.

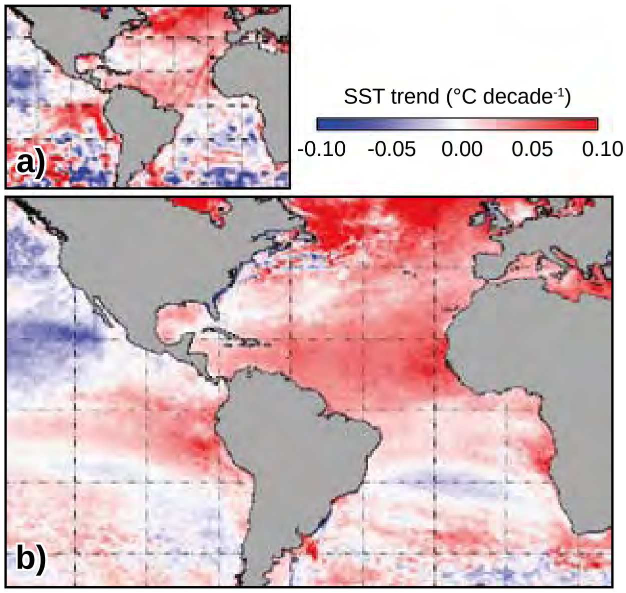


Figure 2. Comparison of the spatial SST trends observed between 1985 and 2006 a) from the enhanced ICOADS data set and b) the AVHRR pathfinder v5 SST product. Figure courtesy of H. Demarcq, IRD, France.

The increase in the accuracy of remotely sensed sea surface temperature since the mid-1980s allowed comparisons of warming trends between EBUEs. The warming is not uniform between the four major EBUEs: the Canary Current ecosystem warmed up by around 1.5°C over the last 22 years, while the other three main EBUEs warmed by less than 0.5°C (Fig. 2). The cause(s) of this warming and its link with trends in wind intensity and direction (which vary according to the data sources) are still debated. The consequences of this warming are diverse and variable according to the ecosystem. A recent finding is that the abrupt inshore-offshore gradient of the wind, which generates a wind-stress curl, plays a more important role than the coastal wind on the plankton and sardine production off central California (Fig. 3).

Although satellite estimates of phytoplankton abundance in the upper part of the ocean are available only from 1997, it appears that there is a decrease in the mean productivity of the global ocean during the last decade. Nonetheless, EBUEs display an opposite trend, in particular in their coastal areas (Fig. 4), which is favourable for pelagic fish species (anchovy and/or sardine). However, off the coasts of Mauritania and Senegal we observe a falling trend in productivity. Further north, in NW Spain, where the production of mussels (shellfish farming) in the deep bays (rias) is very important (15% of the world production), the decrease in intensity of winds and/or changes in direction have reduced the water renewal rate. This triggers an increase in the frequency of red tides, resulting in bans on mussel sales, with heavy economic repercussions.

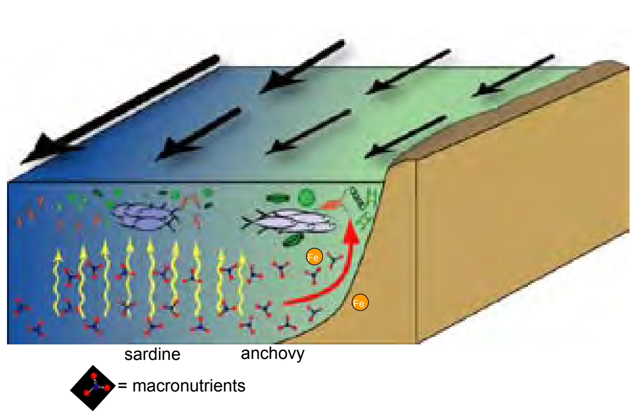


Figure 3a. Low rates of nutrient supply provided by offshore curl-driven upwelling lead to the production of small size classes of plankton which favour sardine, whereas high rates supply inshore favour anchovy. Figure courtesy of Ryan Rykaczewski, University of California, USA, modified after Rykaczeqski and Checkley, 2008.

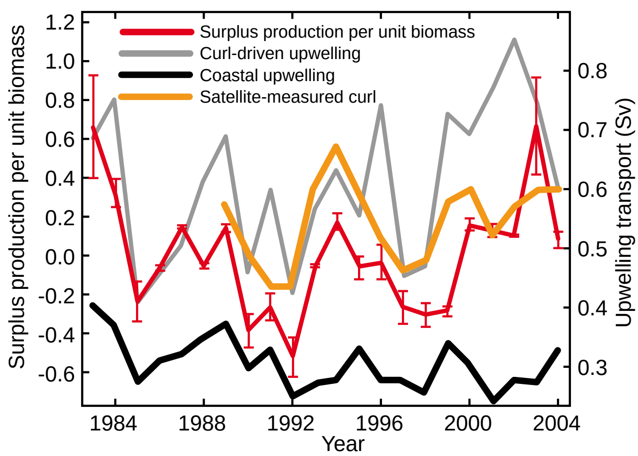


Figure 3b. Sardine production in central California is correlated strongly with curl-driven upwelling, not coastal upwelling. Figure courtesy of Ryan Rykaczewski, University of California, USA, modified after Rykaczeqski and Checkley, 2008.

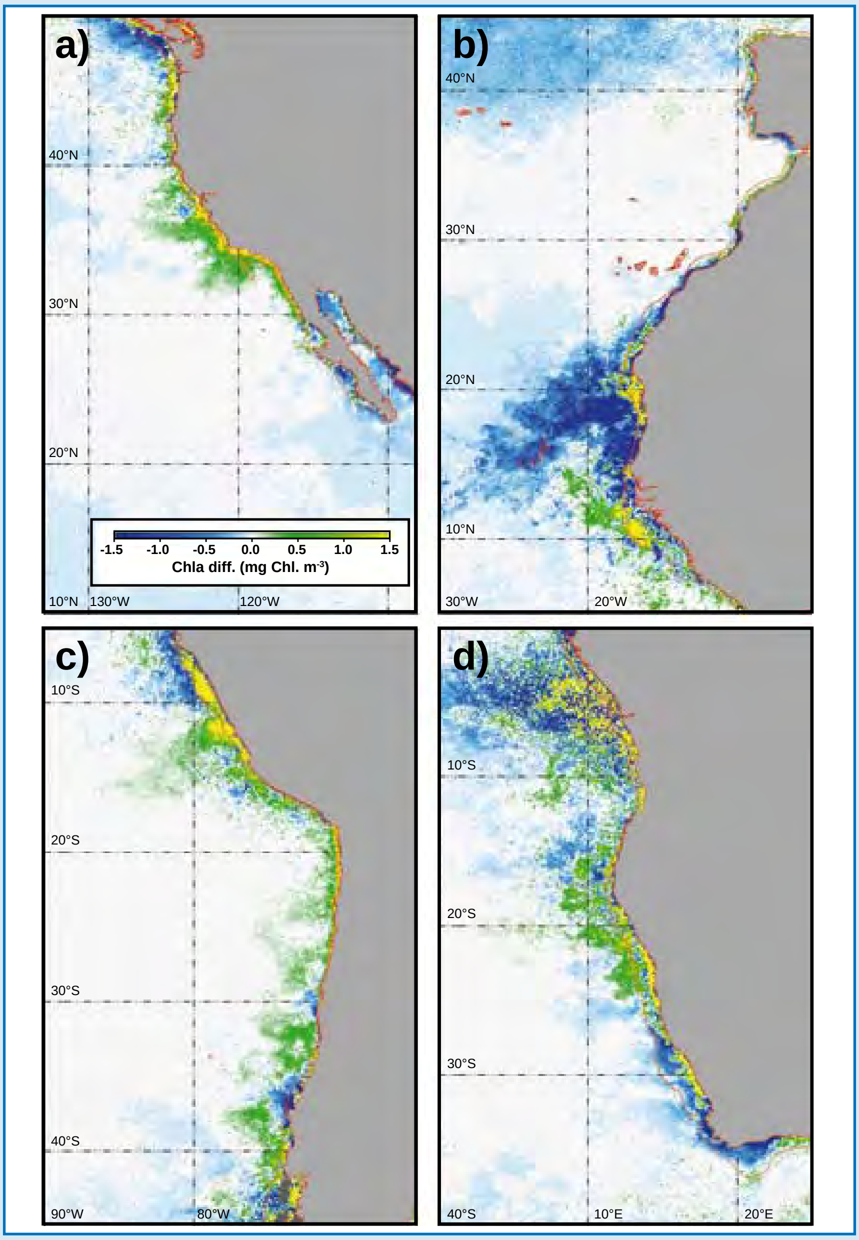


Figure 4. Spatial trends of the chlorophyll biomass observed between 1998 and 2007 from SeaWiFS data for the four EBUS: a) California Current, b) Canaries, c) Humboldt and d) Benguela. The 400m isobath is shown in red. Figure courtesy of H. Demarcq, IRD, France.

The operational importance of biogeochemical cycling in upwelling areas with regards to global ocean production was underlined. Many of the critical biogeochemical conditions are hyper-sensitive to change, so that a small change e.g. in oxygen depletion (resulting from either natural or anthropogenic causes) can lead to major changes in biogeochemical pathways and ultimately to orders-of-magnitude changes in the fisheries yield of these systems. Besides, the role of upwelling ecosystems in the carbon and nitrogen cycle is essential.

From a biological point of view, EBUEs represent carbon sinks. This is due to the high CO_2 fixation by phytoplankton, which exceeds community respiration in the long term. Nevertheless, in spite of the high productivity, which may be up to two orders of magnitude higher than in other coastal or open ocean regions, EBUEs frequently behave as sources of CO_2, since cold upwelled water, with high gas solubility, releases CO_2 when warming at the surface. There is a concern that production increase in certain coastal zones (such as California) may trigger further ocean acidification.

The production of nitrogen dioxide and methane (another greenhouse gas) has been recently considered significant in EBUEs. Nano- and pico-plankton play an important role in the formation on these gases. For instance, bacteria can contribute up to 30% of the carbon dioxide and 50% of the carbon monoxide gas emissions. However, other sources of CO_2 emissions remain to be discovered in order to explain the strong concentrations observed in these last years worldwide.

The zooplankton also strongly reacts to these climatic fluctuations (especially in higher latitudes), although differently according to ecosystems and without showing any global synchrony. The trend component in zooplankton biomass is positive in the Benguela, but negative in the Humboldt and California Current systems. Furthermore, there is evidence of strong poleward displacement of zoogeographic boundaries in time intervals when temperature and stratification anomalies are positive. Zooplankton faunistic assemblages largely depend upon the source of the upwelled waters, which affect their average lipid

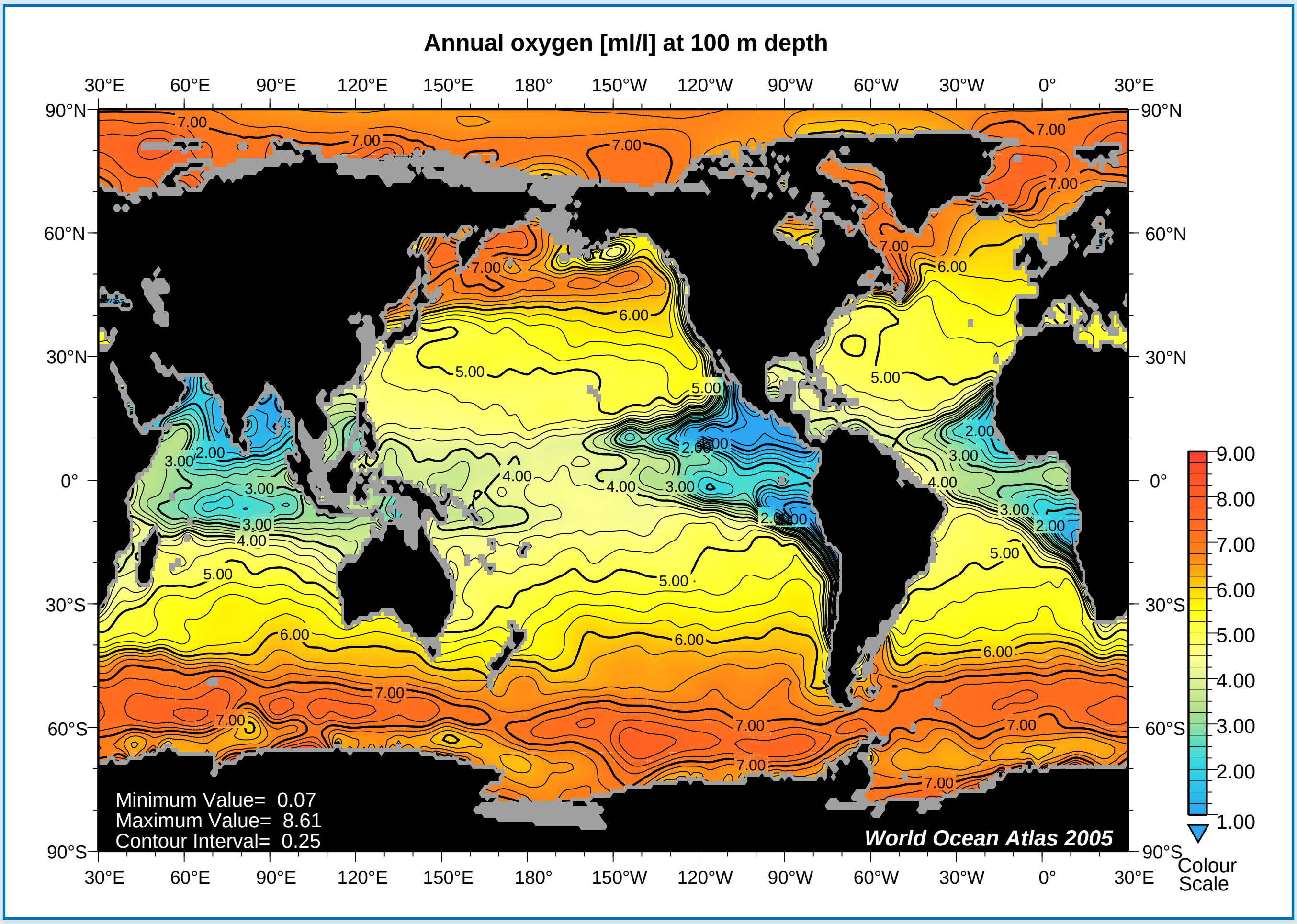


Figure 5. Deep low oxygen zones in the global ocean at 100 m depth (World Ocean Atlas: http://www.nodc.noaa.gov/cgi-bin/OC5/SELECT/woaselect.pl)

composition, which in turn influences fish growth. Recent hydro-acoustic developments have enabled us to separate echoes from fish and zooplankton using standard ecosounder systems (two frequencies only), which should allow a better understanding of the mesoscale spatio-temporal dynamics of the trophic interactions between fish and plankton.

The warming of the oceans is leading to increases in stratification. This has important consequences in upwelling regions because the oxygen content decreases with increasing biological production, promoting suboxic or anoxic environments (Fig. 5). This affects not only the vertical distribution of marine organisms, but also the functioning and structure of the whole food web. In Namibia, for example, the decrease of trade winds, combined with overexploitation, has brought deep changes, including decreasing dissolved oxygen concentrations at depth and increasing methane and hydrogen sulphide emissions. Sardines have practically disappeared from this ecosystem and it is argued that the new conditions favour gobies and jellyfish.

Long-term global warming often aggravates climatic variations that apply to shorter time scales (decades, years or months), likely to cause, for example, a decrease in abundance of African penguins, or slower individual growth, as in the case of the sea lions. In several upwelling ecosystems the species available habitat has been restrained to surface layers due to the growth and ascent of the oxygen minimum zone. This is particularly true in the case off Namibia, Peru and Chile. In extreme cases, the lack of oxygen has forced hundreds of tons of spiny lobsters to come out of the water off South Africa, where they die from dehydration (Photograph 1). This is not a new phenomenon but its frequency seems to have become more accentuated recently.

Biological processes in nearshore marine and estuarine ecosystems can be deeply modified by variation in upwelling processes that occur over a wide range of temporal and spatial scales. Unlike in open waters, the biophysical interaction in the coastal environment has a strong spatially-explicit component due to the persistent topographic features of the coastline. Consequently, research in these areas presented at the symposium focused on the spatial variation in upwelling intensity, on ways to understand and quantify this variation in the physical environment along the coast, and on the consequences for biological systems. Three main pathways of physical-biological coupling were explored in the different presentations: a) spatio-temporal variation in upwelling intensity and nutrient delivery to shore, including its consequences for the dynamics of harmful algal blooms and benthic macroalgae, b) upwelling-driven variation in the supply of organic matter for benthic filter feeders and grazers, and c) the effects of upwelling on larval transport and patterns of recruitment along the shore.

Photograph 1. Spiny lobster walkout off South Africa. Photograph courtesy of G.M. Branch, UCT, South Africa.

Photograph 2. White pelican eating a Cape Gannet chicken. Photograph courtesy of Marta de Ponte Machado 2007, UCT, South Africa.

Large changes in the foraging behaviour of certain species are caused by climate change associated with anthropological effects. For example it was observed that in South Africa pelicans attack other bird species' chicks, such as Cape gannets (Photograph 2). This behaviour has recently intensified due to an artificially increased pelican population. This population expansion may be caused by the availability of agricultural offal to the pelicans, which otherwise were dependent on limited natural sources of food. In a similar way, cannibalism tends to increase in certain species where grown-up fishes (hake, sardine and anchovy) feed on the eggs and juveniles of their own. Finally, although adult sea birds feeding off fishing boats discards survive without any trouble, this food is not appropriate or not of good enough quality for their chicks, causing strong mortality amongst the later.

Another important phenomena, already observed in terrestrial ecosystems, are phenological changes. The changes in the temperature seasonal cycle can provoke a delay of a month or two in the appearance of zooplankton, as observed in California. In other ecosystems, such as the southern Benguela, predators are confronted with unseasonal migrations of their prey. For the last ten years, a progressive shift of the centre of gravity of anchovy and sardine populations from west to east has been observed. Some of their natural predators, such as the Cape gannet and the African penguin, which live and reproduce in particular islands, experienced the disappearance of their prey from their foraging ground, causing reproduction failures. In the 1980s, after the long-term sardine stock collapse in Namibia, these same gannets were able to relocate their colonies to South Africa. It is uncertain whether they will continue migrating if their prey persist in moving east and whether they will find new available islands on which to settle.

Upwelling systems, by virtue of being relatively well understood in terms of their structure and function, and being comprised

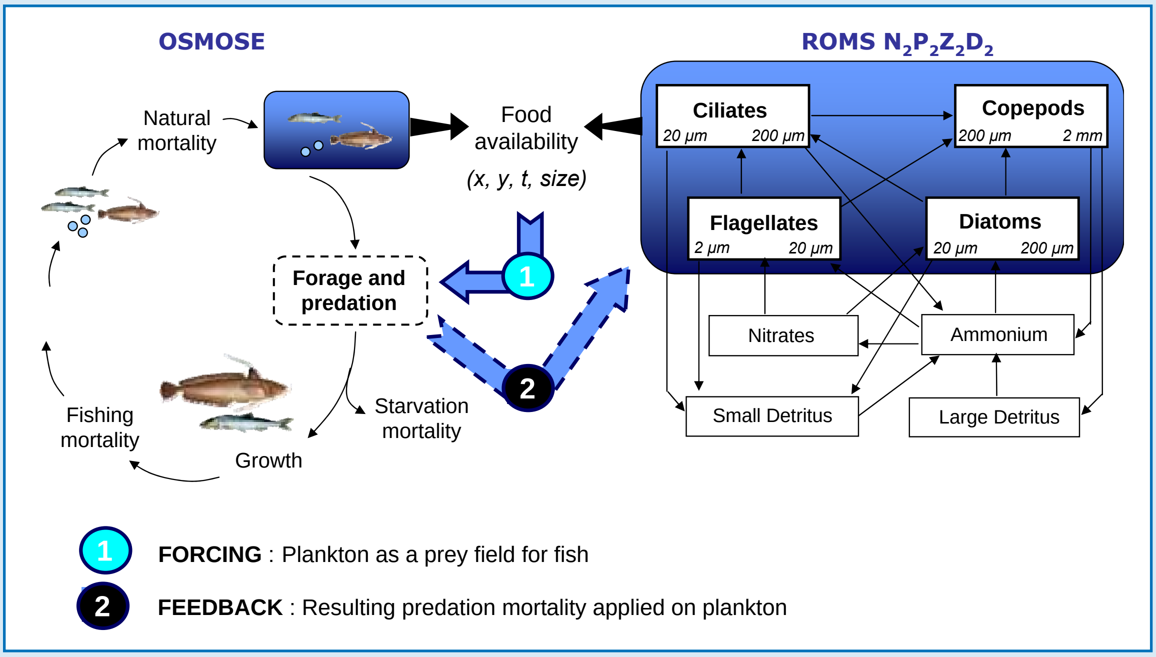


Figure 6. Coupling the OSMOSE IBM size-based model with the ROMS N2P2Z2D2 biogeochemical model. Figure courtesy of M. Travers, IRD, France.

of relatively few species compared to both temperate and tropical ecosystems, are particularly good candidates for end-to-end food web studies. These are defined as studies that aim to integrate across species and functional groups from biogeochemical processes and primary producers through to top predators. There is an increasing number of physical numerical models, which are now coupled to biological compartments that go from plankton to top predators, including fishers.

In addition to individual-based models (IBM) of early life history, two different ecosystem modelling approaches were used to represent marine food webs at the symposium: size-based trophic models (e.g. OSMOSE - Object-oriented Simulator of Marine ecOSystems Exploitation; Fig. 6) and mass-balance models (e.g. Ecopath with Ecosim, EwE). These models are becoming realistic enough to improve our understanding of upwelling ecosystems, particularly on the interactions between exploitation and climate change. We note in particular that upwelling ecosystems are less resilient to these changes when they are intensively exploited. Because they are situated in the centre of the trophic pyramid, pelagic fish often play a central role in regulating the functioning of upwelling ecosystems.

This symposium has confirmed that pelagic fish are more carnivorous (zooplanktivorous) than herbivorous (phytoplanktivorous), which, combined with the evidence that a number of small-sized zooplankton in their diet, shows that in general their food supplies depend on a wider range of organisms than suspected before. Nevertheless, these fishes are very dependent on the upwelling intensity, as much for their food as for the fate of their eggs and larvae, which could be transported offshore with lethal consequences, which is counteracted through retention adaptive strategies, to limit losses.

There is emerging evidence that many of the EBUEs appear to be changing, with either spreading of hypoxic/anoxic areas or appearance of novel hypoxia/anoxia, and that these changes are consistent with possible impacts of climate change. Paleontological studies based on scale depositions in anoxic marine sediments have allowed us to observe biological changes over long time scales. Off Peru, for example, we note that anchovy abundance during the last century was exceptional and that the observed organic carbon increase during the same period is twice as intense as during the last two millenniums. This allows us to interpret present observations in a new and more complete context.

One of the issues raised at the symposium was the need and wish to ensure that ecosystem management takes account of the biological health of stocks and ecosystems, social dynamics of fleet and fishers, as well as other socio-economic considerations (e.g. employment). Vessel Monitoring Systems (VMS) were presented as potential new tools, not just for management (e.g. to monitor effort, study interactions between fleets, monitor protected areas) but to study interactions between resources, fisheries and top-predators (Fig. 7).

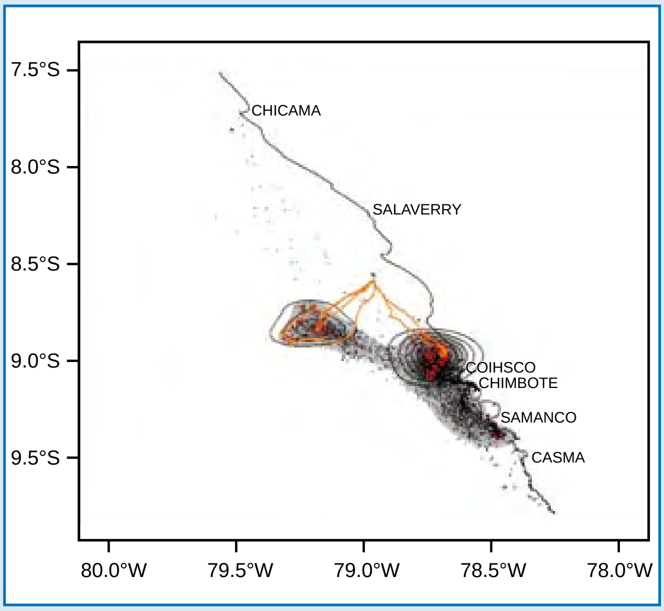


Figure 7. Fishers and seabirds share the same hot-spots. Location of purse-seiners tracked by VMS (black dots: position at hour intervals; grey area: higher probability of boat presence; red dots: location of purse-seining set; black contouring, higher probability of purse-seining) and satellite tracked foraging seabirds living on the Guañape Island (orange lines). Figure courtesy of S. Bertrand, IRD, France.

In conclusion, the symposium confirmed that EBUEs play an essential role in the functioning of the oceans, both at the regional scale (from the coast up to a few hundred miles outside the continental shelf) and globally. EBUEs are characterised by dramatic and sudden changes affecting their dynamics at all temporal and spatial scales, from their climate forcing all the way to the extreme of the trophic chain (top predators and fishermen).

The symposium showed many scientific advances in different fields of marine science and the willingness of the scientific community to make progress toward integrated research. But as usual, as the scientific advancements improve our knowledge, new questions appear, such as whether the importance of wind-stress curl off central California can be generalised to other ecosystems, or whether the links between wind, temperature and phytoplankton production are similar in the four ecosystems. Similarly, the role of iron rich continental dusts deposits on the productivity of the oceans remains an open question. Despite these unknowns, this symposium represented a big step forward in cementing a multi-disciplinary scientific community focused on the dynamics of upwelling ecosystems, able to exchange ideas and share experiences on how to study and manage these particular and important ecosystems.

The proceedings of this conference will be published in the journal Progress in Oceanography, with an expected publication date of 2009. For more information, visit the symposium webpage, http://www.upwelling-symposium.org.

Reference

Rykaczewski R.R. and D.M. Checkley. 2008. Influence of ocean winds on the pelagic ecosystem in upwelling regions. Proceedings of the National Academy of Sciences 105(6): 1965-1970.

Upwelling ECOSYSTEMS

Members of the Secretariat during a moment of leisure: Javier Arístegui, Georgina Rouhana, Pierre-François Baisnée, Mariló Güemes, Jessica Heard, Susana Barroso and Santiago Hernández-León (chair).

Working on the balcony of the conference centre.

Question time for session PL2 chaired by Manuel Barange (left).

Javier Arístegui (centre right) meeting other participants.

Symposium participants networking over coffee.

Santiago Hernández-León and the three convenors: Pierre Fréon, Javier Arístegui and Manuel Barange.

Santiago Hernández-León (chair of the local organising committee) being interviewed for TV.

Participants listening to presentations in a packed hall.

Coffee break by the sea.

Poster session.

Local students at the coffee break.

Ecosystem Studies of Sub-Arctic Seas (ESSAS) programme update

George Hunt[1] (geohunt2@u.washington.edu), Ken Drinkwater[2] and Margaret McBride[2]
[1]University of Washington, Seattle, USA
[2]Institute of Marine Research, Bergen, Norway

Margaret McBride is the ESSAS Coordinator at the newly established ESSAS Project Office in Bergen, Norway.

Establishment of an ESSAS Project Office

The GLOBEC regional programme ESSAS recently established a Project Office in Bergen, Norway, through funding by the Research Council of Norway and the Institute of Marine Research in Bergen. The office is funded at a level of a half time position for a period of 5 years. The office will help coordinate and promote activities within ESSAS and communicate ESSAS science to both the broader scientific community and the general public. ESSAS is pleased to announce that Ms Margaret Mary McBride will be the ESSAS co-coordinator who will head the Office. Ms McBride is a research fisheries biologist with over 30 years of broad international experience (28 years US Federal service), and a record of solid accomplishments strongly contributing at outstanding research institutions. She holds a BSc from Brandeis University (1975) and a MSc in Fish and Wildlife Science from Oregon State University (1989). She studied invertebrate zoology and marine ecology at the Marine Biological Laboratory in Woods Hole, MA. She also has studied biostatistics and survey sampling design at the Harvard School of Public Health Sciences. Her early career (1975-1992) was as a fisheries biologist in the Population Dynamics Branch of NOAA's Woods Hole Laboratory where she conducted stock assessments. She was invited to work (1990-1991) as a visiting scientist at the Institute of Marine Research in Bergen, Norway where she applied a method that she had developed to estimate discards to data from Norway's cod fishery in the Barents Sea. She worked three years (1993-1996) at the US Fish and Wildlife Service on the successful restoration effort for Atlantic coastal striped bass and next devoted three years (1996-1999) foreign service at the Fisheries Research Institute (IIP) in Maputo, Mozambique.

Upon return to the US, she joined NOAA's Chesapeake Bay Office where she led the development of a programme on Fisheries Ecosystem Planning for Chesapeake Bay. Again invited to work at IMR in 2007, she has been, and will continue, working on issues related to ecosystem-based research and management through an Intergovernmental Personnel Action (IPA) between IMR and NOAA Fisheries. As coordinator of the ESSAS Project Office at IMR, she hopes to facilitate collaborative research efforts that acknowledge our joint responsibility as ecosystem stewards to find effective solutions to issues, problems, and concerns shared between nations that jeopardise the health and productivity of sub-Arctic ecosystems. Those who want to contact the ESSAS Office can contact Margaret at margaret.mcbride@imr.no or telephone + 47 55 23 69 59.

New ESSAS Working Group

A major goal of ESSAS is to predict the potential impacts of climate variability on the sustainable use of the sub-Arctic seas. ESSAS has elected to employ a comparative approach to investigate, in each of the sub-Arctic seas, which energy pathways appear particularly vulnerable to decadal and longer-term climate change. The ecosystem response to climate change can be non-linear with thresholds, have complex interactions between species, and feature different species responses to similar climate fluctuations in different ecosystems. Reducing uncertainty about the future states of sub-Arctic ecosystems hinges on our ability to develop future regional climate scenarios as well as reasonable projections of the response of the ecosystem to changes in climate. Predicting future climate states is the primary focus of ESSAS Working Group I on Regional Climate Prediction. Understanding and modelling the complex linkages between observed and projected climate variability and species distributions is the primary focus of two ESSAS Working Groups (Working Group 2: Biophysical Coupling Mechanisms and Working Group 3: Modelling Ecosystem Responses).

A new Working Group (4) on Climate Effects at Upper Trophic Levels (WGCUTL) has been established to assess the effects of ocean climate variation and fishing on the interactions between gadoid fishes and crustaceans by conducting a comparative study across multiple sub-Arctic marine ecosystems. Gadoid fish and crustaceans are important components of the benthic food web in most sub-Arctic ecosystems and are often among the most important commercial fisheries in these systems. Much is already known about the responses of gadoid fish and crustaceans to physical variability in the ocean. However, there is a need to summarise what is known specifically about the responses of these populations in sub-Arctic seas to climate variability in the context of fishery takes and to contrast and compare these responses among different ecosystems. This working group deliberately focuses on a small set of interacting species to identify consistent associations between the major, commercially important, gadoid fish and crustacean species in each system and to evaluate their responses to observed climate variability. Identifying associations will improve our understanding of ocean climate effects or 'bottom-up' processes that are important in regulating these populations. The working hypothesis is that gadoid fish and crustaceans respond in opposite ways to ocean climate variation and that such variation results in differences in productivity and abundance between gadoids and crustaceans.

Physical aspects of the ocean that may be crucial in regulating these responses in sub-Arctic ecosystems include sea ice cover, ocean temperature, circulation, and stratification. The WGCUTL approach is consistent with the ESSAS approach of making comparisons across multiple ecosystems. It is recognised that population responses may not be consistent across all sub-Arctic ecosystems, but similarities and differences will help to identify ecosystem features that are related to the functional mechanisms governing gadoid-crustacean interactions and dynamics. These mechanisms may operate at the adult stages (e.g. through predation or variations in reproductive success), during early life history stages (e.g. through effects on survival of larval or early benthic/demersal stages) and/or at lower trophic levels (variations in food availability). This study is intended to complement other studies of effects of ocean climate on productivity at low trophic levels (e.g. BSIERP/BEST in the Bering Sea, ESSAS Working Group on Biophysical Coupling) to elucidate how bottom-up processes function in regulating ecosystem structure.

To achieve its goals, WGCUTL will engage experts from as many sub-Arctic ecosystems as possible to obtain available datasets from each ecosystem on the variability in abundance of gadoids and crustaceans, as well as relevant ocean climate indices and fisheries removals from each system. Data analyses will be conducted within and across ecosystems to identify important associations and to examine similarities and differences among ecosystems. Results from these analyses will provide a better understanding of the functional relationships between populations of gadoid and crustacean species, and the effects of climate variability on these populations. The Working Group is chaired by Franz Mueter (fmueter@alaska.net) and Earl Dawe (Earl.Dawe@dfo-mpo.gc.ca).

2008 ESSAS Annual Meeting

Erica Head with Neptune at a previous ESSAS Annual Meeting.

ESSAS was invited by Dr Erica Head of the Department of Fisheries and Oceans, Bedford Institute of Oceanography, to hold its 2008 Annual Meeting 13-15 September in Halifax, Nova Scotia, Canada at the Lord Nelson Hotel. The meeting consisted of a half-day workshop on the Role of Advection in Sub-Arctic Marine Ecosystems, a one-day workshop on developing realistic scenarios of the effects of global warming on the climates of the sub-Arctic seas, and a one-day workshop comparing the results of ECOPATH modelling across the sub-Arctic seas. An additional half-day was spent reviewing the results of past workshops on biophysical coupling.

The Workshop on Advection was convened by Dr Ken Drinkwater (ken.drinkwater@imr.no). It compared and contrasted the role of advection within sub-Arctic ecosystems. Of particular interest was the difference between those sub-Arctic seas that receive significant amounts of warm water from the south, such as in the Barents and the Bering Seas, compared to those that receive arctic water from the north, such as the Oyashio and the Labrador and Newfoundland regions. In addition comparisons in advective processes between the sub-Arctic and the Antarctic were explored. In this regard Dr Sally Thorpe (British Antarctic Survey, Cambridge, UK) gave an invited talk on the role of advection on krill in the Antarctic. Other invited presentations included work in the northwest Atlantic on zooplankton (Dr Andrew Pershing, USA) and fish (Dr Ken Frank, Canada). From Pacific sub-Arctic regions there were presentations on the advective supply of offshore prey into the continental shelves in the Oyashio area (Dr Orio Yamamura, Japan) and on advection in the eastern Bering Sea (Dr George Hunt, USA). Rounding out the programme were presentations on larval drift off West Greenland, Iceland and Norway (respectively, Drs Kai Wieland, Denmark; David Brickman, Canada; and Trond Kristiansen, Norway). This workshop took place at the Bedford Institute of Oceanography. The possibility of writing a review paper examining the role of advection on sub-Arctic marine ecosystems was discussed.

The Workshop on Future Climate Scenarios was convened by Dr Jim Overland (NOAA/PMEL, USA, James.E.Overland@noaa.gov). It developed methods to select the most appropriate set of IPCC models for each of the sub-Arctic seas. Selected models must not only hindcast mean climate conditions, but also capture the range of natural variability. The objective was to be able to select a suite of models that can be used to forecast expected climate scenarios, and to then downscale these forecasts so that they can be used to develop physical oceanographic scenarios for each of the various sub-Arctic regions. These essential steps will provide the ESSAS Working Groups on Modelling and Biophysical Coupling with realistic input to determine potential future impacts of climate change on marine ecosystems in sub-Arctic regions and the sustainability of the fisheries. Invited presentations were given on the IPCC model assessments (Dr Vladimir Kattsov, Russia), regional models and downscaling from global models (Drs John Walsh, USA; Enrique Curchister, USA; Mike Foreman, Canada, on the NE Pacific; Simon Prinsenberg, Canada, on the NW Atlantic; and Paul Budgell, Norway, on the Nordic and Barents Seas) and on ecological impacts of future climate (Dr Ken Drinkwater).

The Workshop on Model Comparisons was co-convened by Dr Bernard Megrey (NOAA, USA, Bern.Megrey@noaa.gov), Dr Kenneth Rose (Louisiana State University, USA, karose@lsu.edu), and Dr Shin-ichi Ito (Tohoku National Fisheries Research Institute, Japan, goito@affrc.go.jp). It brought together the results of applications of the ECOPATH modelling system from a number of the sub-Arctic seas including the Barents Sea, the Iceland Sea, West Greenland, the Labrador Shelf, the Bering Sea, the Sea of Okhotsk, and the Oyashio Current system. The aim was that by using the same model to compare the different systems, differences in the model outcomes should reflect differences in the structure or function of the system, rather than in the assumptions or architecture of the models. There was also an invited presentation by Professor Michio J. Kishi, (Hokkaido University, Japan) on a comparison of simulated particle fluxes using NEMURO and other ecosystem models in the western North Pacific, and by Dr Bernard Megrey (NOAA Alaska Fisheries Science Center, USA) on the ECOPATH comparisons that were conducted as part of the MENU (Marine Ecosystems of Norway and the US) programme, and by Dr Kenneth Rose (Louisiana State University, USA) on "Can we compare models without also considering the modeller?" and an invited presentation by Dr Enrique Curchitser and Dr Paul Budgell on "A comparison of sea ice conditions in sub-Arctic seas over the last 50 years."

The ESSAS Science Steering Committee met on 16-17 September in Halifax immediately following the Annual Meeting. They discussed upcoming events including ESSAS contributions to the GLOBEC Open Science Meeting in June of 2009, a multiple session workshop being held by the ESSAS Working Group on Modelling, the potential transition from GLOBEC to IMBER after 2009, and next year's annual meeting.

ICES/GLOBEC programme on Cod and Climate Change: Workshop on Cod and Future Climate Change

Keith Brander[1] and Ken Drinkwater[2]

[1]DTU Aqua - Danish Institute of Aquatic Resources, Copenhagen, Denmark (kbr@aqua.dtu.dk)
[2]Institute of Marine Research, Bergen, Norway

Many of the regions presently occupied by Atlantic cod (*Gadus morhua*) are predicted to undergo significant warming in response to climate change, and indeed during recent years much of the North Atlantic has experienced warming. Increasingly, managers, politicians and the general public have been asking what will be the impacts of future climate change. Such information for cod and the marine ecosystems they inhabit has been limited. Indeed, the few published studies have usually only considered the response of individual species to increased warming without including other components of the marine ecosystem, such as their prey or predators. However, climate change is expected to impact both the structure and function of marine ecosystems and to develop more plausible impact scenarios we need to consider more than the effects on a single species.

In an attempt to determine the extent the impact of future climate scenarios will have on cod and their marine ecosystems in the North Atlantic the ICES/GLOBEC Working Group on Cod and Climate Change (CCC) held a Workshop on Cod and Future Climate Change from 17-20 June 2008 (Fig. 1). Sixteen scientists from 6 countries (Denmark, Germany, Norway, Russia, UK and USA) attended the workshop held at the ICES Headquarters in Copenhagen. The workshop is part of the 2005 strategic and action plan for the CCC programme and is one in a series of annual workshops. Co-convened by Norwegian scientists, Corinna Schrum from the University of Bergen and Ken Drinkwater from the Institute of Marine Research in Bergen, the aim of the workshop was to investigate the response of cod to future climate scenarios based on regional projections of climate and on knowledge of responses (growth, distribution, recruitment) gained during the CCC programme. The workshop also built on the cooperative work with climatologists initiated during the 1997 CCC sponsored Workshop on Prediction and Decadal-Scale Ocean Climate Fluctuations of the North Atlantic.

The Terms of Reference were, in response to future climate change scenarios, to

a) adopt 20–50-year probabilistic projections of future temperature and salinity as a basis for projections of fish population dynamics and distribution (also nutrients)
b) develop methodologies and make projections of likely changes in phytoplankton and zooplankton production and distribution, especially those species eaten by cod and their predators or prey during their life histories;
c) develop methodologies and make projections of likely changes in prey and predators of cod including the forage fishes, such as capelin, herring, sprat and mackerel;
d) develop methodologies and make projections of likely changes in cod production (growth, reproduction, mortality, recruitment) and distribution.

Figure 1. Participants at the Workshop on Cod and Future Climate Change on the roof of the ICES Headquarters in Copenhagen.

The topic which the workshop aimed to deal with has become very prominent over the four years since it was initially planned, with rapidly increasing scientific activity, so CCC has been well ahead of the game. Nevertheless it became clear that in some respects we are not yet able to carry out the planned programme and one of the main outcomes of the workshop was a sober appraisal of where we stand in relation to regional climate projections and some guiding ideas for future work by ourselves and others to integrate such projections with biological impact studies.

The workshop was presented with a mixture of discouraging and encouraging new information concerning regional climate projections for the NE Atlantic and it is clear that the scientific community working on climate impacts needs to be better informed about the current limitations. In the context of the workshop this can be summed up briefly as follows:

- Most of the presently available regional models of future change in the North Atlantic that have been downscaled from Global Circulation Models (GCMs) are not based on the most recent Intergovernmental Panel on Climate change (IPCC) model runs (2007) but rather on earlier IPCC GCMs.
- Comparisons of current conditions from IPCC 2007 model results with actual observations show large differences. For most of the areas occupied by cod recently observed increases in SST exceed the model projections by large amounts (i.e. the North Atlantic has warmed much more rapidly than the models suggest). Projected mean wind stress over the oceans for this area also deviate from that observed in both magnitude and direction.

- Two climate modes, the Atlantic Multidecadal Oscillation (AMO) and the North Atlantic Oscillation (NAO), represent at least half of the observed variability in North Atlantic SST, with the NAO being the dominant signal in many shelf seas. The AMO is not reproduced in IPCC climate models and the NAO is poorly reproduced.
- The models still do not include many of the processes and parameters which affect cod.

These points are not a criticism of the IPCC climate models and existing global projections, which were not designed or intended for regional impact studies of marine species. They show however that a considerable scientific effort is required to design, initialise, run and test regional models which produce output that is relevant for such impact studies. Until this is done the impact assessments must be based on "what if" scenarios, with no probabilistic ascription, such as requested in our ToR (a).

The good news was that models which assimilate recent climate data (and include the decadal modes) show useful forecasting skill, at least over periods of a few years. The two which were available (Smith *et al.*, 2007; Keenlyside *et al.*, 2008) predict little or no warming over the next two years because the internal modes (AMO in particular) offset the global warming trend. However over a longer time the global trend dominates over the regional effect. Temperature and salinity fields from the Hadley decadal predictions (Smith *et al.*, 2007) were provided for the workshop, but full model output would be needed to run 3D regional models and this had not been stored. Cooperation between global and regional modellers is needed on these issues.

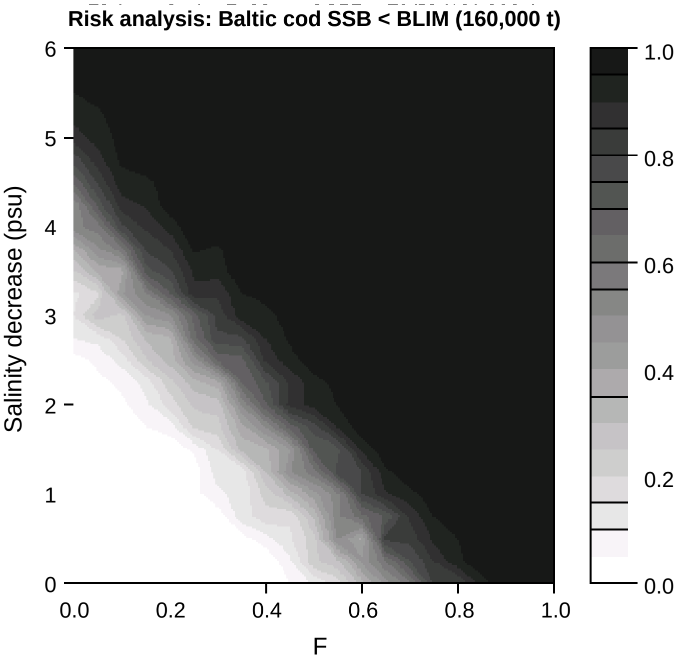


Figure 2. Results from an autoregressive multivariate model showing the combined effects of climate and fishing. The plot indicates the probability of the spawning stock biomass (SSB) falling below the precautionary stock size (Blim) computed as the % of model runs where the predicted SSB falls below 160,000 tonnes. Simulations are run for all combinations of fishing mortalities from 0-1 and decreases in salinity from 0-6 psu (relative to the mean salinity from 1974-2004). The risk of falling below Blim increases rapidly and non-linearly as salinities decrease with increasing fishing mortalities. Figure courtesy of Martin Lindegren.

Without regional climate models it was not possible to go on to implement coupled biological models of lower trophic level dynamics and consequences for cod populations for the next 20-50 years. However, some "what if" scenarios were presented at the workshop. For example multivariate autoregressive models were used to assess possible effects on Baltic cod. These combined the impacts of climate change with the effects of different levels of fishing mortality to explore the risk of stock biomass declining below precautionary reference levels or going extinct (Fig. 2).

The results of a non-spatial model that includes temperature, zooplankton, prey and predators suggest raising the temperature in the Barents Sea by 1-4°C will lead to increased cod growth, increased cod production and a decrease in maturation rates. On the other hand, cod cannibalism is expected to increase as well. In another study exploring the general effect of temperature on cod stocks, it was found that a 30% reduction in the carrying capacity of warm water stocks is expected with a 3°C rise in temperature. Other likely impacts on cod under future warming scenarios included a general northward shift in distribution and an increase in growth. Coupled with expected recruitment changes, there could be an increase in cod production in northern regions and a decline in southern regions. However, fishing pressure will play an important role in determining the actual rates of change of the biomass of cod populations. On the other hand, fisheries management must take into account climate impacts on cod production. In this regard it is encouraging that models have and are continuing to be developed that allow exploration of the combined effects of climate and fishing.

Future work should in the short term continue to explore the "what if" studies to develop future cod scenarios; in the longer term encourage improvements in GCMs, especially through conveying to the modellers what the needs of the impacts community are; develop regional models of future climate in those areas inhabited by cod using downscaling of results from several GCMs that are able to reasonably represent local present climate conditions; use the results of such models to force regional biophysical models to develop scenarios of phytoplankton and zooplankton under future climate; apply the results of both the ocean climate and lower trophic impacts to effects on cod; to develop models that include the higher trophic levels, especially cod; and to explore the combined effects of climate and fishing in order to determine better management strategies under climate change.

The full report of the workshop is ICES CM2008/OCC:09 and can be downloaded from the ICES website: http://www.ices.dk/reports/occ/2008/wkcfcc08.pdf

References

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Smith D.M., S. Cusack, A.W. Colman, C.K. Folland, G.R. Harris and J.M. Murphy. 2007. Improved surface temperature prediction for the coming decade from a global climate model. Science 317: 796-799.

ICES Working Group on Zooplankton Ecology hold their 2008 meeting in Sète

Roger Harris[1] and Astthor Gislason[2]
[1]Plymouth Marine Laboratory, Plymouth, UK (r.harris@pml.ac.uk)
[2]Marine Research Institute, Reykjavik, Iceland

The ICES Working Group on Zooplankton Ecology (WGZE) met at Le Grand Hôtel, Sète, France, from 31 March to 3 April 2008 at the kind invitation of Delphine Bonnet from the Université Montpellier. The meeting was attended by 29 scientists representing 12 countries.

In their discussions the group supported the Planning Group on North Sea Cod and Plaice Egg Surveys in the North Sea (PGEGGS) survey plan for fish eggs and larvae and considered that the samples should also be used, conserved and made available to provide wide scale information on other components of the North Sea plankton. It was assumed that the survey would deploy a flow metered 200 micron net with a double oblique tow profile. If so, then this would be a good standard general mesozooplankton sampling method.

The discussions recognised the strong need and value in efforts that preserve and consolidate taxonomic skills within the ICES community and globally. The group supported the ICES Fiches Identification Sheets for Plankton and considered that the further development of such taxonomic identification resources and training is vitally important. The WGZE recommended that ICES provides active support for future developments of plankton taxonomy, through its publications committee and web presence. Also this effort should seek to be open source and freely available while establishing links to other web based sites and expertise as well as collaborations.

The WGZE considers as a priority action to produce a summary report on zooplankton activities in the ICES area based on the time series obtained in the national monitoring programmes. The most recent report (No. 281: ICES Zooplankton Status Report 2004/2005, 2006) is available at: http://www.ices.dk/products/cooperative.asp.

The purpose of producing such reports is to give a global (ICES scale) and visual overview of zooplankton distributions for the preceding years (in the form of time series) with a brief interpretation of the ecological significance of these results. Important additions and improvements to the Zooplankton Status Report were planned. A species list in electronic format with a search engine has been produced covering 21 monitoring sites in addition to the CPR data for the North Atlantic. The search engine enables a search to be made for common species or groups within the North Atlantic. The Zooplankton Status Report will be published biannually; the next one will be out in autumn 2008.

The WG members reviewed the plans for the new ICES Science Programme, and were generally content with these although they felt that more attention might be given to advances in understanding climate forcing of recruitment variability through integration of field observations and laboratory experiments in coupled physical biological models. The group recommended that the prospect for operational application of these models be explicitly included in the science plan.

Figure 1. Participants at the ICES WGZE meeting in Sète, France.

The WGZE had previously been asked by OSPAR, *To prepare an assessment of what is known of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature. The assessment should look at ecologically indicative species, including the threatened and declining species identified by OSPAR, for which adequate time series data exist, in order to assess to what extent there have been changes in distribution, population and condition of species going beyond what might have been expected from natural. The aim is to prepare an overview as a major contribution towards JAMP (Joint Analytical Model Programme).* In addition to the recommendations the group made in 2007 WGZE made the following general recommendations to OSPAR:

- Long-term funding should be secured to maintain the few time series that exist at single sites and along transects, and to expand the CPR Survey with the aim of increasing the geographical coverage of zooplankton monitoring in the OSPAR area.
- The WGZE recommends that zooplankton species and biomass be included in the JAMP guidelines since there are compelling reasons for this information to be available to assess climate changes effects on the marine community and fishery resources.
- The WGZE considers that OSPAR should recognise the need of improving the monitoring of jellyfish in order to fill the gap of information on this ecologically important group.
- While the WGZE recognises the ecosystem and food web significance of phytoplankton, mesozooplankton, fish, sea mammals and birds, the predatory invertebrate fauna must not be ignored. In taking an ecosystem approach to surveillance, monitoring and management in the OSPAR areas, one should take into account that invertebrate predators are critical to the health and productivity of marine ecosystems, and appear to be sensitive indicators of change.

In reviewing the OSPAR request for a 'Scoping report on summaries of the status of biodiversity', the group felt that for zooplankton the results of the status report with the top ten species list should cover the request in general. Further the group agreed on a list of monitoring activities and products that should be taken into account when considering the status of biodiversity.

The current plans were discussed for the 'Joint ICES/CIESM Workshop to compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM)' (Co-chairs: Astthor Gislason, Iceland, and Gabriel Gorsky, France). The workshop will be held at the Hellenic Centre for Marine Research, Heraklion, Crete, Greece, from 27 to 30 October 2008. It will consist of three days of presentations and discussions, a half day of discussions on perspectives and future plans, and a half day field trip). A website has been created with information about the workshop (http://www.wkzem.net).

Finally the WGZE reviewed the progress of several other national and international projects such as progress in the formation of a new ICES Phytoplankton Working Group, RAPID, BASIN, and ongoing research activities at the Marine Biological Research Station in Sète, University of Montpellier.

Astthor Gislason completes his three-year term of office as chair of WGZE on 31 December 2008 and he was warmly thanked for his excellent leadership of the group. The unanimous proposal for the incoming chair was Mark Benfield. The WGZE proposes to hold its next meeting from 30 March to 2 April 2009 at the Faroese Fisheries Laboratory, Tòrshavn, Faroe Islands, kindly hosted by Dr Eilif Gaard.

Joint meeting with the Working Group on Physical-Biological Interactions (WGPBI)

Both the WGZE and the WGPBI met concurrently in Sète and held a one day joint meeting to discuss issues of mutual interest. The aim of the meeting was to bring modellers and field scientists together to explore how data and models could be combined to elucidate mechanisms explaining observed variations in zooplankton and ecosystem dynamics. The meeting was divided into three sessions: Session 1 with presentations by WGPBI members intended to demonstrate the range of modelling techniques available to the community and a new observational technique; Session 2 where WGZE members presented available data sets and examples of statistical modelling approaches; and Session 3 with joint discussions on possible future interactions between the two groups. The discussions were lively and stimulating with both groups recognising the ambitious agenda. The group aims to address the outcomes of the joint meeting during its next annual meeting in 2009. Presentations during the joint meeting were:

Holographic imagery of turbulence and plankton
Tom Osborn (Johns Hopkins University, Baltimore Maryland, USA)

'LERM' – The first LE plankton ecosystem model with four trophic levels
Matteo Sinerchia and John Woods (Imperial College, London, UK)

Modelling juvenile* Calanus finmarchicus *on Georges Bank: where have all the nauplii gone?
A.B. Neuheimer, W.C. Gentleman, and C. Galloway (Dalhousie University, Halifax, Canada)

Food web modelling – from nutrients to fish
Wolfgang Fennel (Leibniz Institute for Baltic Sea Research, Rostock, Germany)

Zooplankton modelling in the German Bight during GLOBEC-Germany with a view to study sprat larvae growth – do we simulate copepod abundance correctly?
Andreas Moll, Christoph Stegert, Markus Kreus and Wilfried Kühn (Institut fur Meereskunde, Hamburg, Germany)

Mesozooplankton sample collection methods
Mark C. Benfield (Louisiana State University, USA), Jörn Schmidt (Leibniz Institute of Marine Sciences, Kiel, Germany) and Peter H. Wiebe (Woods Hole Oceanographic Institution, USA)

Available field data sets from the North Atlantic and the Mediterranean
Eilif Gaard (Faroese Fisheries Laboratory, Faroe Islands) and Erica Head (Bedford Institute of Oceanography, Canada)

Available data sets: laboratory studies
Roger Harris (Plymouth Marine Laboratory, UK) and Xabier Irigoien (AZTI, Spain)

Statistical analysis – some examples
Cecilie Broms and Webjørn Melle (Institute of Marine Research, Bergen, Norway)

Needs from models: approaches to the biological questions
Jeffrey A. Runge (University of Maine and Gulf of Maine Research Institute, Portland, Maine, USA) and Catherine L. Johnson (Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada)

Effects of climate change on the world's oceans

Roger Harris[1] and Luis Valdes[2]

[1]Plymouth Marine Laboratory, Plymouth, UK (r.harris@pml.ac.uk)

[2]Instituto Español de Oceanografía, Gijón, Spain

The international symposium "Effects of Climate Change on the World's Oceans" co-sponsored by the International Council for the Exploration of the Sea (ICES), North Pacific Marine Science Organization (PICES) and Intergovernmental Oceanographic Commission of UNESCO (IOC), was held at the Congress Centre in Gijón (Spain), 19-23 May, 2008, gathering 382 participants from 48 countries from around the world.

Although we are beginning to document the local effects and consequences of climate change on the functioning of marine ecosystems, there is no comprehensive vision at the global scale, and only limited ability to forecast the effects of climate change. To close this gap, the Gijón symposium focussed on the major issues of climate change that affect the oceans: oceanic circulation, climate modelling, cycling of carbon and other elements, acidification, oligotrophy, changes in species distributions and migratory routes, sea-level rise, coastal erosion, etc. The symposium brought together results from observations, analyses and model simulations, at a global scale, and included discussion of climate change scenarios and the possibilities for mitigating and protecting the marine environment and living marine resources.

The three conveners: Dr John Church (IOC), Dr William T. Peterson (PICES), Dr Luis Valdés (ICES), and the SSC: Dr Richard Feely (USA), Dr Michael Foreman (Canada), Dr Roger Harris (UK), Dr Ove Hoegh-Guldberg (Australia), Dr Harald Loeng (Norway), Dr Liana McManus (USA/Philippines), Dr Martin Visbeck (Germany) and Dr Akihiko Yatsu (Japan), were responsible for preparing the scientific programme. The local organisation was the responsibility of the Instituto Español de Oceanografía - Centro Oceanográfico de Gijón. The full programme of the symposium included 5 general topics divided into 10 scientific sessions, one and a half days of workshops, and 10 plenary speakers.

Four workshops were associated with the symposium

- Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels.
  David L. Mackas (Canada) and Hans M. Verheye (South Africa).
- Linking Global Climate Model output to a) trends in commercial species productivity and b) changes in broader biological communities in the world's oceans.
  Anne Hollowed (USA), Richard Beamish (Canada) and Michael Schirripa (USA).
- Storm surges and flooding in the Baltic Sea.
  Aleksander Toompuu (Tallinn University of Technology, Estonia), Evgueni Kulikov (Russia) and Josef Cherniawsky (Canada).
- Prospects for multidisciplinary long-term ocean observations.
  Ed Harrison (USA), Richard Lampitt (UK) and Doug Wallace (Germany).

Scientific sessions accommodating a total of 215 oral presentations (10 plenary talks and 20 invited speakers included). Parallel to the oral presentations, two poster sessions exhibited 133 posters during the entire symposium.

A selection of the symposium papers will be published in a volume of the ICES Journal of Marine Science in spring/summer 2009.

The symposium covered a wide range of topics: observations (new findings, and gaps), uncertainties in current measurements and the need for new instrumentation, the effects of climate change at several levels (sea level rise and erosion in the coastal zone, temperature and acidification in biota), revision

Figure 1. Participants listening to plenary presentations at the Gijón symposium.

Figure 2. Participants at the Gijon symposium.

of predictions from models, the role of the Intergovernmental Panel on Climate Change (IPCC) in assessing predictions, reporting the effects of global warming in the oceans and methods for adaptation, and finally the identification of challenges and hot spots for special consideration in the next five years.

At the closing ceremony it was agreed that this symposium would be continued or repeated in 2011 or 2012. It was also recognised that this was the largest and most important symposium that has ever been held on the effects of climate change on the oceans.

Further to the symposium a "Policy Forum" article was published in Science by Anthony Richardson and Elvira Poloczanska (Science 320: 1294-1295), entitled, "Under-resourced, under threat". The article pointed out that the recent IPCC Fourth Assessment Report noted 28,586 significant biological changes in terrestrial systems but only 85 from marine and freshwater systems. Of these few observations from aquatic systems, 99% were consistent with global warming, which suggests that aquatic systems may be extremely vulnerable to climate change.

It was concluded therefore that a coherent global vision is needed to better determine the impacts of climate change on marine systems. The Gijón symposium contributed significantly to developing this global vision, as will future climate change symposia.

Figure 3. Discussions at one of the poster sessions in Gijón.

Plenary talks and keynote speakers by sessions

1.1 ***Lynne D. Talley.*** Observed ocean climate changes: A review based on the IPCC AR4 and subsequent works.

1.2 ***Ronald J. Stouffer.*** Oceans role in climate change.

2.1 ***Corinne Le Quéré.*** Recent trend in the global oceanic CO_2 sink.

2.2 ***Ove Hoegh-Guldberg.*** Coral reef ecosystems as casualties of rapid climate change.

3.1 ***Jason Lowe.*** Can we quantify the risk of large increases in sea level extremes?

3.2 ***Dan Baird.*** An assessment of the functional variability of coastal ecosystems in the context of environmental changes.

4.1 ***Joaquim Goes.*** Shrinking snowcaps and rising productivity: response of the Arabian Sea ecosystem to recent climate change.

4.2 ***Patrick Lehodey.*** Forecasts of population trends for two species of tuna under an IPCC scenario.

5.1 ***Eddy Carmack.*** The changing Northern Ocean.

5.2 ***Jane Lubchenko.*** Managing for resilience in ocean ecosystems.

Symposium scientific sessions

Theme 1. Past and future variability and change in ocean climate

- S1.1: Observed climate changes.
- S1.2: Climate model projections.

Theme 2. Interactions between climate variability and change and biogeochemical cycles

- S2.1: Marine carbon cycling and other biogeochemical cycles.
- S2.2: Ocean acidification and coral reef bleaching.

Theme 3. Impacts of climate variability and change on the coastal environment

- S3.1: Natural hazards, sea level rise and coastal erosion.
- S3.2: Estuarine and wetland ecosystem functioning.

Theme 4. Impacts of climate change on marine ecosystems: present status of our understanding

- S4.1: Impacts on lower trophic levels.
- S4.2: Impacts on higher trophic levels.

Theme 5. Scenarios-mitigation-reduction of impact of future climate change on the marine environment: from regional to global scale

- S5.1: Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems.
- S5.2: Adaptation and mitigation of impacts on the marine environment and ecosystems.

Climate Change and Small Pelagic Fish book

Dave Checkley

Scripps Institution of Oceanography, University of California, San Diego, USA (dcheckley@ucsd.edu)

The Small Pelagic Fish and Climate Change (SPACC) programme has completed an edited book that presents the status of the field as of early 2008. Publication, by Cambridge University Press, is scheduled for late 2008 or early 2009 and the editors are Dave Checkley, Jürgen Alheit, Yoshioki Oozeki, and Claude Roy. 82 authors from 22 countries came together to write fifteen chapters addressing the past, present, and future effects of climate change on small pelagic fish.

Chapter 1: History of international cooperation in research
by Jürgen Alheit and Andrew Bakun, describes events in the research environment that led to the formation of SPACC.

Chapter 2: A short scientific history of the fisheries
by Alec D. MacCall, details the fluctuations in the large fisheries for anchovy and sardine that provided the impetus for SPACC.

Chapter 3: Habitats
by Dave Checkley *et al.*, describes the habitats of the major stocks of anchovy and sardine, i.e. in the California, Humboldt, Benguela, and Kuroshio-Oyashio Currents, and in the NE Atlantic. Common and differing features among the populations are noted, and susceptibility to future climate change discussed.

Chapter 4: Variability from scales in marine sediments and other historical records
by Dave Field *et al.*, presents inference from the sedimentary record about the past variation of populations of small pelagic fish. Particular attention is given to methodological issues, in addition to the chronologies and inference from them.

Chapter 5: Decadal-scale variability in populations
by Jürgen Alheit *et al.*, concerns shifts, and their causes, of the abundance of small pelagic clupeiform fish species documented in the historical record.

Chapter 6: Biophysical models
by Christophe Lett *et al.*, presents models for eggs, larvae, and adults, with case studies and a discussion of the use of models to explain and forecast the effects of climate change on small pelagic fish species.

Chapter 7: Trophic dynamics
by Carl van der Lingen *et al.*, provides case studies of feeding ecology of two or more fish species in seven major systems. Linkages between climate and fish are described for many of these systems, and possible impacts of climate change on some of the species.

Chapter 8: Impacts of fishing and climate change explored using trophic models
by Lynne Shannon *et al.*, uses the Ecosim family of models to assess the effects of fishing and climate on the role of small pelagic fish in ecosystems.

Chapter 9: Current trends in the assessment and management of stocks
by Manuel Barange *et al.*, reviews the status of 27 stocks of small pelagic fish, and discusses these in the context of stewardship and governance.

Chapter 10: Global production and economics
by Samuel Herrick *et al.*, assesses the global production, full range of benefits, and the optimal use of small pelagic fish under climate change.

Chapter 11: Human dimensions of fisheries under global change
by Rosemary Ommer *et al.*, considers fisheries for small pelagics in the context of the intersection of natural and social sciences, including social, economic, institutional, and cultural issues.

Chapter 12: Mechanisms of low-frequency fluctuations in anchovy and sardine populations
by Alec MacCall, presents a framework in which to consider the causes of long-term variation of these fish stocks, including physics and biology as well as the impact of fisheries.

Chapter 13: Research challenges in the twenty-first century
by Andrew Bakun, is an analysis of variation in small pelagic fish stocks with an emphasis on future research directions.

Chapter 14: Conjectures on future climate effects on marine ecosystems dominated by small pelagic fish
by Pierre Fréon *et al.*, considers the effects of future climate change on the productivity and composition of lower trophic levels, distributional changes, effects on recruitment, and other biological changes, and identifies research gaps.

Chapter 15: Synthesis and perspective
by Dave Checkley *et al.*, gathers ideas from the prior chapters to arrive at common conclusions as well as expose areas lacking consensus and understanding. It concludes with recommendations for future actions.

This book is a product of many of the efforts of contributors to the SPACC programme over the years. In particular, it represents the fruits of the labours of Jürgen Alheit and John Hunter, the co-founders of SPACC, as well as the continued support of Manuel Barange in the GLOBEC IPO. It is the hope of the editors and the authors that this book will provide a foundation for future research to further the understanding needed to inform management and policy under future, unprecedented change.

If you are interested in purchasing a copy of the book please contact the GLOBEC IPO, globec@pml.ac.uk for further details.

Ten years of change from IMECOCAL observations in the southern region of the California Current Ecosystem

Tim Baumgartner[1], Reginaldo Durazo[2], Bertha Lavaniegos[1], Gilberto Gaxiola[1], José Gómez[1] and Joaquín García[1]

[1]Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, Baja California, Mexico

[2]Universidad Autónoma de Baja California, Ensenada, Baja California, Mexico

In October 2007, IMECOCAL completed its tenth year of quarterly cruises dedicated to monitoring and analysis of the state of the pelagic ecosystem in the southern region of the California Current (see Baumgartner *et al*., 2000). IMECOCAL (Investigaciones Mexicanas de la Corriente de California) is an inter-institutional programme administered through CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada) with active participation of scientists from UABC (Universidad Autónoma de Baja California), CICIMAR (Centro Interdisciplinario de Ciencias Marinas), CIBNOR (Centro de Investigaciones Biológicas del Noroeste), UNAM (Universidad Nacional Autónoma de México), USON (Universidad de Sonora), and INAPESCA (Instituto Nacional de la Pesca y Acuicultura). It has been supported principally through Mexican federal funds obtained through competitive grant awards from the National Council of Science and Technology (CONACYT) plus initial start up support from the Inter-American Institute (IAI) for Global Change Research, early assistance from NSF, as well as timely support from the IAI-EPCOR research network (Eastern Pacific Consortium for Research in Coastal and Oceanic Regions) and CICESE institutional funds that have maintained continuity in the observational programme.

IMECOCAL is a member of the GLOBEC family of national programmes with goals and objectives designed to support its international research agenda for monitoring and analysis of marine ecosystem dynamics. Although IMECOCAL is not a resource agency programme, the continuity of environmental observations it provides is critical to detecting and understanding the year-to-year and decadal-scale changes in resource populations that are also key trophic links within the pelagic ecosystem, and is therefore highly relevant to the needs of ecosystem-based fishery management. This article summarises the results of the first ten years of IMECOCAL observations of interannual through multidecadal changes in the ecosystem through comparisons with observations that were initiated in the mid-twentieth century by the CalCOFI (California Cooperative Oceanic Fisheries Investigation) programme.

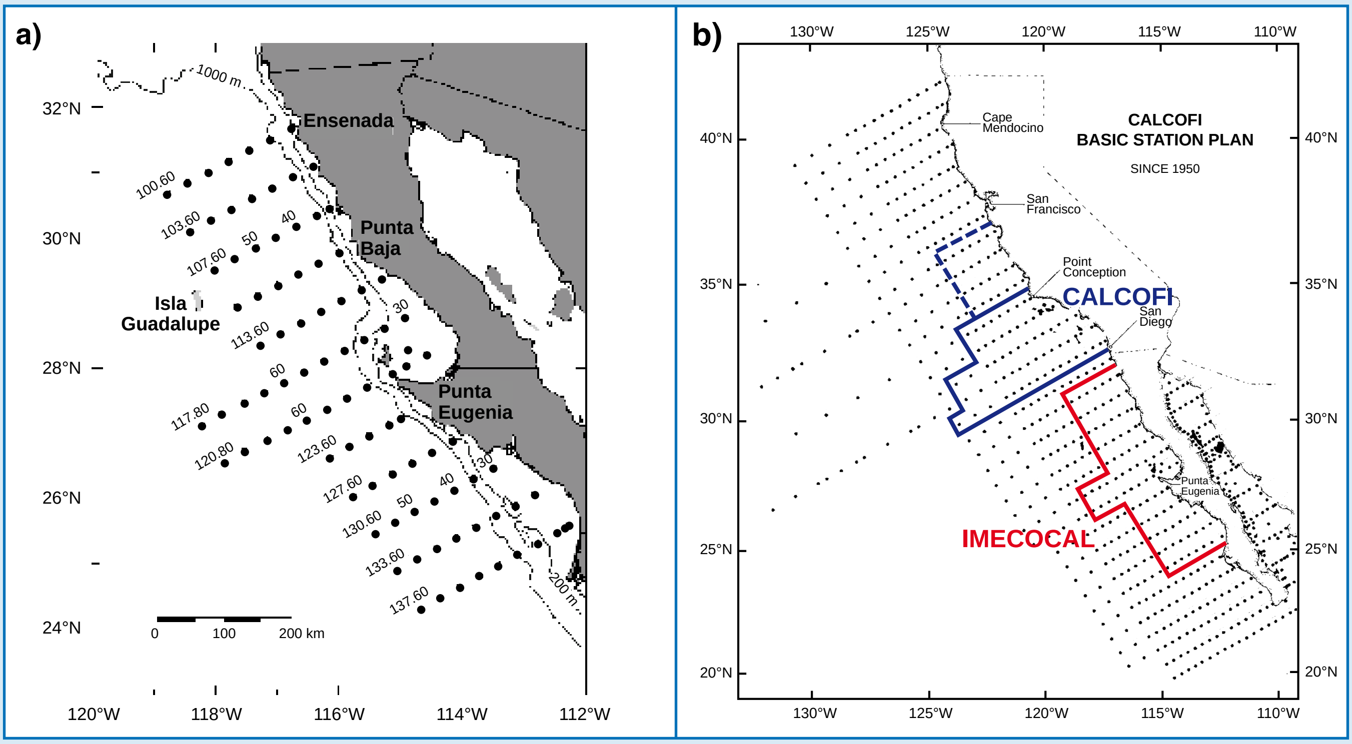

Figure 1. a) IMECOCAL sampling plan shown with line and station numbers indicated for the quarterly cruises. b) Original overall station plan adopted for CalCOFI surveys for region between northern California and Baja California (and Gulf of California) shown by black points. The area of quarterly CalCOFI surveys since the early 1980s is shown outlined by the blue border. The dashed blue border represents the additional area covered by CalCOFI underway sampling since 1997. The quarterly IMECOCAL surveys, in operation since October, 1997 (indicated by red border), follow the CalCOFI grid pattern established off Baja California.

IMECOCAL and the CalCOFI legacy

Regular quarterly cruises for *in situ* sampling and data collection are carried out by IMECOCAL aboard the CICESE research vessel *Francisco de Ulloa* (the 41st cruise was just completed at the beginning of August 2008). The IMECOCAL cruises (Fig. 1a,b) are coordinated as closely as possible with the CalCOFI surveys to provide coverage of the combined regions of the California Current Ecosystem (CCE) within the same time frame. Both the CalCOFI and IMECOCAL cruises collect physico-chemical data as well as biological measurements of primary production, and sampling of zooplankton and ichthyoplankton on station and by underway collection of temperature, salinity and fluorescence along with continuous sampling of fish eggs between stations by continuous pumping with a CUFES (Continuous Underway Fish Egg Sampler described in Checkley *et al*., 2000) system. Together the IMECOCAL and CalCOFI surveys now approach the scale of sampling that matches the true scale of processes that determine the state of the ecosystem of the California Current as well as point out the contrasts in the physical and biological character of the central and southern regions of the CCE.

CalCOFI was launched in 1949 with monthly cruises (through 1960) that originally covered part or all of the region extending from northern California and Oregon, USA, into the waters off Baja California, Mexico (Fig. 1b). It grew out of cooperative efforts, beginning in the 1920s, among the old US Bureau of Commercial Fisheries, Scripps Institution of Oceanography, the California Academy of Sciences, and the California State Department of Fish and Game. The original purpose of the CalCOFI surveys was to determine the cause of the decline in the sardine population off California, adopting what became known as the "oceanographic approach" to fisheries research. By the 1960s the original goals of CalCOFI were evolving and coalescing into a plan for a more holistic study of the coastal pelagic ecosystem. This newer approach enfolded the sardine problem into the question of how the combined influence of a changing environment and commercial harvesting produced the collapse of the population (Hewitt, 1988). Although the sardines had not returned, the rise in anchovy abundance and development of a commercial fishery in the 1970s provided a further economic stimulus for continuation of the programme. The demise of the anchovy, belated recovery of the sardine, changing ocean conditions and changes in abundance and composition of the plankton have provided a continuous stream of new questions to answer along with the old.

Both the spatial and temporal coverage of CalCOFI has varied significantly since the beginning of the 1960s as a function of evolving goals, available budgets, institutional support and scientific-technical manpower. The current sampling pattern (solid blue borders in Fig. 1b) was adopted at the beginning of the 1980s and extended northwards in 1997 (dashed blue border in Fig. 1b) with the latitudinal expansion of the sardine spawning habitat. The IMECOCAL sampling programme (Fig 1a,b) was designed by Mexican scientists in collaboration with CalCOFI to fill the observational gap left off Mexico from the contraction of the CalCOFI survey pattern at the end of the 1970s (Fig 2).

Because the CalCOFI programme has resulted in one of the more complete descriptions of the physical dynamics and the changing biological structure of a major eastern boundary current (e.g. Reid, 1960; Brinton, 1960; Chelton *et al*., 1982; Lynn and Simpson, 1987; Baumgartner *et al*., 1992; McGowan, 1995, McGowan *et al*., 2003, DiLorenzo *et al*., 2005) it is possible now to characterise the current state of the ecosystem in the context of the response to changes in climate over the past 50 to 60 years and beyond. In particular, the first thirty years of physical and biological sampling by the CalCOFI programme (1950s through the 1970s; Fig. 2) allows us to compare the state of the ecosystem observed today in the southern region of the California Current with that of the earlier decades. The periods of sampling by the IMECOCAL and the CalCOFI programmes are shown in Figure 3 in the context of the history of ocean climate depicted by the Pacific Decadal Oscillation Index (PDOI) shown as the series of annual means beginning in 1920 and the expanded series of monthly means of the PDOI beginning in 1996.

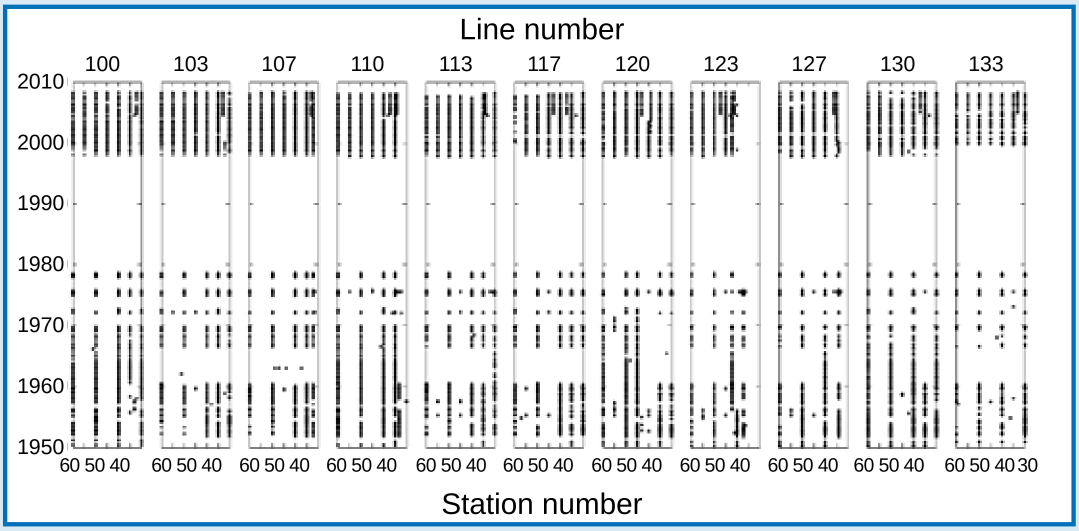

Figure 2. Sampling history plotted as the annual quarters in which lines and stations (cf. Fig. 1a) were occupied during cruises over the southern region of the California Current system by CalCOFI (1950s through 1970s) and by IMECOCAL, beginning in October 1997.

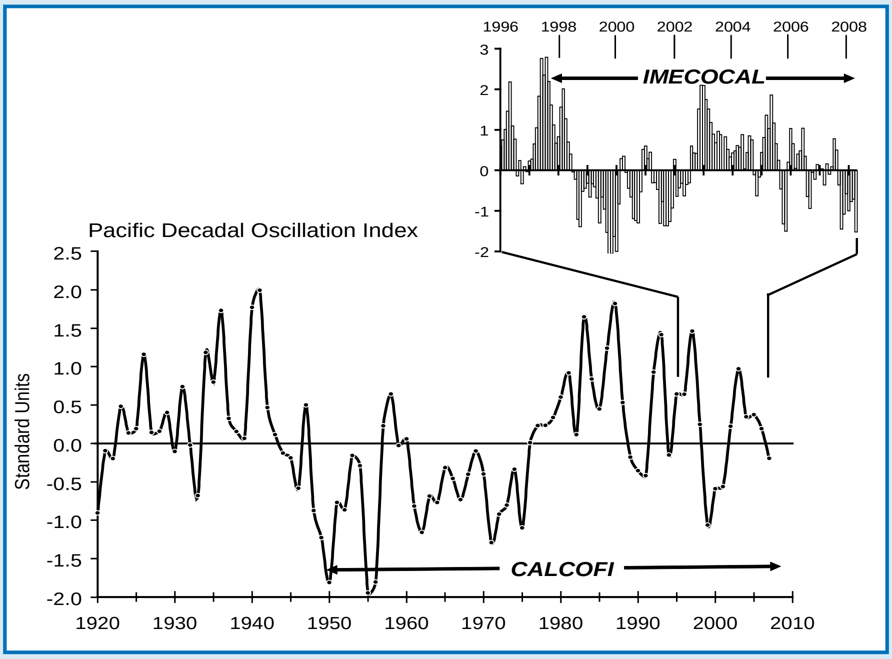

Figure 3. The sampling periods of the IMECOCAL and CalCOFI programmes are shown in the context of the interannual to interdecadal scales of climate variability in the region of the California Current system represented here by the Pacific Decadal Oscillation Index (Mantua et al., 1997). This index is the time series of the leading EOF calculated from the SST anomaly field north of 20°N, after removing the long-term trend of ocean warming. The PDOI is plotted here as annual means for the period 1920-2008, and as monthly means in the 1996-2008 plot. Data are from the internet site at url: http://jisao.washington.edu/pdo/PDO.latest

The Pacific Decadal Oscillation Index (PDOI) represents the interannual through interdecadal changes in the ocean-atmosphere climate system that affect the northeast Pacific; it is the time series of the leading Empirical Orthogonal Function (EOF) of the field of monthly SST anomalies north of 20°N from which the long-term warming trend has been removed (Mantua *et al*., 1997). Elimination of the multi-decadal warming trend from the PDOI emphasises the interdecadal component of space-time variability in the North Pacific but also suppresses the global warming signal. The series of annual means of the PDOI beginning in 1920 shown in the lower panel of Figure 3 indicates a history of three temperature regimes that have persisted over periods of roughly 25-30 years. Because the EOF analysis does not filter out the higher frequency interannual signal, the annual means of the PDOI in Figure 3 also show the response to the 4-7 year ENSO phenomenon.

The plot of annual means of the PDOI in Figure 3 indicate that the initiation of CalCOFI sampling coincided with the establishment of the period of cooler temperatures that began to dominate the northeast Pacific in the late 1940s. It is particularly noteworthy that the period of CalCOFI sampling in the southern region of the CCE shown in Figure 2 covers the period of the cooler regime and ended at the transition into the warm regime at the end of the 1970s. The intensive quarterly sampling by IMECOCAL over the southern region of the CCE since the fall of 1997 not only captures the essence of the variability in ocean climate depicted by the monthly means of the PDO in Figure 3, it allows us to compare the ecosystem state of the warm interdecadal regime established by the early 1980s with the state of the ecosystem during the cool regime observed by the CalCOFI programme in the three decades after 1950.

It is important to point out here that the current trend in the PDOI may be signaling another transition into a cooler regime in the coming years. If this proves to be the case, it will be consistent with the dominant interdecadal period of 50-70 years found in the oscillations of sardine abundance in the California Current (Baumgartner *et al*., 1996) over the past 1600 years. Maintaining the IMECOCAL surveys will be critical to capture such a transition in the ocean ecosystem states off Mexico and to investigate the interactions with the long-term process of ocean warming associated with the greenhouse effect.

Spatial variability in the structure of the California Current Ecosystem

The large-scale structure of the coastal pelagic ecosystem is evident from the onshore-offshore and latitudinal variability in chlorophyll concentrations shown in Figure 4a with composited SeaWiFS imagery from 45°N to 20°S. The turning of the flow of the California Current towards the coast and separation into a local poleward flow along the coastal area of the Southern California Bight (SCB) and an equatorward flow off Baja California is represented schematically in Figure 4a by the red arrows. The turning of the flow into the SCB bends and distorts the frontal zone running from Oregon to southern California. The continuity of the coastal band of elevated primary productivity is interrupted by the intrusion of the offshore oligotrophic oceanic water that is entrained by the flow into the coast, indicated on Figure 4a by the low pigment concentrations in the SCB and off northern Baja California. The turning and dividing of the flow south of Point Conception (34.5°N) is a permanent feature in the spatial structure of the CCE that is due to the interaction of the flow field with the continental boundary and associated offshore bathymetry. Thus the IMECOCAL region is separated from the CalCOFI region by a major hydrographic feature known as the Ensenada front (Haury *et al*., 1993).

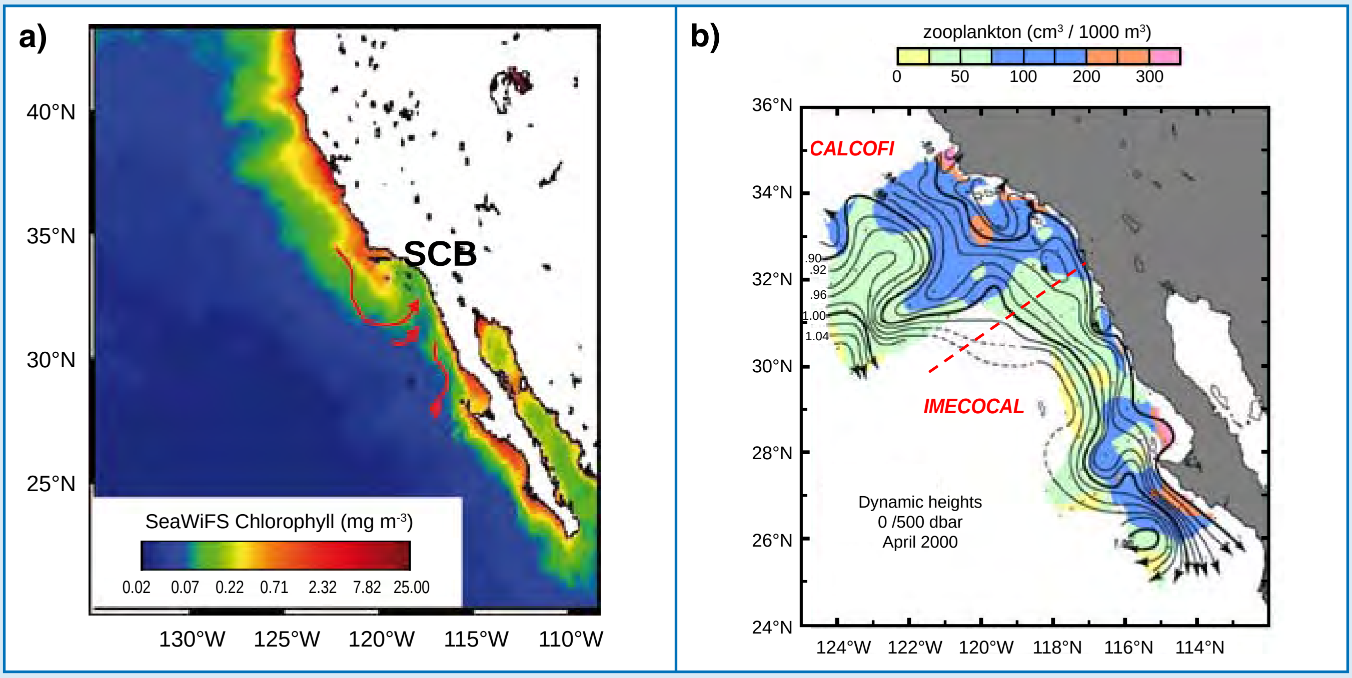

Figure 4. a) Six-year averages (1997-2003) of surface chlorophyll concentrations in the California Current (CC) from SeaWiFS imaging for June through August. Red arrows represent deflection of the main axis of the CC towards the coast, with the northward branch flowing into the reentrant of the Southern California Bight (SCB) and a southward branch flowing inshore along the Baja California peninsula (figure modified from the original in Mackas et al., 2006.). b) IMECOCAL and CalCOFI data sets combined to indicate the macro-scale bio-physical coupling in the central and southern regions of the California Current system for April 2000. The surface circulation is indicated by the dynamic height contours (calculated for 0/500 db, with direction of flow shown by arrowheads) plotted over a colour base depicting concentration of zooplankton volumes collected by standard oblique bongo-net tows.

The pattern of chlorophyll distribution in Figure 4a is evident in the distribution of zooplankton biomass in Figure 4b. The zooplankton concentrations are plotted over the dynamic heights here to indicate the association with the coarse scale pattern of circulation. This plot was created with the combined hydrographic data and zooplankton displacement volumes from the April 2000 IMECOCAL and CalCOFI cruises. The relationship of zooplankton concentrations to the general circulation in Figure 4b reflects the shoreward deflection of the equatorward flow. The distribution of zooplankton biomass marks the frontal system developed between the entrained offshore water to the south, and the coastal water with higher concentrations of zooplankton from the north. This pattern indicates that the frontal system acts to block the advection of nutrients and zooplankton from the CalCOFI region into the IMECOCAL region. Reduction in zooplankton volumes off northern Baja California thus appears to result from the restriction of the southward transport of coastal water from central and southern California plus the reduction of productive coastal habitat to the south by compression of the oceanic habitat into the coast.

The importance of the patterns of chlorophyll and zooplankton distributions for structuring the habitat of the small pelagic fish is evident in Figure 5a which shows the relationship between the spatial variation in concentration of the sardine eggs relative to the zooplankton concentrations (from Fig. 4b) during April 2000. The heaviest concentration of spawning adults during this period was located in the CalCOFI region, following a latitudinal band located offshore between 50 and 200 km (roughly following the frontal zone between the high and low chlorophyll concentrations in Figure 4a). This is the more northerly sardine stock that is associated with the subarctic to transitional habitat in the California Current (*cf*. Baumgartner *et al*., 2005) with its maximum southern extension occurring during spring with the intensification of the equatorward flow. Note that the sardine spawning habitat in the IMECOCAL region during April 2000, was confined to a band much closer to shore due to the shoreward deflection of the flow and displacement of favourable habitat towards the coast. There were also lower egg concentrations relative to the region off central and southern California (Fig. 5a,b) that is consistent with the lower concentrations of food for the spawning adults.

The plot in Figure 5c suggests that the spawning sardines may select intermediate concentrations of zooplankton biomass (approximately 50-500 ml/m^3) in which to deposit their eggs. These concentrations are found in the transition between the nutrient enriched coastal waters with higher concentrations of the phyto- and zooplankton and the offshore oligotrophic oceanic waters containing lower concentrations of zooplankton. This transitional area is also characterised by higher vertical stability that would favour survival of the sardine eggs and larvae. The low egg concentrations associated with very high zooplankton volumes may also indicate that egg numbers are reduced by increased predation in these areas.

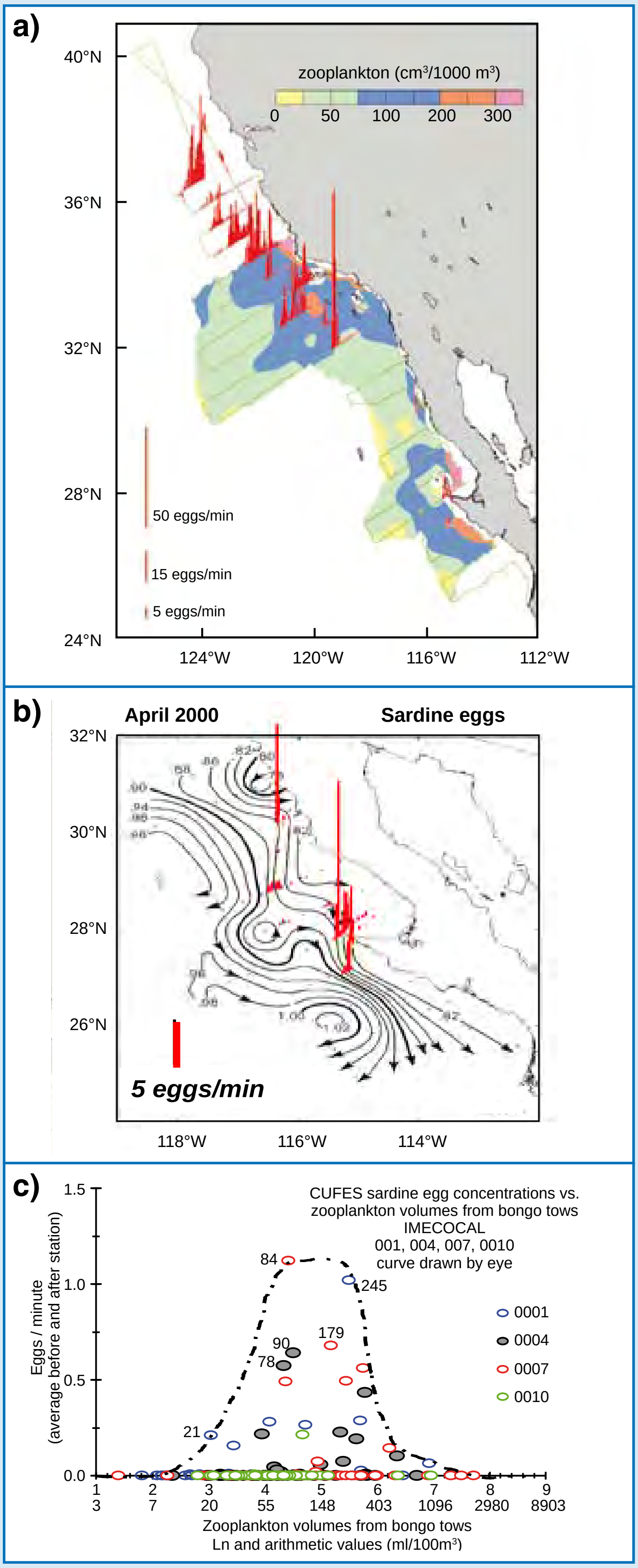

Figure 5. a) Distribution and relative concentrations of sardine eggs from CUFES samples shown as red vertical bars over colour base depicting zooplankton volumes during spring (April) 2000. b) Amplification of sardine egg concentrations off Baja California collected by IMECOCAL in April 2000 (shown as red vertical bars, as in a) plotted over dynamic height contours to show major features in surface flow. c) Sardine egg concentrations off Baja California plotted against zooplankton volumes collected by standard oblique bongo net tows in the IMECOCAL region during the January, April, July, and October cruises of 2000.

Temporal changes in the state of the ecosystem

The ten years of IMECOCAL observations beginning in October 1997 provide the means to document interannual to decadal-scale changes in the southern region of the CCE. Comparison of these observations to the CalCOFI sampling from 1950 through the late 1970s allow us to evaluate the long-term changes in ecosystem conditions. The four variables plotted in Figure 6 are used as leading indicators of change in the physical and biological states of the ecosystem for early detection of turning points. The four series are plotted as quarterly anomalies from the long-term means of observations taken over the entire sampling grid so that the effects of seasonal changes are suppressed in order to clearly document the regional response to interannual and longer-term climate forcing.

Accumulation of the ten years of the quarterly data also allows us to detect and describe changing relationships among the physical and biological variables that represent different responses to change in the dominant process of climate forcing. The plots in Figure 6 describe the change in zooplankton biomass (sampled by oblique bongo net-tows from 200 m to the surface) and chlorophyll concentrations (at 10 m depth) that represent phytoplankton biomass in relation to the changing conditions of near surface temperature and salinity (at l0 m depth). The relationships among the series of variables at first seem counter intuitive and therefore are an important guide to exploring the nature of the ecosystem response to climate.

The salinity anomalies in Figure 6 exhibit more coherent variability than the temperature anomalies which appear much noisier, although the overall character and trends of the temperature series reflect the more continuous change in the salinity signal. Together the series of regional temperature and salinity anomalies mark significant shifts in the character of ocean climate that are consistent with the changes indicated in the monthly PDOI series in Figure 3.

Change in the physical state of the system can be described from Figure 6 as beginning with the transition from conditions imposed by the intense but relatively short-lived *El Niño* of 1997-98, that was characterised by strong positive anomalies in both temperature and salinity over the region, to the strong *La Niña* conditions of 1998-99, with negative anomalies of salinity associated with negative temperature anomalies (*cf.* Durazo and Baumgartner, 2002). This early phase was followed by a period of generally persistent negative or neutral temperature anomalies suggesting prolonged *La Niña* conditions (of varying strength) from 1999 through mid-to-late 2002 (*cf.* the monthly PDOI series in Figure 3). This cool period ended abruptly after mid-2002 and was replaced by a period of prolonged warming consisting of multiple, relatively moderate *El Niño* events into 2005, upon which it began to be interrupted by increasingly intense cooling spells (*cf.* Fig. 3). This warm period now appears to have been terminated by the relatively strong *La Niña* conditions that appeared in late 2007 (see discussion by K. Wolter of the these periods of prolonged warming and cooling in terms of the multivariate ENSO Index, on the internet site at http://www.cdc.noaa.gov/people/klaus.wolter/MEI/).

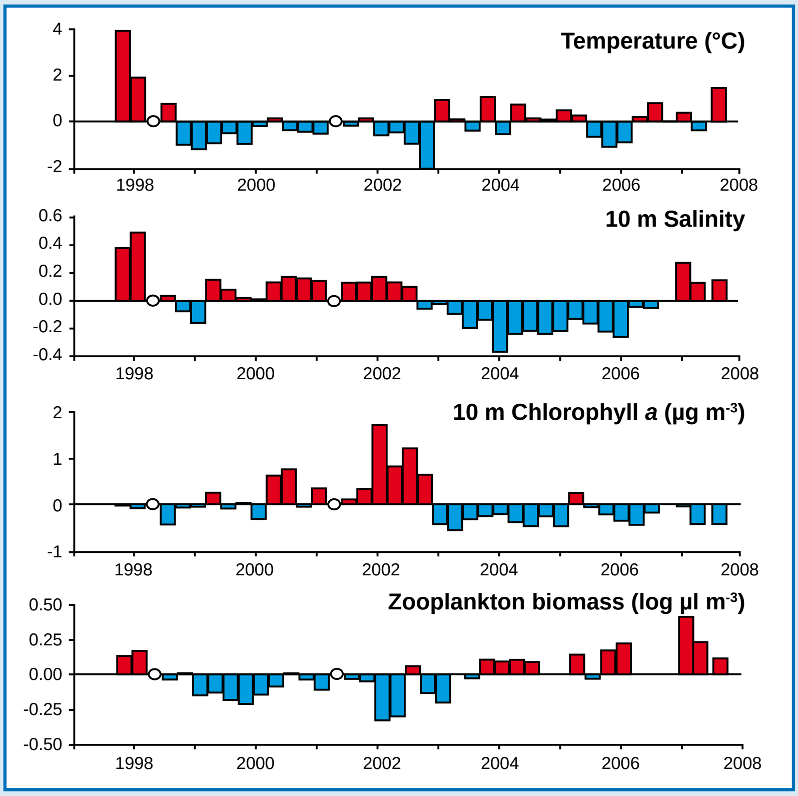

Figure 6. Leading indicators of change in the physical and biological states of the pelagic ecosystem from quarterly IMECOCAL cruises (October 1997 – October 2007). The four time series track the regional anomalies of the four variables calculated as deviations from the long-term means of the quarterly observations taken over the entire sample grid shown in Figure 1a. The temperature and salinities at 10 m were taken from CTD profiles; the chlorophyll concentrations are from water samples taken at 10 m; the zooplankton biomass was measured as displacement volumes from standard oblique bongo net-tows (0-200 m). The two periods without samples are indicated by small circles along the 0-axis.

One of the unusual and unexpected aspects of the variability in temperature and salinity anomalies in Figure 6 is the switch in their relationship from positive to negative correlation during the *La Niña* conditions in 1999. This inverse correlation between salinity and temperature persists through the cool period lasting into mid-2002 and across the transition into the generally warmer conditions that persisted over the IMECOCAL region into 2007. Inversion in the relationship between temperature and salinity suggests a difference in kind or degree between the dominant processes of climate forcing acting over the IMECOCAL region during the strong influence of the *El Niño-La Niña* period of 1997-99 and the period between 2000 and 2006.

Analysis of the period of strong ENSO dominance (1997-99) by Durazo and Baumgartner (2002) suggests that the core of Subarctic Water (characterised by low salinity and low temperatures) of the California Current - that penetrates equatorward into the area south of Punta Eugenia (location given on Figure 1a) during neutral and cool years - was blocked and strongly mixed with warm, salty Subtropical Surface Water (normally found to the west and southwest associated with the central gyre). Durazo and Baumgartner (2002) argue that this warm, salty water was advected from the west and southwest in a large-scale convergence towards the coast that fed the poleward flows that were established during the winter of 1997-98, moving and spreading the warm, salty water northward along the coast north of Punta Eugenia. This advective transport was then reversed with the transition to the strong *La Niña* conditions with intensification of equatorward flow and the penetration of cool, low salinity Subarctic Water off central and southern Baja California. The importance of this mechanism - responsible for the positive correlations between temperature and salinity during the ENSO phase - appears to have played a diminishing role by early to mid-1999.

The biological response to the physical changes in the environment over the IMECOCAL region during the period of ENSO dominance in1997-99 is indicated by the chlorophyll and zooplankton anomaly series also plotted in Figure 6. The regional response of the phytoplankton biomass (indicated by the chlorophyll) to the *El Niño* conditions appears as a weak negative anomaly. The positive anomaly in the zooplankton volumes (obtained from the logarithm of the regional mean) indicates elevated levels of biomass during the *El Niño* phase in October 1997 and January 1998, compared to the almost neutral response of the phytoplankton (*cf.* Lavaniegos *et al.*, 2002). A comprehensive analysis of the copepod assemblage from the bongo net-tows from the *El Niño* period by Lavaniegos and Jiménez (2006) demonstrates the dominant presence of “invasive”species linked to the central gyre and more tropical waters to the west and south (the central and tropical-equatorial species in biogeographic terms). At the same time, the abundances of many species associated with the California Current were reduced. Thus the biological response of the zooplankton to this *El Niño* agrees with the physical mechanism proposed by Durazo and Baumgartner (2002). It is reasonable to infer that the overall increase in biomass in zooplankton was due to the increased abundance of the tropical-equatorial and more oceanic species from the west-southwest that more than compensated for the reduction in abundance of Subarctic-Transitional species of the California Current.

To address the question of how climate forcing changed over the IMECOCAL region after 1999, it is useful to examine the evolution of temporal variability in the salinity signal from plots of the data along each of the sampling lines as arranged in Figure 7. Viewing the regional spatial scale of the temporal variability in the salinity anomalies in this way confirms that the strong positive salinity anomaly associated with the elevated temperatures during the 1997-98 *El Niño* were more intense, and characterised by strong spatial coherence in the southern region. There is significant decay of the intensity and coherence of this salinity signal north of line 110 as shown by Durazo and Baumgartner (2002) who noted that the salinity signal originated south of line 120 and was transmitted northward over the region through poleward flows concentrated along the coast.

The inverse correlation between temperature and salinity anomalies over the period from 2000 through 2005 suggests that the dominant climate forcing was related to the changing intensity of regional upwelling of cool, and more saline subsurface water relative to the surface water. In this case the role of lateral horizontal advection and displacement of contrasting types of water is subordinated to vertical uplift of higher density water (lower temperatures and higher salinity) from the same water mass (Subarctic Water) of the California Current. We also note that the salinity anomalies are more coherent in the northern and central areas, and strengthen somewhat from lines 100 south to line 120 (Fig. 7), whereupon they become less organised and more discontinuous south of line 123. This suggests a slight strengthening of a coherent upwelling signal extending from northern Baja California into central Baja California, with the coherence decaying southward from line 123 to line 137. The decay in coherence south of line 123 is also likely to be due to the increasing influence of Subtropical Surface Water in this area. This is consistent with the regional pattern of primary productivity associated with seasonal upwelling shown by Espinoza-Carreon *et al*. (2004) that is also mirrored to some extend in the pattern of chlorophyll and zooplankton concentrations off Baja California in Figure 4a,b.

This interpretation of the importance of the role of variable upwelling rates as the dominant mechanism for the change in the salinity anomalies is supported by the contrasting intensities and patterns of Ekman transport over the California Current south of 40°N as shown by Figure 8 for the spring of 2001 and spring 2004, the two periods that roughly represent the times of mature development of the positive and negative salinity anomalies in Figure 6 and 7. The positive salinity (associated with cooler temperatures) can be explained by the response to stronger upwelling over the entire region of the California Current driven by elevated offshore Ekman transport in the period of 2000-2002. The transition to a negative salinity anomaly after mid-2002 (associated with generally positive temperature anomalies over the region) is consistent with a relaxation of the upwelling intensity that would be associated with the reduction

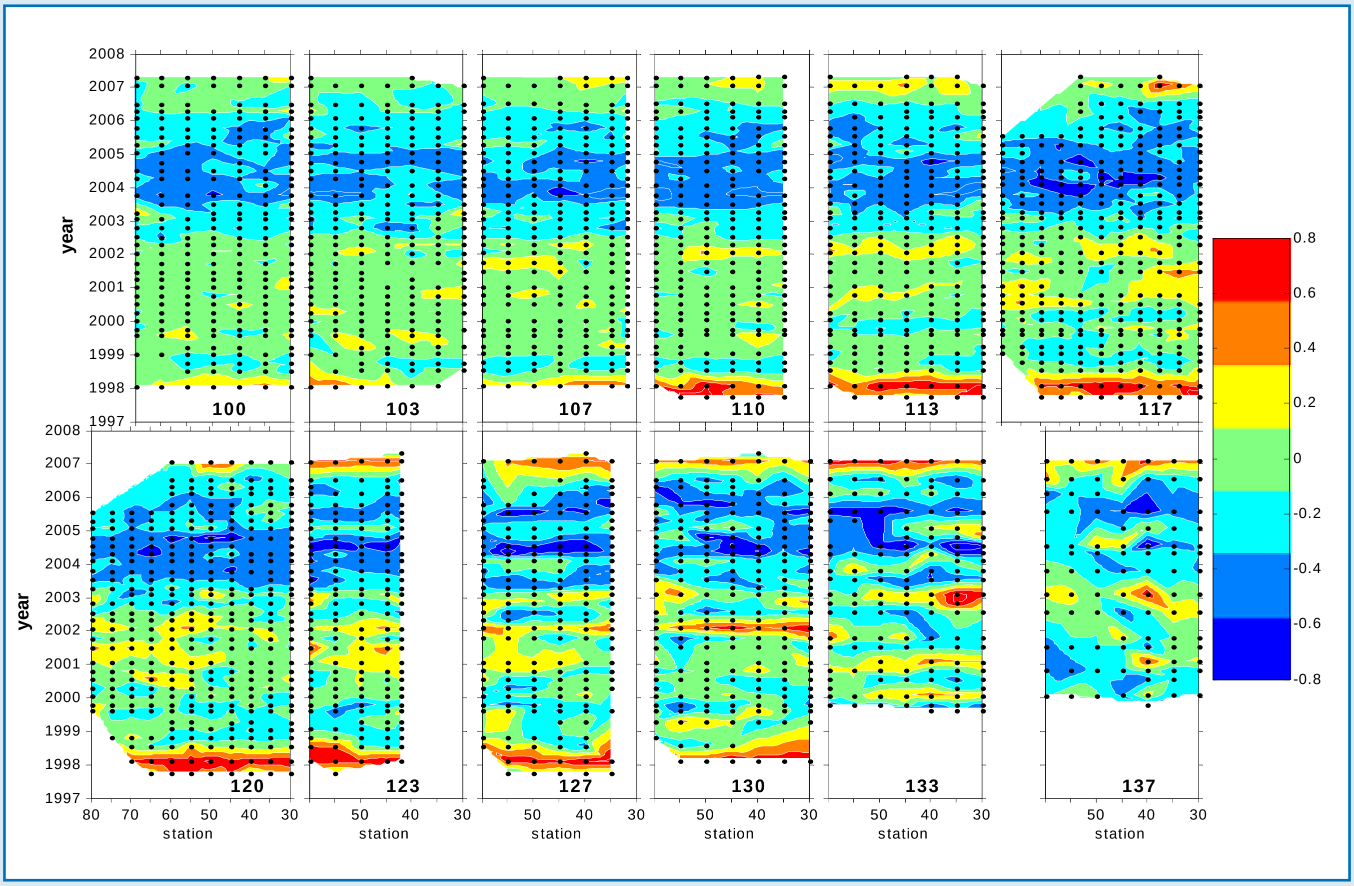

Figure 7. Evolution of salinity anomalies at 30 m depth along the lines of the IMECOCAL sample grid (cf. Fig. 1a and Fig. 2). Data plotted as quarterly samples corresponding to the line numbers and stations occupied between October 1997 and April 2007.

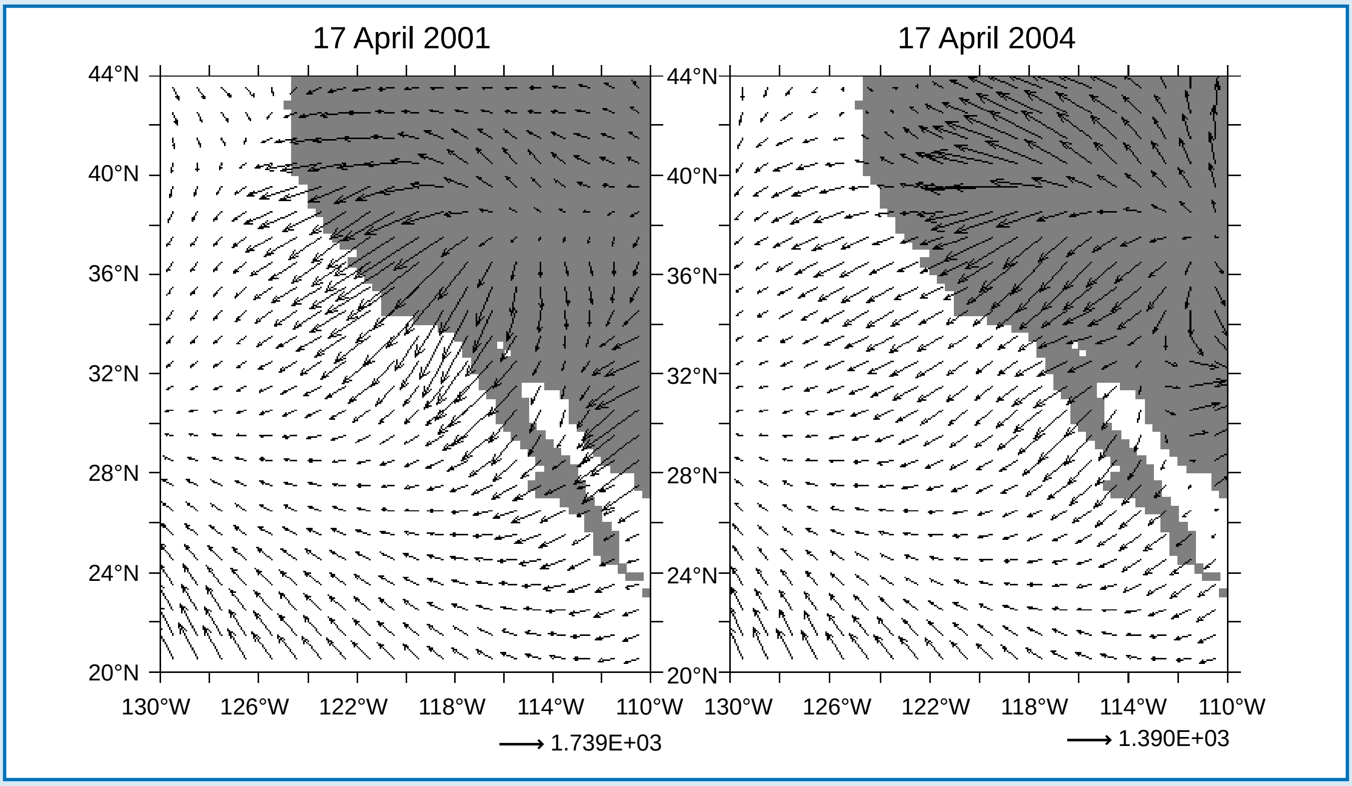

Figure 8. Ekman transport vectors over the region of the California Current, for April 2001 and April 2004, obtained from winds derived from the surface pressure fields by FNMOC. Plots were taken from Live Access Server of the NOAA/SWFSC/ERD internet site at: http://las.pfeg.noaa.gov/las6_5/servlets/dataset

in Ekman transport between the end of 2002 and 2006 (Fig. 8). This shift in physical dynamics came as a consequence of change in the structure and intensity of the regional wind field related to shifting patterns of atmospheric pressure. This change in the pressure field was presumably a response to atmospheric teleconnections from the tropics that transmitted the effects of the transition from the prolonged *La Niña* type state to the prolonged *El Niño* conditions in the tropics between 2000 and 2006.

The importance of the change in the intensity of Ekman transport to the ecosystem structure off Baja California can be appreciated by comparing the change in relative distribution and character of the spawning habitats of two small pelagic fish species off Baja California between the spring of 2002 and spring of 2003 presented in Figure 9. This figure compares the spawning distribution of sardines (*Sardinops sagax*) with Jack mackerel (*Trachurus symmetricus*) from CUFES samples taken on IMECOCAL cruises in these two years that bridge the shift in ocean conditions (*cf.* monthly PDOI, Figure 3 and salinity anomaly in Figure 6 and 7. The spawning habitat of the Jack mackerel is normally found offshore in more oceanic waters than those occupied by the sardine which prefers the transitional habitat between the coastal and oceanic waters. Figure 9 shows that egg distributions of *Trachurus* were compressed much further into the coast in 2003 than in 2002. Likewise, sardine eggs were more widely distributed (at higher concentrations) along the coastal margin and further offshore in 2002 than in 2003. During 2002 the eggs of the northern sardine stock extended southward to the area off central Baja California associated with the equatorward penetration of the Subarctic Water carried by the California Current. During 2003 the egg concentrations of the northerly "subarctic" sardine stock were dramatically reduced and were shifted northward as shown in Figure 9. Note that the grouping of sardine eggs around Punta Eugenia (~28°N) and occurrences further south in 2003 belonged to the southern stock associated with water in southern extent of the California Current where it is strongly modified by the mixing with Subtropical Surface Water. Eggs of this stock were not observed during 2002.

Surface flow fields off Baja California during these two cruise periods (Fig. 10) indicate roughly 25% stronger equatorward flow of the California Current during spring of 2002 relative to the spring of 2003. The stronger flow during 2002 is characterised by an intense jet south of 30°N. The stronger Ekman transport plus the intensified flow of the California Current would maintain the oceanic water (and spawning habitat of *Trachurus*) further offshore as observed during 2002 while favouring the sardine spawning in the transitional frontal zone between the coastal water influenced by upwelling and the warmer, more stable oceanic water offshore. Relaxation of the Ekman transport and diminished intensity of equatorward flow in 2003 would have allowed a broad front of offshore oceanic water to converge shoreward and to reduce the width of the coastal zone off northern Baja California as observed in 2003. This would have brought the more oceanic habitat favoured by *Trachurus* into the coastal zone at the same time the sardine habitat was substantially reduced by displacement to the north.

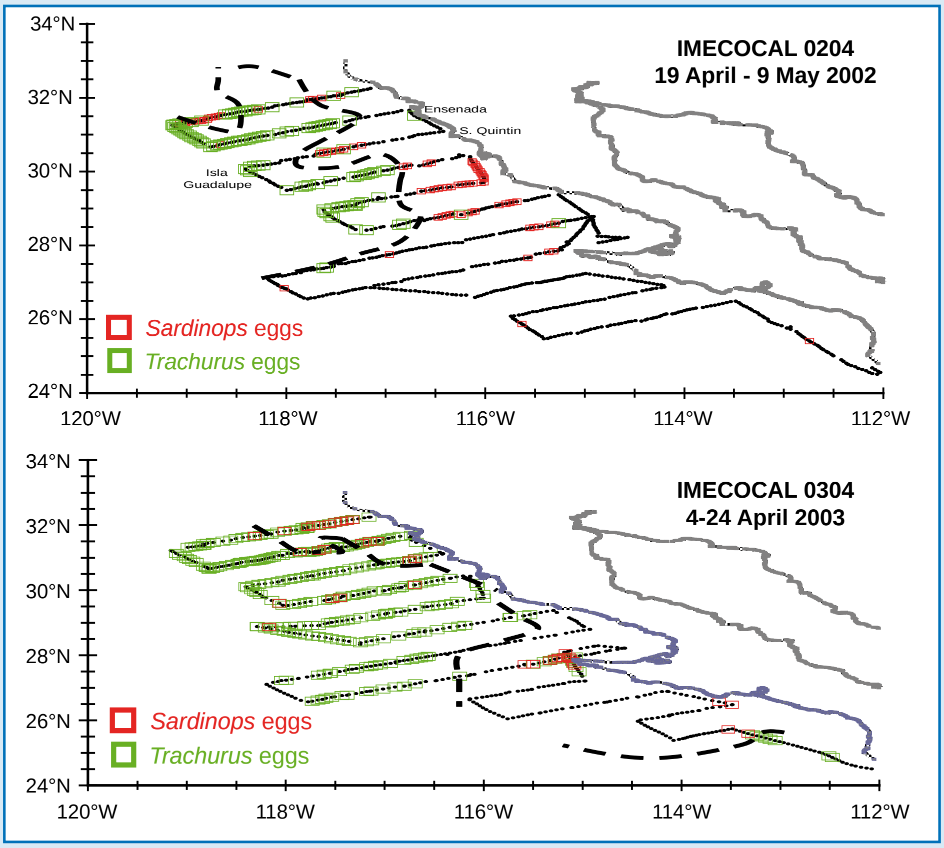

*Figure 9. Comparison of the spawning distribution of sardines (*Sardinops*, open red squares) and Jack mackerel (*Trachurus*, open green squares) collected by CUFES on IMECOCAL cruises during the springs of 2002 and 2003. The heavy black dashed curve marks the transitional boundaries between the spawning habitats of the two species in each year. Note the intrusion of the *Trachurus* habitat into the coastal area off northern Baja California in 2003 compared to 2002. The coastal-oceanic transitional habitat is normally preferred by the spawning sardines which were apparently displaced northward during April 2003 by compression of more oceanic habitat toward the coast.*

Returning to Figure 6 with the indicator series of the physical and biological states of the ecosystem, we can now consider the implications of the strong similarity in the variability of the zooplankton biomass and the chlorophyll concentrations, particularly by focusing on the longer-term, decadal scale change in the character of the two series. At this longer-term scale the two series are clearly negatively correlated suggesting that variability of the regional mean phytoplankton biomass is related to the regional zooplankton biomass through top-down control by predation of zooplankton on the phytoplankton.

It is important to recognise, however, that this inverse relationship between biomass of zoo- and phytoplankton is embedded within the physical dynamics of the system, such that the prolonged period of elevated phytoplankton biomass (and reduced zooplankton biomass) occurred with the enhanced offshore Ekman transport (*cf.* Figs. 8, 9 and 10) and upwelling (the period of positive salinity anomaly in Figure 6). The increase in zooplankton biomass that accompanied the reduced phytoplankton biomass occurred during the period of diminished Ekman transport and general relaxation of upwelling and reduced alongshore geostrophic flow after 2002. Thus the physical dynamics may play some direct role in regulating ecosystem structure and function by influencing factors like encounter rates between predator and prey, that would be linked to growth and survival of the zooplankter predators, as a function of the rates of offshore and alongshore transport. Another important factor to consider is the effect of change in habitat properties in the transition between the contrasting periods of 2000-2002 and 2003-2005. This could produce two effects on community structure, the first being a change in the composition of the phytoplankton food source to effect a change in the structure and function of the zooplankton assemblage, and the second being the alteration of zooplankton composition with species more favourably adapted to the new habitat conditions replacing the original assemblage. What is now abundantly clear is that we can discount any simple linear and positive relationship between production of phytoplankton and the increase of zooplankton over the southern region of the California Current system (*cf.* relevant discussion in Lavaniegos *et al.*, 2002).

Comparison of the IMECOCAL collection of zooplankton biomass over the past 10 years to the CalCOFI data base that includes samples from the IMECOCAL region during its first three decades reveals not only the long-term trends in the southern region but also reveals the varying response of the CCE to long-term climate change as a function of latitude. Figure 11 demonstrates the regional differences in multidecadal change in the CCE. The series on the left of Figure 11 portray the magnitude of change in the absolute biomass of zooplankton in the four principal regions of the California Current south of 40°N. These biomass series are presented as the log values of the mean displacement volumes from the sampling lines (see figure legend) that represent seasonal (quarterly) resolution of the variability in the four regions. Only nocturnal values were used in the plots since these are the most complete data set available over the entire region and are not biased by diel vertical migration. The absolute values on the left

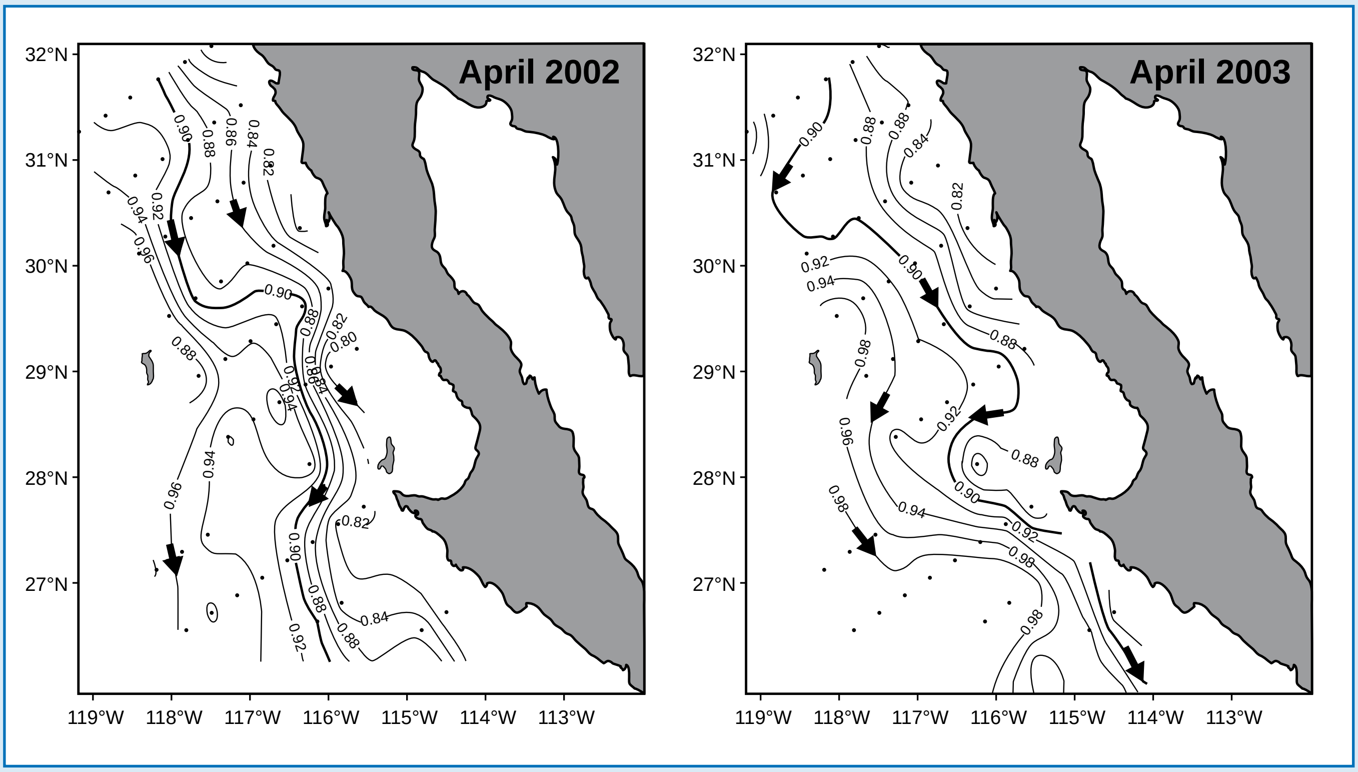

Figure 10. Pattern and intensity of surface geostrophic flows off Baja California during spring 2002 and 2003, depicted by contours of dynamic heights (0/500 mb) from April IMECOCAL surveys.

side are plotted as the mean values with the 95% confidence intervals indicated by the vertical bars. The panels on the right side of Figure 11 contain the plots of the biomass anomalies calculated as the deviation from the seasonal mean values. With the effects of the annual cycle removed, the anomaly plots more clearly demonstrate the long term changes and resolve the shorter term interannual variability. Note that the only region that has been continuously sampled is the core region of CalCOFI off Southern California. The sampling in the northern Baja California region extends through 1985 (as opposed to that shown by the history of sampling on Figure 2). This is because CalCOFI continued sampling on lines off northern Baja California into the mid-1980s.

The most striking feature of this interregional comparison is the dramatic difference in the trends of the biomass anomalies in the past ten years between the two regions off Baja California and the two regions off California. They are essentially opposed to one another. The northern region off central California exhibits the highest absolute values of zooplankton biomass in the first three decades of sampling, while the samples available in the last twenty years indicate that the biomass there has fallen to levels similar to that in the adjacent region off southern California. The absolute biomass in the two regions off Baja California was lower than off southern California in the early period of sampling, however the reversed trends between the two Californias in the past ten years has brought them into near parity. Roemmich and McGowan (1995) reported the decline in zooplankton biomass off southern California (the trend seen in Figure 11) relating it to the effects of ocean warming and resulting increased stability that would lower nutrient supply to the euphotic zone and reduce primary production. However, Lavaniegos and Ohman (1999) argued that the decline in biomass was more likely due to a change in species composition leading to a reduction in gelatinous forms.

Another important feature of the combined anomaly series of zooplankton biomass in Figure 11 is the latitudinal variability in the response to the ENSO cycle associated with the 1957-59 *El Niño* event. The effect on the biomass can be clearly traced from the region off central Baja California into southern California, but then is difficult to detect off central California. The response to this *El Niño* off central Baja California was very abrupt and lasted for almost 5 years. The responses during this period are less intense and of shorter duration the further north we look, so that the response off central California appears to be masked by higher frequency variability that appears unrelated to the remotely forced *El Niño* signal, but this could also be an artifact of the poorer resolution due to reduced continuity of the sampling in the north. It is interesting to note that the 1982 *El Niño* appears to be more clearly represented in the anomaly series off central California and is also evident off southern California, but is not well represented in the biomass anomalies off northern Baja California where the sampling covered this event.

Finally, one of the more important features to recognise in Figure 11 is the dramatic change in the response to ocean warming events or trends that is found in both of the zooplankton biomass

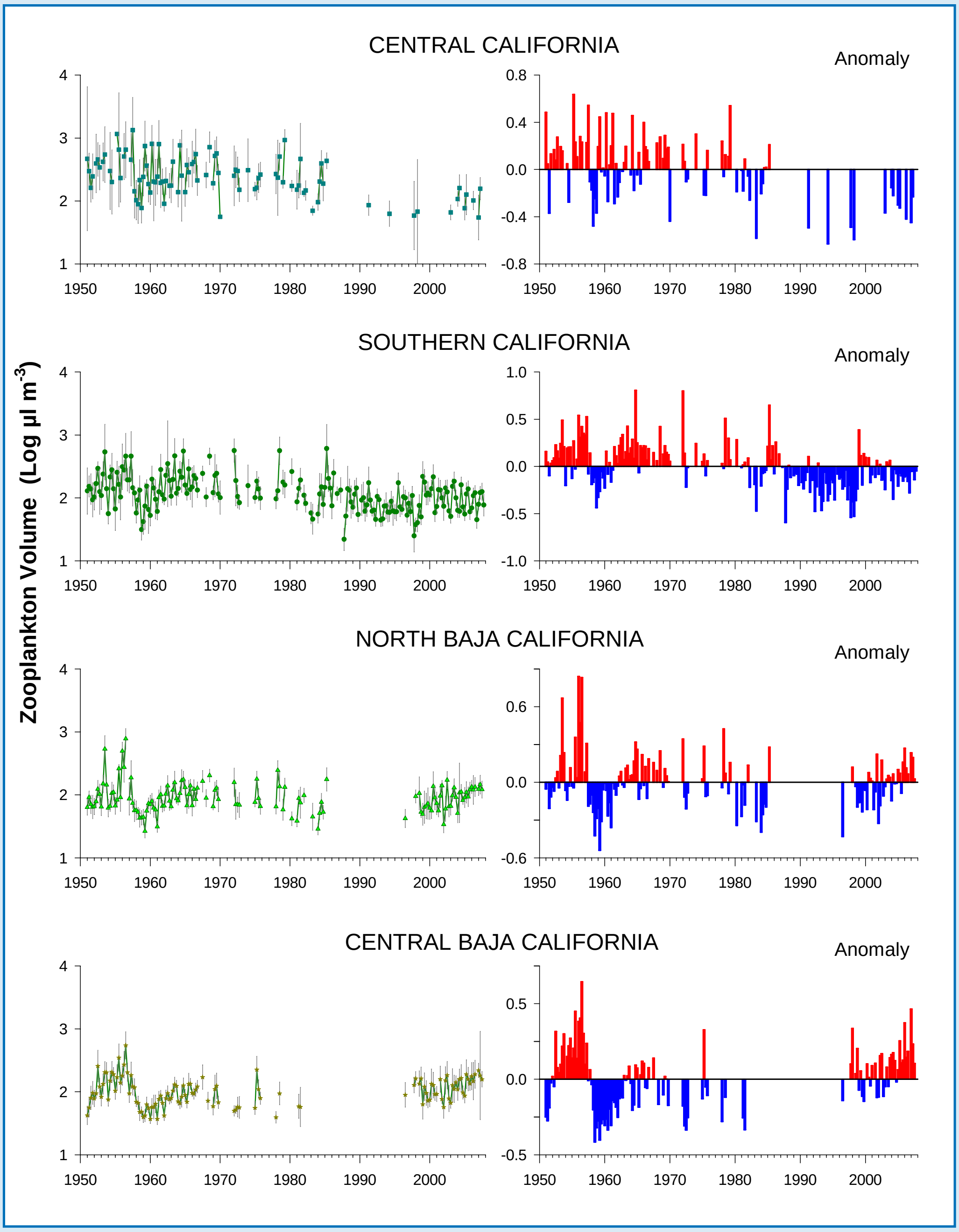

Figure 11. Comparison of series of zooplankton biomass in the California Current indicating regional differences in the long-term change, from the CalCOFI and IMECOCAL databases (cf. Fig. 2). The four regions represented are: Central California (lines 60-70; 36°-38°N), Southern California (lines 80-93; 32.5°-34.5°N), Northern Baja California (lines 97-110; 30°-32°N), and Central Baja California (lines 113-117, 25.5°-29.5°N). The panels on the left show the logarithm of the quarterly values of mean biomass levels (with 95% confidence interval) over the corresponding lines. The panels to the right show the plots of the corresponding series of biomass anomalies obtained by removing the seasonal (quarterly) means from the values.

anomaly series off Baja California. The anomalous increase in biomass associated with the 1997-98 *El Niño* event plus the trend of increasing biomass anomalies off northern and central Baja California in the past 10 years of IMECOCAL data represents an opposite response to warming that was observed from the CalCOFI sampling during the 1957-59 warming event. This dramatic shift in the zooplankton community response to ocean warming has occurred since the end of the 1960s and reflects the nature of the change in the biogeographic affinities of the majority of species, from an assemblage comprised of predominantly Subarctic forms during the cool regime prior to the mid-1970s (*cf.* Fig. 3) to one in which tropical and warm oceanic forms are becoming ever more dominant. The lack of a clear signal in the zooplankton response to the 1982-83 *El Niño* off northern Baja California indicates that the transition in the zooplankton composition began to occur soon after the beginning of the warm regime (indicated by the switch in the PDOI in Figure 3). It is also interesting to consider that the combination of the switch to a warm regime in the mid-1970s, plus the additional effect of the large-scale ocean warming due to the greenhouse effect, has resulted in less favourable habitat for the Subarctic species even as far north as central California.

The past ten years of IMECOCAL monitoring has provided the observations needed to evaluate the linkage between regional changes in the physical and biological processes in the pelagic ecosystem and climate forcing over interannual to decadal scales. This enables us to propose explanations for the dominant physical processes as a guide to exploring the mechanisms that are altering distributions and abundances of the species assemblages of zooplankton and small pelagic fish and to draw some preliminary conclusions on the complex interactions among trophic levels that are mediated by physical processes. Together with the CalCOFI observations initiated almost 60 years ago, the IMECOCAL data reveal that the ongoing dramatic changes began to affect the ecosystem structure throughout the central and southern regions of the CCE beginning in the late 1950s or perhaps somewhat earlier as detected in analysis of change in the foraminifera species preserved in the coastal sediments off southern California (Field *et al.*, 2006). The difference in regional responses in zooplankton biomass and species composition between the central and southern regions of the California Current appear to be consistent with large-scale habitat modification over the entire ecosystem by long-term ocean warming.

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Legacies of the US GLOBEC programme: managing fisheries and protected species

Elizabeth Turner

US GLOBEC Programme Manager, NOAA Center for Sponsored Coastal Ocean Research, Silver Spring, USA

The US GLOBEC programme has been ongoing, with funding from the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), since 1991. The objective of US GLOBEC research is to understand the basic mechanisms through which climate change affects target species and their associated prey and predators, based upon studies of key processes, large-scale observational programmes using advanced observational systems, and new information extracted from long-standing programmes and data sets (http://www.usglobec.org/).

GLOBEC was conceived and implemented as a basic research programme relating climate change to marine animal populations. Indeed, over the course of the programme, US GLOBEC has produced an impressive body of research results, reported in over 600 individual peer-reviewed publications to date (http://www.usglobec.org/papers.php). In addition, numerous special issues of major scientific journals have highlighted US GLOBEC research results (http://www.usglobec.org/issues.php).

In addition to its success as a basic research programme, the US GLOBEC programme has begun to provide the scientific underpinnings for sound management of marine ecosystems. In particular, GLOBEC results and products now enable transitioning to a wide variety of operational tools for managing marine resources in an ecosystem context.

The first example of this transitioning is the use of a circulation model developed under the GLOBEC Georges Bank programme to evaluate the effectiveness of closed areas as a scallop management strategy on Georges Bank. GLOBEC models were used in 1998 to predict the trajectories and settlement patterns of larval scallops. These results were presented to the New England Fisheries Management Council, and to the (then) Secretary of Commerce Daley to inform and provide background for decisions on the reopening of closed areas to scalloping. Key locations within the existing closed areas were identified as important source areas for scallop larvae including a designated Habitat Area of Particular Concern in Closed Area 2.

In the California Current programme, several monitoring lines were set up during the field research. One of these, the line off Newport, Oregon has proven to be a valuable indicator of ocean conditions that influence returns of ocean going fish stocks. This has garnered operational support from the NMFS Stock Assessment Improvement programme, which is now supporting the Newport biweekly time series.

GLOBEC scientists were instrumental in the writing of a document that summarised the broader ecosystem interactions and dynamics of krill in the California Current. This review led to a Pacific Fisheries Management Council decision to ban the harvest of krill (http://www.pcouncil.org/cps/cpskrill.html). More recently, US GLOBEC scientists were awarded a NOAA Bronze Medal for developing a web-based description of eleven ocean productivity indicators which enable forecasts of west coast adult salmon returns six months to one year sooner than previous techniques (the Bronze Medal is the highest NOAA honour award that can be granted by the Under Secretary of Commerce for Oceans and Atmosphere; see GLOBEC International Newsletter 14(1): p.18). Forecasts of coho and Chinook salmon returns are posted on the website (http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/g-forecast.cfm) of the Northwest Fisheries Science Center, a partner in GLOBEC research. Analyses of ocean conditions and their impacts on salmon populations have recently been presented to the Pacific Fishery Management Council, and included in their 2008 deliberations on limiting or closing salmon fishing along the Oregon and California coasts (see accompanying discussion on page 58).

US GLOBEC support was essential for establishing the Southeast Alaska Coastal Monitoring (SECM) project of NOAA/NMFS Auke Bay Laboratories. The SECM has focused on oceanographic and biological factors affecting the growth and survival of southeast Alaska juvenile pink and coho salmon entering the Gulf of Alaska. Scientists from NOAA/NMFS and the Alaska Department of Fish and Game (ADFG) are now using information from the monitoring programme to develop prediction models for pink salmon returns to southeast Alaska, and the ADFG has incorporated SECM data into its current region-wide forecast.

Through the GLOBEC Northwest Atlantic programme, and later, the Center for Sponsored Coastal Ocean Research (CSCOR) Synthesis and Forecasting programme, links were identified between the North Atlantic Oscillation (NAO) Index, deep water temperatures in the Gulf of Maine, and the abundance of the Gulf's dominant zooplankton species, the copepod *Calanus finmarchicus*. As a result of this research, the Gulf of Maine Ocean Observing System (GoMOOS; http://www.gomoos.org/) has developed an operational system to predict temperatures at Buoy N from the NAO, and from the predicted or observed temperatures to forecast *Calanus* abundance. From the *Calanus* data, the number of right whale births can also be predicted (http://www.gomoos.org/environmentalprediction/index.html).

Detailed information about *Calanus* collected throughout the GLOBEC Northwest Atlantic programme has been used to relate their distribution and abundance to temperature data sensed remotely from satellites. Because *Calanus* serves as a dominant food source for right whales, *Calanus* abundance maps can used to estimate the presence of right whales in key habitats in the region. These satellite-based forecasts became operational through GoMOOS in Spring 2008. The forecasts provide analyses to NOAA's aerial survey team that allow them to improve the efficiency and safety of their right whale surveys to assist in the conservation of this endangered species.

GLOBEC is recognised internationally as a source of information on fish recruitment and variability in oceanographic processes. Both the International Council for the Exploration of the Sea (ICES) in the Atlantic, and its counterpart in the Pacific (North Pacific Marine Science Organization, aka PICES), have used GLOBEC scientists and results in responses to governmental requests for information. An example is a recent report for PICES on "Fisheries and Ecosystem Response to Recent Regime Shifts" (see http://www.pices.int/publications/scientific_reports/Report28/Rep_28_default.aspx). GLOBEC scientists also contributed greatly to the PICES Ecosystem Status Report, at http://www.pices.int/projects/npesr/default.aspx

These are just a few examples of how US GLOBEC has begun to provide practical tools for the management of marine resources. Additional transitioning of research results to operational application is anticipated during the final pan-regional phase of US GLOBEC, presently underway.

Ocean ecosystem indicators of salmon marine survival in the northern California current

NOAA Northwest Fisheries Science Center

http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm

The NOAA Northwest Fisheries Science Center has collected physical and biological ocean data during research cruises made since 1996 to study the coastal upwelling ecosystem off the Pacific Northwest (Fig. 1). Using these data, we have developed environmental indicators to provide forecasts of salmon returns based on ocean ecosystem indicators. These forecasts are presented as a practical example of how ocean ecosystem indicators can be used to inform management decisions for endangered salmon. At this time, the forecasts are qualitative in nature: we rate each in terms of its "good," "bad," or "neutral" relative impact on salmon marine survival (Table 1). We use a suite of indicators, which complement existing indicators used to predict adult salmon runs, such as jack returns, smolt–to–adult return rates, and the Logerwell production index. The strength of this approach is that biological indicators are directly linked to the success of salmon during their first year at sea through food–chain processes. These biological indicators, coupled with physical oceanographic data, offer new insight into the mechanisms that lead to success or failure for salmon runs.

	Juvenile migration year				Forecast of adult returns	
	2000	2005	2006	2007	Coho 2008	Chinook 2009
Large-scale ocean and atmospheric indicators						
Pacific Decadal Oscillation (PDO)	blue square	red square	red square	yellow square	yellow dot	yellow dot
Multivariate El Niño Southern Oscillation Index (MEI)	blue square	red square	yellow square	blue square	blue dot	blue dot
Local and regional physical indicators						
Sea surface temperature anomalies	blue square	red square	yellow square	red square	red dot	red dot
Coastal upwelling	blue square	red square	yellow square	blue square	blue dot	blue dot
Physical spring transition	blue square	red square	blue square	yellow square	yellow dot	yellow dot
Deep water temperature and salinity	blue square	red square	yellow square	blue square	blue dot	blue dot
Local biological indicators						
Copepod biodiversity	blue square	red square	red square	yellow square	yellow dot	yellow dot
Northern copepod anomalies	blue square	red square	red square	blue square	blue dot	blue dot
Biological spring transition	blue square	red square	red square	blue square	blue dot	blue dot
June spring Chinook	blue square	red square	yellow square	blue square	--	blue dot
September Coho	blue square	red square	yellow square	red square	red dot	--

Key: blue square good conditions for salmon; yellow square intermediate conditions for salmon; red square poor conditions for salmon; blue dot good returns expected; -- no data; red dot poor returns expected

Table 1. Ocean ecosystem indicators of the Northern California Current. Colored squares indicate positive (blue), neutral (yellow), or negative conditions (red) for salmon entering the ocean each year. In two columns to the far right, coloured dots indicate the forecast of adult returns based on ocean conditions in 2007.

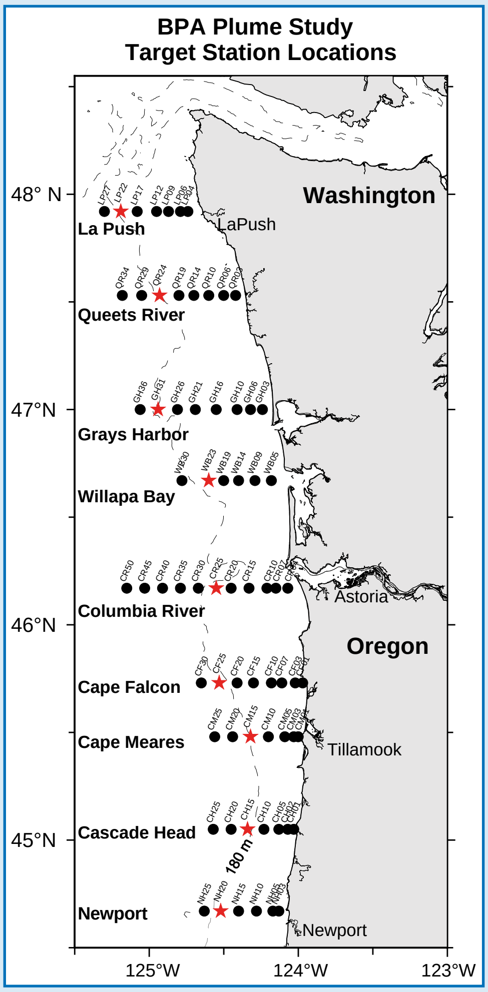


Figure 1. Stations sampled in June and September during juvenile salmon surveys. The sampling has been ongoing since June 1998. The Newport line (at the southern end of the grid) has been sampled every two weeks since 1996.

Tommy Dickey awarded prestigious Naval Oceanographic Services Chair

Tommy Dickey, Naval Oceanographic Services Chair

Tommy Dickey, a founder member of the GLOBEC Scientific Steering Committee, is one of only two leading scientists to have been awarded a prestigious Secretary of the Navy and Chief of Naval Operations Chair in Oceanographic Sciences. The Office of Naval Research Program recognises pioneering academic leaders in oceanography with collaborations across scientific disciplines. Tommy was influential in the early development of GLOBEC and organised and chaired a meeting in 1993 on Sampling and Observational Systems at the Intergovernmental Oceanographic Commission in Paris from which GLOBEC Report No.3 was produced.

Tommy, a professor in the Department of Geography, is principal investigator of the University of California, Santa Barbara's (UCSB) Ocean Physics Laboratory. His primary research interest is interdisciplinary oceanography, with an emphasis on upper ocean dynamics and bio-optical variability. He has used new technologies in the deployment of physical, chemical, biological, and optical instrumentation on autonomous platforms in coastal and deep open-ocean settings around the world. The recorded data are returned by satellite communication. This innovative research has spanned and linked the sub-disciplines of physical, optical, geological, chemical, and biological oceanography and has led to new interdisciplinary observational capabilities that have vastly increased the number of measurable variables and expanded observable time and space scales. Tommy has also been one of the leaders in the development of bio-optical oceanography, an area of special interest to the Navy.

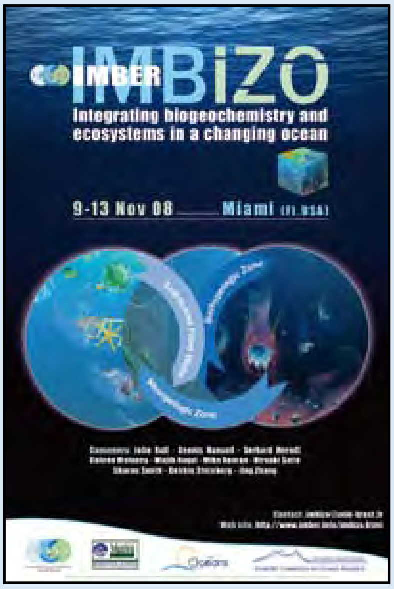
"This award represents a significant milestone in my career here at UCSB," said Tommy. "It will enable me to pursue additional research and perform advanced analyses and observations that I would not otherwise be able to do. In addition, I plan to complete a second textbook, this one on the applications of optics for oceanography."

With the federal support, Tommy and his research team will explore ocean responses to hurricanes, mesoscale eddies, and optical variability forced by ocean dynamics. As part of the ocean optics portion of the project, he will be leading an Office of Naval Research Program that will conduct field experiments in the Santa Barbara Channel later this year and in the Pacific Ocean off of the Hawaiian Islands in 2009.

Tommy received his PhD from Princeton University in geophysical fluid dynamics and has been a member of the UCSB faculty since 1996. A fellow of the American Geophysical Union, he has served as an editor for six scientific journals and has led six major multi-institutional ocean research programmes sponsored by the Office of Naval Research.

The Office of Naval Research Program was established by the Secretary of the Navy and the Chief of Naval Operations in 1984 to reinvigorate Naval oceanography. The research chair, a lifetime appointment, is awarded to two distinguished oceanographers every four years. Recipients also serve as advisors to the Chief of Naval Research.

Thomas Sanford, professor of oceanography at the University of Washington, was also awarded a Naval chair this year. Past recipients include UCSB alumnus Robert Ballard, discoverer of the Titanic and scientist emeritus from the Woods Hole Oceanographic Institution; Walter Munk of the Scripps Institution of Oceanography at UC San Diego; and other luminaries in the field.



First IMBER IMBIZO: Integrating biogeochemistry and ecosystems in a changing ocean

IMBIZO is a Zulu word that means "gathering" or "meeting". IMBER will conduct a series of IMBIZO's over the next decade, with the first gathering planned for 9-13 November 2008 in Coconut Grove, Miami, Florida.

The IMBIZO's innovative format of three concurrent and interacting workshops with joint plenary and posters sessions will provide a forum for stimulating discussion between interdisciplinary experts and encourage the linkage between biogeochemistry and ecosystem research.

The three concurrent workshops cover the topics:

- **End-to-end Food Webs (co-chaired by Coleen Moloney and Mike Roman)**
- **Mesopelagic (co-chaired by Debbie Steinberg and Hiroaki Saito)**
- **Bathypelagic (co-chaired by Dennis Hansell and Gerhard Herndl)**

Knowledge and research on Chilean fisheries resources: diagnosis and propositions for a sustainable development

Eleuterio Yáñez[1] (eyanez@ucv.cl), Exequiel González[1], Héctor Trujillo[1], Luis Cubillos[2], Samuel Hormazábal[2], Lorena Álvarez[1], Alejandra Órdenes[1], Milton Pedraza[2] and Gustavo Aedo[2]

[1]Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile

[2]Universidad de Concepción, Concepción, Chile

The Chilean fisheries are in great and urgent need of systematising both information and knowledge to design and implement a fisheries research programme in support of fisheries management. The objectives of this project (Yáñez *et al*., 2007) were: 1) to develop a knowledge matrix of main fishing resources, 2) to conduct a comprehensive literature review upon which to base a diagnosis of the current state of knowledge on the main fishing resources of Chile, and 3) to propose a research programme in support of future management of these resources based on past experience and a prospective vision of fisheries management and related research.

This research was conducted under two premises: first, fisheries management and related research must contribute to the attainment of sustainable development of Chilean fisheries and second, effective fisheries management and research applies to a common language and framework leading to the cooperation between the government, the private sector and the public in general, in order to build political-social-economic feasibility for sustainable fisheries development. This approach, led to the use of a prospective vision base on systems representation of the fisheries activity and the consideration of four Clusters of Minimum Knowledge (CMK: oceanography, biology, technology and socio-economy) used to understand the structure and function of the fisheries system. A structural matrix analysis of the knowledge elements related to fisheries, based on Godet (1994), was conducted to estimate the driving-dependency level in the system and to identify the key driving forces in the Chilean fisheries system. A bibliographical analysis aimed to characterise the present status of fisheries research and knowledge was focused on 31 main species (grouped as fish, crustaceans, molluscs, echinoderms and algae), and conducted using a bibliographical database specially built following a literature review which included more than a thousand references. A comparative analysis of the resulting matrix of key-knowledge elements deemed necessary for Chilean fisheries management and the results of the bibliographical analysis enabled the identification of coincidences and gaps in information and knowledge on fisheries research in Chile.

Results of the structural matrix analysis showed the existence of 61 key-knowledge related elements of fisheries and fisheries management. The analysis also showed that these key-knowledge elements are grouped by required CMK, where 28% pertain to the oceanography cluster, 13% to the biology cluster, 25% to the technology cluster and 33% to the socio-economic cluster (Fig. 1). In addition, the matrix analysis allowed us to classify the key-knowledge elements into those pertaining to the power zone as drivers of the system (independent variables) and those pertaining to the conflict zone as the linkage variables in the system (Table 1).

Table 1. Key forcing knowledge for sustainable development of the main fishing resources of Chile

Power zone (drivers)	Conflict zone (linkage)
Oceanography	
1) Tide 2) Swell 4) Coastal currents 5) Circulation of great scale 10) Rossby waves 21) ENSO 22) Regime shift A) Storm E) Wind	6) Coastal circulation 9) Turbulence 11) Vertical and horizontal gradients 14) Mesoscale structure 15) Productivity plankton
Biology	
	27) Distribution, abundance and population
Technology	
44) Catchability coefficient 64) Type of product	47) Fishing effort 49) Catch
Economy	
AG) Subsidies 103) Final product demand 126) Discount rates	AH) Marginal user cost from resource AI) Marginal user cost from ecosystem 97) Social marginal cost from externalities 119) Use level

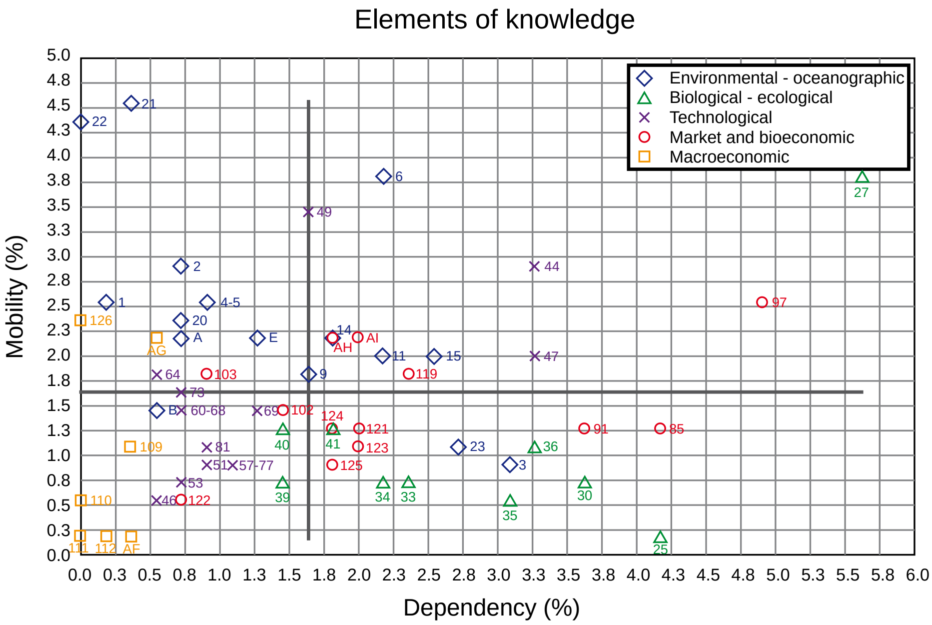


Figure 1. Cognitive system's knowledge elements driver dependence forcing power.

Elements	Xiphias gladius	Trachurus murphyi	Sardinops sagax	Clupea benticki	Engraulis ringens (north)	Engraulis ringens (south)	Merluccius gayi gayi	Merluccius australis	Macruronus magellanicus	Micromesistus australis	Genypterus blacodes	Dissostichus blacodes	Epigonus crassicaudus	Hoplosthetus atlanticus	Beryx splendens	Raja chilensis	Isurus oxyrinchus	Priorace glauca	Lithodes santolla	Jasus frontalis	Heterocarpus reedi	Cervimunda johni	Pleucorondes monodon	Concholepas concholepas	Loxechinus albus	Mesodesma donacium	Gari solida	Fissurella cumingi	Thais chocolata	Macrosystis sp.	Durvilea antarctica
Tide	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Swell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Coast current	0	2	2	2	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0
Large scale circulation	0	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coastal circulation	0	10	12	12	16	10	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	2	0
Turbulence	1	3	2	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Mesoscale structure	0	2	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rossby waves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENSO	2	8	7	7	9	3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	2	0	0	1	0	3	0
Regime shift	0	1	2	2	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Storm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	1	4	2	2	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Planktonic productivity	1	3	3	3	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Vertical and horizontal gradients	10	39	22	22	36	17	10	3	1	0	0	0	0	0	0	0	0	0	0	0	1	2	6	7	2	1	0	1	0	1	0
Distribution, abundance and population structure	20	95	42	42	57	31	48	23	17	8	9	20	2	9	0	3	1	1	9	5	18	19	28	35	19	9	1	8	0	20	7
Catchability coefficient	12	30	12	8	12	8	19	9	8	8	9	12	0	6	0	4	2	1	11	3	10	8	6	12	5	4	1	2	0	3	1
Fishing effort	20	53	17	23	18	18	24	27	24	15	19	26	0	6	0	7	4	3	9	3	15	15	16	18	11	3	6	8	1	1	1
Catch	34	94	27	40	43	32	42	44	30	20	27	32	2	9	0	9	4	3	12	10	29	31	29	25	20	10	7	14	2	6	2
Type of product	1	39	8	3	0	2	10	6	3	1	2	5	2	2	0	3	0	0	2	0	4	1	2	3	1	3	1	0	1	1	1
Social marginal cost from externalities	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Final product demand	1	0	0	0	0	0	2	3	1	1	1	1	0	2	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
Use level	0	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0
Marginal user cost from resource	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginal user cost from ecosystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discount rates	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0

Figure 2. Matrix frequency of occurrence of key-knowledge by species. Green shading denotes biological elements, blue: oceanography, pink: technology and orange: economy (see Table 1).

Elements	Xiphias gladius	Trachurus murphyi	Sardinops sagax	Clupea benticki	Engraulis ringens (north)	Engraulis ringens (south)	Merluccius gayi gayi	Merluccius australis	Macruronus magellanicus	Micromesistus australis	Genypterus blacodes	Dissostichus blacodes	Epigonus crassicaudus	Hoplosthetus atlanticus	Beryx splendens	Raja chilensis	Isurus oxyrinchus	Priorace glauca	Lithodes santolla	Jasus frontalis	Heterocarpus reedi	Cervimunda johni	Pleucorondes monodon	Concholepas concholepas	Loxechinus albus	Mesodesma donacium	Gari solida	Fissurella cumingi	Thais chocolata	Macrosystis sp.	Durvilea antarctica
Tide								X	X		X													X	X	X	X	X	X	X	X
Swell																								X	X	X	X	X	X	X	X
Coast current							X				X					X			X		X	X	X	X	X	X	X	X	X	X	X
Large scale circulation	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X		X											
Coastal circulation	X	X	X	X	X	X	X	X	X	X						X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Turbulence			X	X	X	X	X	X	X	X	X			X	X															X	X
Mesoscale structure	X	X	X	X	X	X								X	X		X	X		X											
Rossby waves	X	X	X	X	X	X	X				X						X	X													
Rossby waves	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Regime shift	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
Storm		X																													
Wind			X	X	X	X	X	X	X	X									X	X	X	X	X			X	X				
Planktonic productivity			X	X	X	X	X	X	X	X	X		X				X							X	X	X	X	X			
Vertical and horizontal gradients	X	X	X	X	X	X											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Distribution, abundance and population structure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Catchability coefficient	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fishing effort	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Catch	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Type of product	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Social marginal cost from externalities	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Final product demand	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Use level	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Marginal user cost from resource	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Marginal user cost from ecosystem	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Subsidies	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Discount rates	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Figure 3. Research priority programme for fishing resources of Chile. Green shading denotes biological elements, blue: oceanography, pink: technology and orange: economy (see Table 1).

Results from the bibliographical analysis showed that the most relevant set of existing fisheries research documents refer to technical reports (40%) and thesis (34%). It also highlighted the small number of existing articles published in scientific journals. Results also showed that 91% of existing research conducted in Chile aims to obtain information and knowledge on environmental, biological and technical aspects of fisheries, only 9% of research aimed to generate information and knowledge on socio-economic aspects of fisheries.

Results from the comparative analysis showed that the frequency of occurrence found for each knowledge element associated to each species shows the relative importance of the element within the cognitive system. The biology (distribution, abundance and population structure) and the technology related cluster (catchability coefficient, effort, catch and type of product) were the most studied elements for all species whereas oceanography and economy were the less studied elements, mostly zero frequency of occurrence in the database (Fig. 2).

A scientific research priority programme for the main fisheries resources of Chile, showing aspects in need of continuous research and gaps in urgent need of being filled, was designed based on the previous results and complemented by expert judgement. According to this research programme driver elements pertaining to the biology, technology and socioeconomic knowledge clusters need to be carefully studied for all fisheries, while driver elements from the oceanography knowledge cluster need to be studied with a different emphasis for different species and groups of species (Fig. 3).

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Yáñez E., E. González, H. Trujillo, L. Álvarez, L. Cubillos, G. Aedo and M. Pedraza. 2007. Diagnóstico del estado del conocimiento de los principales recursos pesqueros de Chile. Informe Proyecto FIP 2005-25, 163pp.

Challenges for a new generation of marine ecosystem models:

Advances in Marine Ecosystem Modelling Research (AMEMR) Symposium, 23-26 June 2008, Plymouth UK

Jeremy C. Blackford

Plymouth Marine Laboratory, Plymouth, UK (jcb@pml.ac.uk)

Modelling has for a long time been an important tool for scientists of all disciplines providing a methodology for the testing of understanding, synthesis and prediction. For the largely inaccessible marine system in particular, modelling provides a vital extrapolation capability.

Whilst their rapidly increasing sophistication coupled with the evolving computational capacity can make models potentially very persuasive, there is equal potential to mis-inform as well as elucidate. Simultaneously the emerging appreciation of the complexity of marine systems at many scales delivers huge challenges to model based science. Concurrently, model based predictions for example addressing climate change are squarely in the public domain and many environmental managers are using models to aid their work. Thus models are becoming increasingly scrutinised and the onus is to develop models that are rigorous, demonstratively evaluated and in themselves understood. Clearly a 'model' can be mean many different things to different people, from precise replication to broad representation, from phenomenological models to process models, from simplistic to complex. Frequently poor definition of a given model's *raison d'être* and lack of consideration of its limitations lead to misconceptions and erroneous interpretation.

The AMEMR conferences (and associated workshops) were initially conceived to provide a forum for marine ecosystem modellers to discuss and share problems and solutions. At the first AMEMR conference, held in 2005, a number of key challenges to the modelling community were stated, namely:

- How do we balance increasing model complexity to represent all relevant processes with the subsequent increase in uncertainty in parameterisation?
- How can we enhance collaboration between modellers and experimentalists?
- How can we better evaluate, understand and reduce model errors?

The 2008 meeting, three years on, gave the community an opportunity to gauge progress and define a new set of key challenges.

The conference was attended by around 160 scientists with significant representation from the Americas, Australasia, and Asia as well as Europe and the UK. The entire meeting was held in plenary, a deliberate strategy to facilitate cross-disciplinary communication and fertilisation, although the number of quality abstracts submitted would have allowed parallel sessions, this would be contrary to the ethos of AMEMR. The conference comprised nine sessions over the four days covering climate related change, evaluation, operational models, complexity, processes, biodiversity, higher trophic levels, end to end ecosystems and environmental management.

Jerry Blackford (PML) giving his keynote presentation.

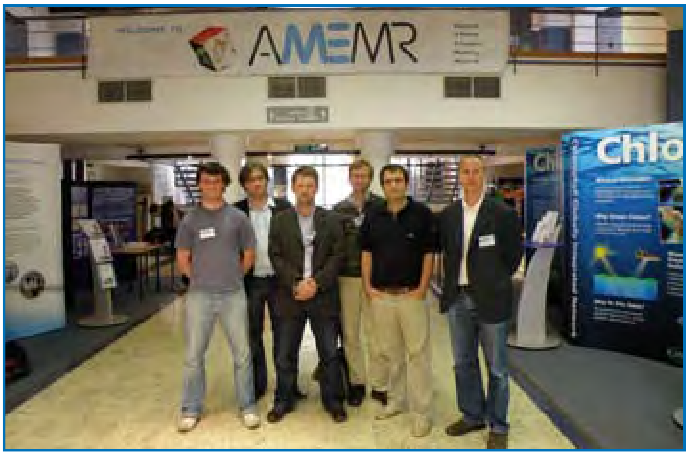
Eight keynote talks where featured during the meeting:

- Climate change and impacts: decades to centuries.
  Andreas Oschlies, IFM GEOMAR, Germany.
- The challenges of modelling ecosystem response to ocean acidification.
  Jerry Blackford, PML, UK.
- A global bio-economic approach of small pelagic fisheries.
  Christian Mullon, IRD, France.
- Novel modelling approaches to relate biodiversity of marine sediments to ecosystem functioning.
  Matthijs Vos, NIOO-KNAW, Netherlands.
- Complexity, food web theory, and marine ecosystem modelling.
  Mike St John, University of Hamburg, Germany.
- Modelling emergent biogeography.
  Mick Follows, MIT, USA.
- Approaches to end to end ecosystem models.
  Beth Fulton, CISRO, Australia.
- Coupling hydrodynamic, NPZ, and fish models: can the biology and people keep up with the computers?
  Kenny Rose, Louisiana State University, USA.

In addition we heard 60 further talks and saw 75 posters of a consistently high standard.

Three years between meetings is almost Olympian in time scale but does ensure that sufficient time is available for scientists to respond to challenges. In particular the magnitude increase in papers that seriously consider model evaluation is encouraging as are the

Poster displays at the conference.



Left to right: Rob Holmes, Icarus Allen, Jerry Blackford, Momme Butenschon, Luca Polimene and Patrick Stromberg from PML.

development in methods of treating complexity and generally a more considered approach to model interpretation. So what are the key challenges facing current model development?

Complexity remains perhaps the key challenge to the next generation of models. Much of the debate in the past has focussed on the continuum between NPZ and functional group models, the veracity of their process descriptions and the accuracy of parameterisations. Whatever the critique of individual models there is a hint that models of this type that are more complex (i.e. that avoid fixed stoichiometry or include more trophic links) perform better, but it is only a hint, the expected breakthrough to a model that performs well globally has not yet occurred (although the underpinning imperfect physical descriptions of regional and global systems remains an important factor).

So, if recreating contemporary observations remains a challenge, where does this leave predicting the future? Considering future response to high CO_2, whether within a coupled climate model or focussing on marine ecosystems, the potential for acclimation, adaptation, feedbacks and species shifts are poorly represented by the Newtonian approach. For example the shift from cold water to warm water calanoid species with their different phenologies in the north east Atlantic. Another example, particularly important when considering the impact of ocean acidification is that not all coccolithophores are the same nor may respond in the same way, so how should this diverse group be represented in models?

A common objection to increasing complexity in Newtonian type models is the definition and parameterisation of each new functional group, usually at best based on experiments on a minute handful of species or laboratory cultures that do not represent the mean of the functional group and cannot represent its diversity or plasticity. Another omission from many models is that of trophic structure, which in itself affords a degree of plasticity to a model system but it relies on a complex structure to provide the nodes between the links.

This suggests the question: are these thermodynamic or Newtonian approaches – characterised by energy and mass conservation fundamentally limited and is a different paradigm needed to help us explain and represent observed systems, moving away from over determined parameter formulations and process realism to more realistic structures (e.g. food webs). A relatively new class of models has a very appealing solution to defining model structure – let the model work it out, e.g. 'Darwinian' approaches such as complex adaptive systems and stochastically defined emergent systems. These have the advantage of conceptual simplicity, a sound physiological basis without undue constraint and the ability to create detailed structure.

Another recognition is that future states will be affected by multiple interacting drivers. Climate, weather, acidification, eutrophication and resource use are certain to alter. Some modelling work indicates that the possibility, for example, that impacts of acidification could be very sensitive to weather and climate. Hence a challenge emerges firstly to assess multiple driver impacts but also to get reasonable predictions of future weather patterns or human behavioural responses, both in themselves highly stochastic.

In listing emerging challenges, it is a common phenomenon that there is increasing pressure on scientists to deliver products that speak more directly to research users – policy makers and environmental managers. Policy makers in particular crave certainty, something that deterministic models apparently deliver but rarely can do so with much certainty. It is envisioned that probabilistic approaches based on scenario ensembles are more likely to deliver reliable information to policy makers, but this puts pressure on computational resources and analysis techniques. Thus the development of efficient and clever analysis methodology, (multivariate, Bayesian, neural nets etc.) is the final challenge listed here.

On a lighter note, during the meeting an informal competition for best student poster resulted in joint first prize being awarded to Letizia Tedesco and Lavinia Patara, both PhD students at CMCC Bologna each receiving a bottle of Plymouth Gin.

A special issue of the Journal of Marine Systems containing a selection of papers based on work submitted at the conference is in preparation and will be dedicated to the memory of Mike Fasham the eminent UK marine (modelling) scientist who sadly died shortly before the conference. The issue will edited by Icarus Allen and Jerry Blackford (PML), Tom Anderson (NOC), and Kenny Rose (Louisiana State).

Given the very positive feedback generated about the meeting it is our intention to organise a further meeting, probably around June 2011, again to give serious opportunities for paradigms to develop and mature. Clearly four straight days in the conference hall left most of us feeling somewhat drained, in 2011 the organisers undertake to include an afternoon off mid-conference to allow people to enjoy some of the amenities to be found in the Plymouth region.

Gales along the Cantabrian coast

Luis Ferrer (lferrer@pas.azti.es), Manuel González, Almudena Fontán, Julien Mader, Pedro Liria, Manel Grifoll, Ganix Esnaola and Adolfo Uriarte

AZTI-Tecnalia, Pasaia (Gipuzkoa), Spain

The coastal trapped disturbances, known locally as Gales (*Galernas*), are typical phenomena that take place along the northern coast of Spain. The Operational Oceano-Meteorological System established for the Basque Country, which combines data acquisition (6 coastal stations and 2 deep sea buoys, see Fig. 1) together with numerical modelling at several spatio-temporal scales, is able to detect such disturbances. Gales are defined as sudden and violent storms, with strong winds blowing from south to west, propagating along the Cantabrian coast from west to east. The arrival of a cold front is characterised by a sudden change of the wind direction and magnitude, which can rise above 100 km·h^{-1}; the sky gets dark and a strong decrease of temperature of up to 10°C takes place in a very short period of time, together with a rapid decrease of the atmospheric pressure. The sea becomes bulky and short but intense rains can occur.

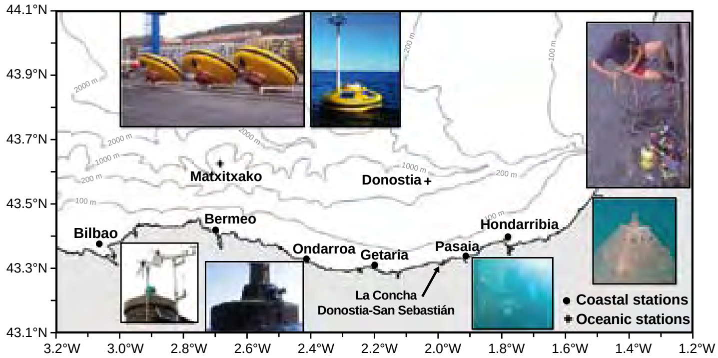


Figure 1. Location of the oceano-meteorological stations established for the Basque Country (Department of Transport and Civil Works, Basque Government).

An example of data collected during one of these gale events (15 July 2007, 16:00-18:00 hr) is shown in Figure 2. At the Pasaia coastal station, the gale was characterised by a decrease in air temperature from 35°C to 20°C, and an increase of more than 1°C in sea surface temperature when the event finished (Fig. 2a). This was preceded by decreases of the atmospheric pressure and solar radiation, reaching values below 1008 hPa and 100 W·m^{-2}, respectively (Fig. 2b). With the passage of the cold front, the wind direction changed from south to west, with a peak of wind speed around 15-16 m·s^{-1} (Fig. 2c). The maximum wave height increased from values below 1 m to up to 3.5 m, with a decrease of the mean wave period from 8 s to 5 s, typical period of wind-generated sea waves (Fig. 2d). Gales are well-known in beaches such as La Concha, in Donostia-San Sebastián (Gipuzkoa, Basque Country), where children enjoying the beach immediately recognise them and know that is time to go back home.

Acknowledgements

This work was supported by the Department of Industry, Trade and Tourism (ETORTEK Program) of the Basque Government.

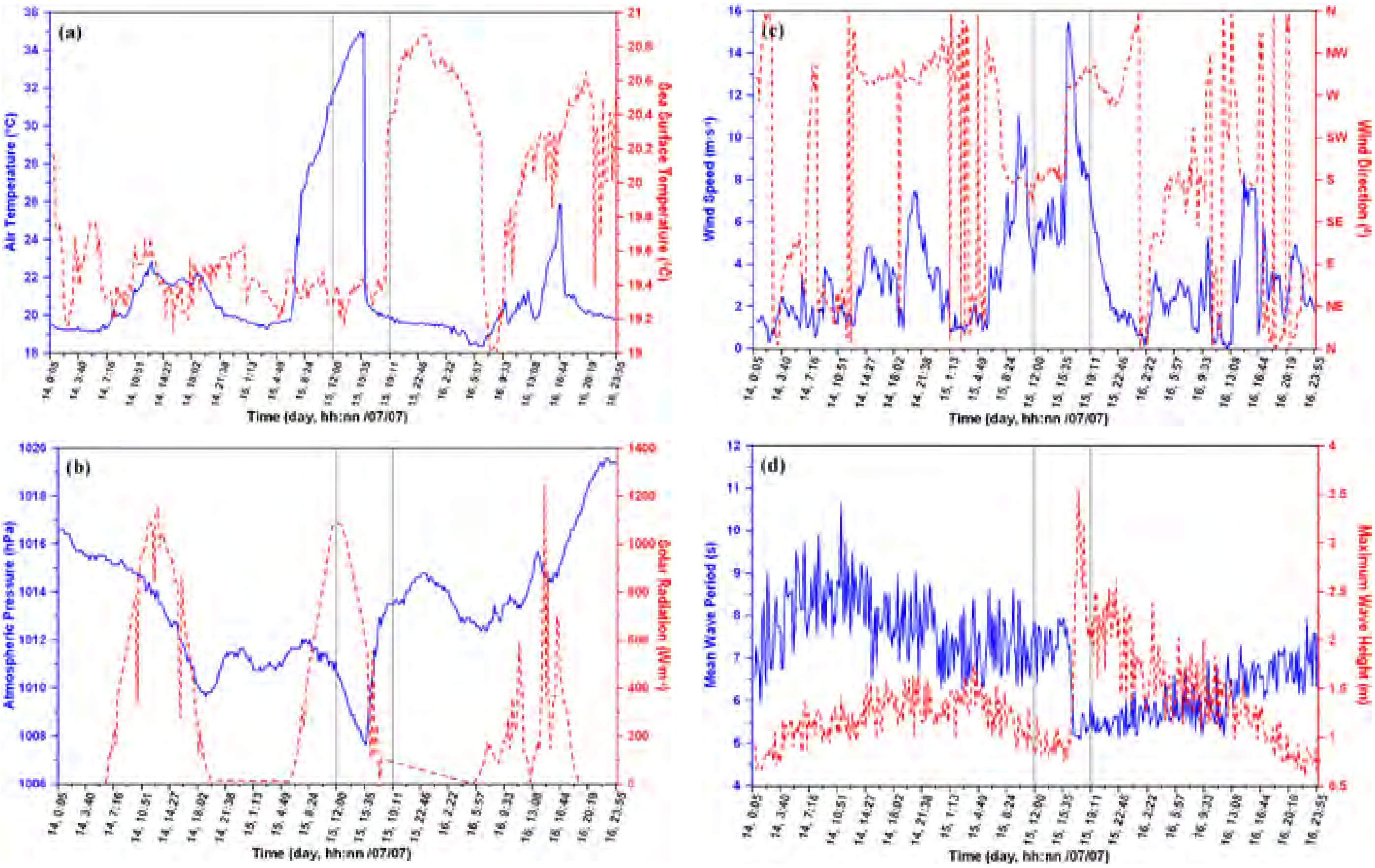


Figure 2. Evolution of oceano-meteorological parameters at the Pasaia coastal station for the gale occurred on 15 July, 2007: a) air and sea surface temperatures; b) atmospheric pressure and solar radiation; c) wind speed and direction; and d) mean wave period and maximum wave height.

This conference will culminate the integration and synthesis activities of the international GLOBEC programme by providing a new mechanistic understanding of the functioning of the marine ecosystem, in order to develop predictive capabilities and propose a framework for the management of marine ecosystems in the era of global change.

Symposium scope

The conference will comprise workshops/theme sessions, plenary and poster sessions. The first two days will be devoted to topical workshops proposed by the GLOBEC community. Three days of plenary sessions will follow, along these themes:

- GLOBEC achievements
- Ecosystem structure, function and forcing
- Ecosystem observation, modelling and prediction
- Ecosystem approach to management
- Marine ecosystem science: into the future

A poster session will also be included and a commercial fair is under consideration.

Venue information

The conference will be held at the Victoria Conference Centre, B.C., Canada. For further information visit: http://www.victoriaconference.com

Registration

Registration and abstract submission are available from http://www.globec.org

Convenors

Dr Ian Perry, Pacific Biological Station, Fisheries & Oceans Canada, Nanaimo, Canada

Dr Eileen Hofmann, Centre for Coastal Physical Oceanography, Old Dominion University, Norfolk, USA

Dr Manuel Barange, GLOBEC IPO, Plymouth Marine Laboratory, Plymouth, UK

Key dates

15 January 2009	Abstract submission deadline
15 January 2009	Financial support application deadline
28 February 2009	Abstract acceptance notification
30 March 2009	Early registration deadline
22-26 June 2009	Symposium
31 July 2009	Manuscript submission deadline

Financial support

Full or partial support will be offered to students and researchers, with priority given to those from developing countries. Application details will be available from the conference website.

Output

Symposium proceedings will be published as a special volume in an international peer reviewed journal.

Authors will be offered the opportunity to make their posters and presentations available through the symposium website.

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CALENDAR

6-8 October 2008: SCOR/IAPSO Working Group 129 on deep ocean exchanges with the shelf, Cape Town, South Africa
https://www.confmanager.com/main.cfm?cid=1293&nid=9421

14-15 October 2008: 2nd QUEST_Fish PI meeting, Plymouth, UK
http://web.pml.ac.uk/quest-fish/background.html

20-24 October 2008: 5th World Fisheries Congress, Yokohama, Japan
http://www.5thwfc2008.com

20-21 October 2008: SCOR 50th Anniversary Symposium, Woods Hole, USA
https://www.confmanager.com/main.cfm?cid=1285

22-24 October 2008: SCOR General Meeting, Woods Hole, USA
https://www.confmanager.com/main.cfm?cid=1285

23 October - 2 November 2008: PICES XVII meeting, Dalian, China
http://www.pices.int/meetings/annual/PICES17/background.aspx

27-30 October 2008: Joint WGZE/CIESM workshop to compare zooplankton ecology and methodologies between the Mediterranean and the North Atlantic (WKZEM), Heraklion, Crete, Greece
http://www.globec.org/calendar/meetings/WKZEM_2008.pdf

3-7 November 2008: ICES/PICES/GLOBEC WKSPLIM meeting, Kiel, Germany

9-13 November 2008: IMBER IMBIZO, Miami, USA
http://www.confmanager.com/main.cfm?cid=1185

13-14 November 2008: Meeting of the Chairs of European National Committees of IGBP, Lisbon, Portugal

11-15 November 2008: World conference on marine biodiversity, Valencia, Spain
http://www.marbef.org/worldconference/

25-27 November 2008: EUR-OCEANS final meeting, Rome, Italy
http://www.eur-oceans.eu

12-13 January 2009: GLOBEC France Symposium, Paris, France.

12-16 January 2009: Fifth EGU Alexander von Humboldt Conference. Iphakade: Climate changes and African earth systems - past, present and future, Cape Town, South Africa
http://www.humboldt5.uct.ac.za/

10-12 March 2009: Climate change: global risks, challenges and decisions, Copenhagen, Denmark
http://climatecongress.ku.dk/programme/

30 March - 1 April 2009: SCOR Projects Summit, University of Delaware, Newark, USA
http://www.scor-int.org/

15-17 April 2009: IGBP SC meeting, Otaru, Hokkaido, Japan
http://www.igbp.kva.se

27-29 April 2009: QUEST Annual Science Meeting, South Cerney, UK
http://quest.bris.ac.uk

22-26 June 2009: 3rd GLOBEC Open Science meeting, Victoria, BC, Canada
http://www.globec.org/

GLOBEC INTERNATIONAL

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